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Geohydrology of the Roy-Solano area, Harding County, New Mexico

Frederick D. Trauger and Churan, Kenneth, R.
1987, pp. 295-315. https://doi.org/10.56577/FFC-38.295

in:

Northeastern New Mexico, Lucas, S. G.; Hunt, A. P.; [eds.], New Mexico Geological Society 38 th Annual Fall Field Conference Guidebook, 354 p. https://doi.org/10.56577/FFC-38

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GEOHYDROLOGY OF THE ROY–SOLANO AREA, HARDING COUNTY, NEW MEXICO

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Abstract—The well-field for the Village of Roy taps the Ogallala Formation, a relatively thin aquifer having a minimum extent of about 6.7 mi^2. In a year of normal precipitation, the aquifer receives annual recharge of about 160 acre-ft or two to two and one-half times the amount withdrawn by the village based on production for the years 1984 and 1985. All wells in the Roy well-field tap the same aquifer; thus, pumping any one well affects water levels in all the wells. The well-field is capable of supplying water to the village at the present rate of pumpage with no danger of serious depletion under conditions of normal to slightly sub-normal annual precipitation.

Annual withdrawals from the well-field could be increased by as much as 25% over the next 40 years without detrimental lowering of the pumping levels. The well-field can sustain appreciably higher rates of withdrawal for periods of four to six months with consequent additional lowering of the water levels by only a few tenths of a ft. The transmissivity of the Ogallala Formation in the Roy well-field is about 15,000 gpd/ft. The storage coefficient is about 0.03. Water from the Ogallala and Romeroville-Mesa Rica formations is a bicarbonate water ranging from hard to very hard and is generally satisfactory for human and livestock use.

INTRODUCTION

The Village of Roy in the summer of 1985 received funds from the Interstate Stream Commission to study the long-term potential of the municipal well-field to supply the town at current rates of usage. Roy is in western Harding County, northeastern New Mexico (Fig. 1), and has a long history of problems with providing an adequate water supply to the residents. The purpose of the proposed study was to make a quantitative analysis of the well-field currently supplying the town, to estimate the amount of water in storage and to determine the potential, if any, for developing additional water from the well-field. In addition, the town officials asked that the study provide information on the possible development of additional supplies of water in other areas.

This paper is an abridged version of the report resulting from that study. For detailed description of the geology and hydrologic methodology see the report "Quantitative analyses of the Roy Municipal Well Field, Harding County, New Mexico" by F. D. Trauger, K. R. Churan and H. T. Kelly, 1986, at the offices of the New Mexico State Engineer, the Interstate Stream Commission, Santa Fe and the Village of Roy.



FIGURE 1. Map showing location of study area in Harding County, New Mexico.

To determine the amount of water in storage, it was necessary to conduct a detailed canvass of wells in the general area believed to encompass the well-field aquifer. Some data were available in files of the U.S. Geological Survey (USGS), Water Resources Division, Albuquerque, and a search of the records in that office was made prior to conducting the pumping test and well canvass. The information available for wells in the area is summarized in Table 1.

The Water Resources Division, in cooperation with the New Mexico Bureau of Mines and Mineral Resources, had begun a qualitative study of the water resources of Harding County in 1966. Although no report has been published, the basic data from that study provided information on water levels, the depth of wells and geologic information for many wells in the area. Also available were geophysical logs for an oil test drilled about 1.25 mi east of town. The interpretation of the logs provides information concerning the thickness and water-bearing characteristics of the formations underlying the area to a depth of about 864 ft. The test hole, for which a driller's log (Table 2) also is available, reportedly was drilled to a depth of 1,211 ft (Galloway, 1958, p. 29–31), but when the gamma ray and neutron logs were run in 1969 by USGS personnel, it was found open only to 864 ft. The caving occurred at approximately the base of the Redonda Formation.

Several qualitative hydrologic studies of the Roy area were made prior to the Harding County study started in 1966 by the USGS. The State Engineer Office (SEO) released a report (Galloway, 1958) that summarized data available relative to municipal, domestic and stock water-supplies in the vicinity of Roy. The Galloway report included also a history of the city's efforts to develop and maintain a municipal water supply. Galloway, in 1958, experienced difficulty in obtaining records and reliable information on prior efforts; even fewer records were available in 1985.

Of interest in the Galloway report (1958, p. 11) is the reference to the W. C. Powell memorandum report (1946?) in which Powell writes that an area "north of Roy some six miles was explored and found to be non-productive." Powell gave no specific locations and made no mention of how the exploration was done. No records are available in city files of any wells drilled for the city in such an area. However, "six miles north of Roy" would place the area about one mi west of Chicosa Lake, in sec. 21, T21N, R26E. USGS topographic map, "Mills East," shows three wells in the SE quarter of the section, in the central part of the Big Chicosa Lake basin. Allen Floersheim, former mayor of Roy, reports these wells were those drilled for the village about 1960,

TABLE 1. Records of wells in the Roy area, Harding County, New Mexico. Location number: see explanation in text. Depth of well: depths are in ft below land surface. Reported depths are followed by the letter "R." Altitude: altitude of land surface at well, interpolated from topographic map; generally accurate within 1/2 contour interval on source map. Water level: reported depths are given to nearest ft; measured depths are given to the nearest tenth of a ft. 1958 measurements from Galloway (1958); 1966–1982 measurements from records of U.S. Geological Survey; 1985 measurements by Geohydrology Associates, Inc. Stratigraphic unit: Je, Exeter/Entrada Sandstone; Jm, Morrison Formation; Kdr, Romeroville Sandstone; Kdm, Mesa Rica Sandstone; Kg, Graneros Shale, Greenhorn Limestone, Carlile Shale sequence; To, Ogallala Formation; Qal, alluvium; Qld, lake deposits. Method of lift and power source: P, plunger or cylinder pump; T, turbine pump; Ts, submersible pump; N, none; e, electric motor; g, gasoline-driven engine; w, windmill. Use of water: D, domestic; I, irrigation; Ob, observation; Ps, public supply; S, stock; N, none. Remarks: Y, yield; gpm, gallons per minute; K, specific conductance in micromhos, by field test; T, temperature in degrees Fahrenheit (F); wl, water level in feet; rept, reported, reportedly; Ch, chemical analysis in Table 4; UTM, unable to enter for measurements; Ob, observation well, record of water-level changes; Log, driller's log in Table 2; dd, drawdown.

Location number	Owner or tenant	Depth of well (feet)	Diameter of well (inches)	Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Water level: Date	Stratigraphic unit	Method of lift and power source	Use of water	Remarks
18.27. 1.311	L. W. Hill	216	5	5558	175.0	9-16-70	To/Kdr	P,w	S	Y, 1gpm; K, 480; T,15°C, shut off to measure; wl recovered 8 ft in 18 min.
3.343	R. O. Goodhue	251	6	5565	205.9	8-19-70	To/Kdr	N	N	-
6.442	Mackey & Bivens	45	6	5530	28.4	8-19-70	Kdr	P, w	D	Y, 1gpm
6.444	Mackey & Bivens	9	120	5520	5.2	8-19-70	Kdr	P, w	S	Y, 2gpm; rept never goes dry, dug
9.311	J. Gardner	14	28	5495	13.5	7-23-70	Qal/To	N	N	Dug, operating windmill 50 ft. east
14.111	Thompson & Lane	16	120	5385	14.0	8-19-70	Kdr	P, w	S	Dug, "Leatherman Windmill" on map
14.212	Thompson & Lane	197	6	5445	162	8-19-70	Kdm	P, w	S	K, 460, Ch.
19.26. 3.222	--	198	6	5812	132.3	11-5-85	To/Kdr	P, w	D, S	-
3.312	W. Garms	117	7	5814	100.3	7-15-70	To	P, w	S	uncased, pumped recently
3.424	A. Unruh	124+	6	5760	103.3	11-7-85	To	P, g	S	-
4.222	--	118	6	5816	91.3	11-5-85	To	P, w	S	Not pumped recently
7.344	T. A. Weathers	105	6	5775	40.6 42.0	7-25-70 6-5-79	Kdr	P, w	S	Sucker rod broken 7-25-70
9.321	A. J. Baum	360	6	5828	297.1 297.0	7-24-70 8-5-70	Kdm	N	N	
11.121	J. Weisdorfer	109	4	5757	77.6 77.6	7-24-70 8-19-70	To	P, w	S	Off for 10 hrs. 7-24-70
12.111	J. Weisdorfer	83	4	5727	75.6	11-7-85	To	P, w	S	Found off, rept. weak
13.343	D. M. Martinez	304R	6	5705	284R	8-19-70	Kdm	P, w	D	UTM, 1985
15.234	T. A. Weathers	44	36	5700	35.5	8-5-70	Kdm	P, w	S	Dug, pumping, Ch.
19.27. 2.144	J. A. Dahl	116	8	5633	72.7	9-16-70	To	N	N	
3.131	--	100	6	5702	"Dry"	11-7-85	To	P, w	S	Muddy at bottom, some water in tank
5.331	Village of Roy (No. 2 well)	80R	11	5668	60R 59.2 57.0 56.1	7-30-58 1-12-67 6-7-79 11-18-85	To	Ts, e	Ps	wl after being off 18 hrs (recovery 0.02 in last 58 min.); wl after 9.25 hrs pumping was 64.47 ft, 1-12-67; Ch. Y rept 25 gpm to line; 3 HP pump
5.332	Village of Roy (No. 3 well)	94R	11	5665	61.0 56.2 58.0 58.5	7-29-58 1-12-67 6-7-79 11-18-85	To	Ts, e	Ps	Pump off since 12-23-66; No. 1 well off for 9½ hrs, Y rept 25 gpm to line; 3 HP pump
5.334	Village of Roy (No. 1 well)	71R	11	5658	60R 54.3 55.5 52.3 53.7	7-30-58 1-12-67 8-7-70 11-18-85 12-03-85	To	Ts, e	Ps	wl after pump off 9½ jrs. 1-12-67; found pumping 8-7-70, turned off; wl after 35 min recovery; well No. 2 pumping, No. 3 off. Ch. K, 430, T, 63°F, Y rept 65 gpm to line; 15 HP pump
5.334a	Village of Roy (No. 5 well)	69R	10	5658	50.5 51.0 51.2	7-10-70 11-18-85 12-03-85	To	Ts, e	Ps	Not equipped, 7-10-70; Ob; 5 HP pump installed Nov. '84, Y rept 32 gpm to line
6.242	B. Kiersey	98	6	5687	72.0	10-30-85	To	P, w	S	Found off, Ob well for pump test on town well No. 1
6.424	B. Kiersey	88	4	5688	83.7	11-7-85	To	N	N	Found sealed, opened to measure during pump test of town well No. 1
6.444	B. Kiersey	78	6	5675	77.9	10-29-85	To	P, w	S	Will pump sand if cylinder set too low; ob well for pump test on town well No. 1
7.212	B. Kiersey	79	6	5672	69.0	11-22-85	To	Ts, e	D, S	Pumped recently
7.444	L. Garrison	186R	6	5703	-	11-22-85	To	Ts, e	D, S	UTM
8.122	Village of Roy (No. 4 well)	113	11	5654	51R 51.8 50.4	1946 11-05-85 11-18-85	To	Ts, e	Ps	Pumped recently; ob well for pump test on No. 1 well; Y rept 65 gpm to line; 15 HP pump
8.211	--	57+	6	5648	57+	11-4-85	To	P, w	S	Unable to get sounding line past cylinder
9.313	M. Hern	80	5(?)	5634	33.9	11-6-85	To	P, w	S	Y rept 2.5 gpm at 30 ft; Log

TABLE 1 (continued).

Location number	Owner or tenant	Depth of well (feet)	Diameter of well (inches)	Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Water level: Date	Stratigraphic unit	Method of lift and power source	Use of water	Remarks
10.331	L. J. Heafner		6	5644	195.4	8-21-70	To/Kdm	P, w	S	Y, 2 gpm; K, 560; T, 61°F
13.124	F. J. Smith	121	6	5510	--	7-22-70	To	P, w	S	Y, 6 gpm; K, 490
14.112	A. Leifeste	108	6	5575	Dry	7-22-70	To	N	N	Water seeping into hole from well, but no accumulation
16.244	State of New Mexico	234	6	5634	184.7	8-21-70	Kdm	P, w	D	Found off
17.133	J. Garison	125	6	5676	118.8	7-22-70	To	P, w	S	Found off, tank full
19.27.18.133	Martinez	165R	8	5685	150R	8-19-70	To/Kdr	P, w	S	UTM, 1985; Y, 2 gpm
18.213	J. Garrison	159	6	5705	142.4	11-22-85	To/Kdr	Ts, e	D, S	Not used recently
21.433	--	926	95-8	5610	-	8- -58	-	P, w	S	Rept to have been Southern Pacific Railroad well, cased to 765 ft; Log
22.122	Martinez	227	9	5575	131.2	8-21-70	To/Kdm	N	N	Rept to have been supply well for RR, originally drilled to 480 ft, cased to 180 ft; Y rept 20 gpm; Log
23.313	J. Allen	182	7	5570	132.6	8-21-70	To/Kdr	P, w	S	Found off
24.334	F. J. Smith	133	5	5518	94.6	6-8-79	To	P, w	S	Not in use; mill out of order
25.122	J. Allen	98	6	5515	98	1-11-67	To	P, w	S	Little water, could be rainfall
25.311	J. Allen	200	5	5545	130.0	9-16-70	Kdr	P, w	S	Y, 1 gpm; K, 470; sl after 30 min. recovery; 2.6 ft dd at Y of 1gpm
28.241	Town of Solano	166	-	5630	109.2	6-8-79	To/Kdr	N	N	
30.212	Hughes	97	6	5585	-	7-23-70	To	P, w	S	Pumping, UTM
32.133				5594				P, w	S	UTM; Y, 1 gpm; K, 900
32.344	C. Duree	200R	6	5578	120R	11-22-85	To/Kdr	P, w	S	Rept weak
34.224	Carbonic Chemical Corp.	215	10	5568	131.6	9-21-70	To/Kdm	N	N	Y rept 30-50 gpm when drilled
34.313	Callahan Cattle Co.	149	5	5541	106	9-21-70	To/Kdr	P, w	S	Y 1.5 gpm; k, 495; shut off to measure wl; recovered from 118.6 to 106.0 in 30 min.
35.141	Town of Mosquero (No. 2 well)	214	8.5 6.5	5548	122.4	10-1-70	To/Kdm	Ts, e	Ps	North well; 8.5 in casing to 104 ft, 6.5 in liner
35.144	Town of Mosquero (No. 1 well)	208	8.5 6.5	5549	119.7	9-21-70	To/Kdm	Ts, e	Ps	South well; 8.5 casing to 95 ft, 6.5 in liner; Y rept 28 gpm; no pump at time of wl measurement
35.414	Callahan Cattle Co.	161	6	5547	103.5	7-23-70	To/Kdr	P, w	S	Found off
19.28.19.333		133	6	5513	85	7-29-70	To/Kdr	P, w	S	
25.123	J. G. Bright	40R	5	5317	12R	2-8-67	Qal	P, w	S	Rept water hit @ 15 ft in sand, under clay; rose to 12 ft rept not turned off since 1948 (Off Map)
27.444	J. Trujillo	76	-	5444	63.7	7-29-70	To	P, w	S	Mill out of order; tank dry (Off Map)
30.121	F. Galey	98	5	5527	Dry	1-11-67	To	P, w	S	100 ft east of old dug well; out of order
20.25. 1.324	J. W. Scott	24	72	5868	4.3	8-22-70	Kg	P, w	S	Dug, found destroyed, 6-4-79
24.444	Kraft	135	5	5860	80.6	4-18-67	Kdr	N	N	Found destroyed, 6-4-79
20.26. 3.141	D. Linder	90	6	5885	71.7	4-4-67	To	P, w	D	Y, 2 gpm; rept good well; Ch
3.141a	D. Linder	91	7	5885	71.6	4-4-67	To	P, w	S	Rept good well
3.434	E. Abernathy	70	6	5849	57.1	4-28-67	To	N	N	
3.442	E. Abernathy	102	7	5835	70.9	4-28-67	To	P, w	S	Y, 2 gpm; K, 420
4.332	R. Pendleton	63	42	5870	65.5 51.7	4-3-67 6-4-79	To	N	N	Dug, culvert casing to 10 ft.
9.122	B. McDonald	53	6	5855	46.1	4-4-67	To	N	N	Pumped recently, bad splash
9.314	J. D. Kraft	96	5	5853	48.6	4-3-67	To	P, w	S	
10.441	J. Craig	156R	6	5831			To	P, w	S	Water rept in sand and gravel at 90 ft., Log
11.332	J. Craig	35	60	5780	29.2	4-3-67	To	P, w	S	Dug, mill out of order
12.111	Ivey Ranch, Inc.	36	6	5754	29.9	8-22-70	To	P, w	S	Found pumping; k,500; T, 59°F, recovered 0.04 ft in 20 min.
14.311	J. Bertholf	108	5	5788	54.0 53.5 41.6	1-09-67 7-10-70 2-10-82	To	N	N	Old Scott Place, Ob

TABLE 1 (continued).

Location number	Owner or tenant	Depth of well (feet)	Diameter of well (inches)	Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Water level: Date	Stratigraphic unit	Method of lift and power source	Use of water	Remarks
14.443	Martinez	150	6	5789	95.9	4-3-67	To/Kdr	P, w	S	
15.222	J. Bertholf	90	5	5813	55.7	4-3-67	To	P, w	S	Not used recently
16.311	J. Craig	148R	7	5883	66.6	7-30-58	Kdm	P, w	D, S	Pumped recently; dd rept to be about 30 ft with windmill
16.322	Village of Roy	419R	8	5850		1946	Kdm			Test hole, rept. pumped 10 gpm
17.334	Kraft-Key	130	6	5902	98.7 74.2	4-26-67 6-4-79	To/Kdr	P, w	S	On but not pumping 4-26-67
20.26.20.244	L. Playton	429R	5.5	5880		7-24-58	Jm	E	D	Y, 2.5 gpm; K, 1010; T, 66°F; Ch
20.414	J. Grady	116	6	5892	101.2	8-23-70	To	P, w	D	Y, 3 gpm; T, 65°F; Ch
20.441	W. Baum	367	5	5891	370R	8-2-58	Kdm	N	N	Bad splash from 290 ft down, UTM, wl, 1970; well is at NE corner of Modern Hotel. One of old city supply wells. Rept to have been 456 ft deep, pump 20 gpm.
22.133	J. Christman	104	6	5857	102.0 100.6	7-31-58 11-6-85	To	P, w	D, S	Not presently in use
22.433	Rigoni	135	6	5835	110R	7-29-58	To	P, w	D, S	UTM, 1985, rept strong; this well was adjacent to 1930's Roy well field
22.433a	Rigoni			5835		11-7-85	To	N	N	Dug, not visited '85; this is the "tunnel" well of Roy well field, 1930; had horizontal collecting gallery; 225 ft E of house (Galloway, 1958)
23.323	J. M. Beard	181	5	5835	150R	8-31-58	To/Kdr	P, w	D, S	Rept well deepened from 160 ft, 1956, Ch; y, ½gpm; T, 60°F
23.424	L. Gambrel	250R	12	5800	122.8 150.1 152.8	7-24-58 8-11-70 6-7-79	Kdm	N	N	Oil test hole, Morad-Gambrel No. 2, cased 250 ft; K, 308; T, 59°F; rept drilled 1955; Ch; 1958 wl may be high because of residual mud in hole
23.444	L. Gambrel	126	4	5790	Dry	8-11-70	To/Kdr	N	N	
24.344	L. Gambrel		4	5975		11-7-85		N	N	Oil test, 1961, clogged; Log
25.121		116		5784	96.8	10-7-85	To	P, w	S	Could not get sounding line past cylinder at 116 ft
25.311				5995	UTM	11-7-85	To(?)	Ts, e	D,S	Not currently in use
26.111	L. Gambrel	140	6	5836	128.0	11-6-85	To/Kdr	N	N	
26.112	L. Gambrel	864	10-6	5823	816.5	10-1-69	Je	N	N	Oil test rept drilled to 1211 ft, found open to 864 ft, gamma ray and neutron logs in appendix; rept principal water-bearing bed was cemented off (Galloway, 1958)
20.26.26.211	L. Gambrel	135	6	5812	132.3	7-23-70	To/Kdr	P, w	S	Out of order
26.411	L. Gambrel	135	6	5780	107.8 107.6 108.6	8-2-58 8-11-70 11-7-85	To/Kdr	P, w	S	Found off in '70 & '85; Ch
27.122	Rigoni	111	6	5837	105.2	11-7-85	To	P, w	S	Found off
27.212	Rigoni	1000R	7	5836		11-8-85		N	N	Oil test, rept bottomed in Chinle Fm., sealed
27.212a	Rigoni	500+R	7	5836	180+	11-8-85		N	N	Oil test, rept over 500 ft deep, no pressure indicated on gage and no air movement when shut off valve opened; measured thru valve, splash at 180 ft prevented getting wl, rept drilled in 1983±
31.423	J. Mahoney	56	6	5752	49R	7-15-70	Kdr	P, w	S	
34.213		128	6	5809	116.4	11-6-85	To/Kdr	P, w	S	Pumped recently
34.444			6	5812	UTM	11-4-85		P, w	S	Y, 1 gpm
36.333		197R		5710		1946				Test hole for Village of Roy, 1946; rept Y less than 15 gpm; Log (Galloway 1958)
20.27. 3.313	H. C. Mitchell	100R	6	5614		8- -66	Old	P, w	S	Rept pumped at 100 gpm from alternating beds of sand and clay
4.422	H. C. Mitchell	21	36	5617	17.6	7-9-70	Old	P, w	S	Dug, not in use, Ob
6.442	E. A. Ivey	61	7	5665	31.2	7-15-70	Kdr	P, w	S	Shut off to measure; wl recovered 1.5 ft in 35 min.
9.333	H. C. Mitchell	320R	6			8- -66	Jm	N	N	Rept hit weak flow at 125 ft, went to 320 ft but proved too weak to keep in service

TABLE 1 (continued).

Location number	Owner or tenant	Depth of well (feet)	Diameter of well (inches)	Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Water level: Date	Stratigraphic unit	Method of lift and power source	Use of water	Remarks
11.242	H. C. Mitchell	310R	6	5662	210R	1967(?)	Kdm	P, w	S	Y, 1 gpm, rept weak, poor quality
13.413	E. B. Little	207	6	5576	170.5	7-22-70	Kdm	P, w	S	Shut off to measure wl; measured 2.8 ft in 35 min.
15.432	R. E. Hicks	186	5	5705	185.3	4-14-67	Kdm	N	N	
17.441	W. W. Bowman	91	6	5728	75.0	7-22-70	To	P, w	S	Shut off to measure wl, recovered 1.6 ft.
20.27.17.333				5736				P, w	S	
18.313				5724				P, w	S	
19.241		312	6	5730	219.5	11-7-85	Jm(?)	N	N	Splash on tape
20.434	Anderson	363R		5715	220.9	11-7-85		P, w	S	Y rept 10 gpm
21.131	R. E. Hicks	349	8	5725	282.3	7-10-70	Jm(?)	N	N	Ob
22.411	R. E. Hicks	73R	6	5651		2-22-56	Kg(?)	P, w	S	In creek bed; Log
24.133	E. B. Little	13	42	5560	11.4	7-22-70	Qal/To	N	N	Dug, nearby 160 ft drilled well rept good
26.213	G. Richards	229	6	5640	UTM	7-22-70	Kdm	P, w	S	Shut off to measure; UTM because of heavy splash but seems to between 170 ft and 200 ft.
27.133		349	6	5707	UTM	11-7-85	Jm(?)	P, w	S	Pumping, heavy splash; Y, 3gpm; K, 1500
28.124		87+	6	5700	UTM	11-7-85	To(?)	P, w	S	Measured to top of cylinder
29.331	H. Unruh			5745			To(?)	P, w	D, S	
29.444	H. Unruh	106	6	5722	103.2 101.3	7-10-70 10-31-85	To	P, w	S	Rept drilled to 117 ft but sanding up
31.132	E. Kiersey	119	6	5750	107.8	8027079	To	P, w	D	Light intermittent pumping before measurement
31.222	H. Unruh	136	6	5745	105.1 110.4	10-31-85 1-09-67	To	Ts, e	D	Rept will pump 20 gpm steady
31.344	E. Kiersey	161	4	5740	110.2 109.8	7-10-70 11-7-85	To/Kdr	N	N	Ob
32.143	Unruh	119	6	5713	90.6	10-30-85	To	P, w	S	Not pumped recently
32.433				5719	UTM	10-30-85	Old/To	P, w	S	Winterized, pumping
34.322	Anderson	245	6	5652	156.7	8-22-70	Kdm	P, w	S	K,1250; turned off to measure; wl after 30 min. recover; Ch
20.27.35.423	Anderson		6	5635			Kdr(?)	D, W	S	
36.242	State of New Mexico	157R	6	5553	147R	8-22-70	To/Kdr	Ts, e	S	K, 1400 (from tank); Ch
36.244	State of New Mexico	14	36	5542	6.6	8-22-70	Qal/To	P, w	D	Dug, K,760; rock cribbing; Ch
21.25.24.242	Coop. Grazing Assoc.	52	54	6001	49	4-25-67	To	P, w	S	Dug
24.433	B. Steinbaugh	115	6	6005	54.2	4-28-67	To/Kg	P, w	S	Rept Y 15 gpm at 90 ft; Log
25.344	P. Hooper	78	6	6022		8-24-56	To/Kdr	P, w	S	Rept Y 10 gpm at 60 ft; Log
35.422	J. Scott	115	5	5902		5-16-56		P, w	S	
21.26.20.244	W. Fluhman	57	6	5873	37.7	5-1-67	To	P, w	S	Shut off to measure wl rose 80 ft in 50 min., still rising slowly; T, 51°F K, 910
21.3144	W. Fluhman	49	8	5861	20.8	5-1-67	Qal/To	T, e	I	Chicosa Well No.1; Ch
21.3231	W. Fluhman	53	7	5860	16.5	5-1-67	Qal/To	T, e	I	Chicosa Well No. 2
21.413	W. Fluhman	45	7	5865	19.7	5-1-67	To	P, w	S	Chicosa Well No. 4
21.4311	W. Fluhman	52	7	5859	18.6	5-1-67	Qal/To	T, e	I	Chicosa Well No. 3
22.132	State of New Mexico	36	7	5865	16.4	5-1-67	Qal/To	T, e	I	Chicosa Lake State Park
22.134	State of New Mexico	48	7	5872	25.3	5-1-67	Qal/To	T, e	Ps	Chicosa Lake St. Park; fluoride concentrates rept by State Health & Social Serv. Dept to vary from 2.5 to 5.8 ppm

TABLE 1 (continued).

Location number	Owner or tenant	Depth of well (feet)	Diameter of well (inches)	Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Water level: Date	Stratigraphic unit	Method of lift and power source	Use of water	Remarks
22.311	State of New Mexico	47	7	5875	24.2	5-1-67	Qal/To	T, e	Ps	Chicosa Lake St. Park; not in use
24.422	U.S. Government	38	7	5783	23.3	7-9-70	To	P, w	S	Strong smell of sulfur; Ch
27.112	W. Fluhman	58	6	5867	22.0	5-1-67	To	P, w	S	Found off
29.223	L. Shurbet	85	6	5887		8-20-54	To		S	Rept Y 6 gpm at 65 ft; Log
31.4133	T. J. Moore	149	6	5963	53.0 54.7	4-28-67 6-4-79	To/Kdr	N	N	
21.26.32.144				5905			Qld	P, w	S	
32.341				5910			Qld	P, w	S	
33.311	H. A. Anderson	206	6	5933	124.1	4-28-67	To/Kdm	P, w	S	Pumping on arrival, no water coming out; shut off, wl rose 72 ft in about 10 min still rising slowly; K, 400 (from tank)
34.133	W. Fluhman	98	8	5905	79.1	4-4-67	To	P, w	S	Not used recently
34.334	F. H. Proctor	51	6	5854	33.4	4-4-67	To	P, w	S	Rept a strong well
35.211	Ivey Ranch Inc.	101	6	5907	63.7	7-15-70	To	N	N	
21.27.20.143	R. Rigoni	130	6	5792	66.3	4-27-67	To/Kdr	N	N	Old homestead well
21.242	H. C. Mitchell	224	6	5768	158.9	7-15-70	Kdm	P, w	S	Turned off to measure, wl rose 0.2 ft in 45 min, rept strong; deepened from 160 ft in 1957
23.334	H. C. Mitchell	297	5	5720	264.6	7-15-70	Kdm	N	N	
26.222	H. C. Mitchell	195	6	5700	192.6 191.2	4-20-67 6-7-79	Kdm	N	N	
27.343	H. C. Mitchell	147	6	5695	130.4	7-9-70	To/Kdr	N	N	
32.123	R. Rigoni	164	6	5720	128.3P 120.6	7-15-70 6-7-79	To/Kdr	P, w	S	Y rept 1 gpm at 140 ft, 3 gpm at 190 ft; Log

and that they did find an appreciable amount of water. However, State Health Department personnel declared the water to be of unsatisfactory quality for public use because of high fluoride content.

It is reported also by Galloway (1958, pp. 8–13) that numerous test holes were drilled in the immediate vicinity of Roy in an effort to obtain water in the Romeroville Sandstone. None of the wells produced a supply of water considered adequate to warrant development. Studies by several consultants in the period 1935–46 led eventually to the development of the present field of five wells in Weisdorfer Draw, approximately 6.25 mi southeast of the center of town.

After several test holes were drilled in the area, four wells were drilled in 1946–47 to the Romeroville Sandstone, but apparently not into the Romeroville for more than a few ft, although the original recommendations by the consultants had indicated the Romeroville should be penetrated to a depth of several hundred ft. A fifth well was drilled, probably about 1960, but was not placed into service until about 1984. An examination of available well records from the vicinity of Roy, Solano and Mosquero clearly indicates that the Romeroville-Mesa Rica sequence of sandstone is not likely to yield more than 10 to 20 gallons per minute (gpm) to wells.

If better records were available concerning the depth of wells, materials penetrated and water-level fluctuations over the years, it would have helped greatly in the present evaluation of the well-field. Accurate records of production, in conjunction with water-level fluctuations, would indicate clearly when yields could be increased or should be decreased.

The field work for this investigation was done mostly in October and November of 1985. The update of the well canvass was conducted by geohydrologists F. D. Trauger and K. R. Churan. The pump test was run by Trauger, Churan and S. E. Kelly. H. T. Kelly analyzed the data from the pump test to determine the hydrologic coefficients of the Ogallala aquifer (see Kelly, 1987, this guidebook).

Well-numbering system

The system of numbering wells and springs in this report is based on the Federal system of subdividing land into townships, ranges and sections. The well number, which consists of four parts separated by periods, also indicates the location of the nearest 10-acre tract in the section. The first three parts represent, in reading order, the township north, the range east and the section (Fig. 2).

The fourth part of the number usually consists of three digits which indicate the 10-acre tract in which the well is located. The section is divided into quarters, quarter-quarters, etc., and numbered 1, 2, 3 and 4, as indicated in Figure 2. The first digit of the fourth part of the well number gives the quarter section; the second digit gives the quarter-quarter, and the third digit designates the 10-acre tract. Thus, well

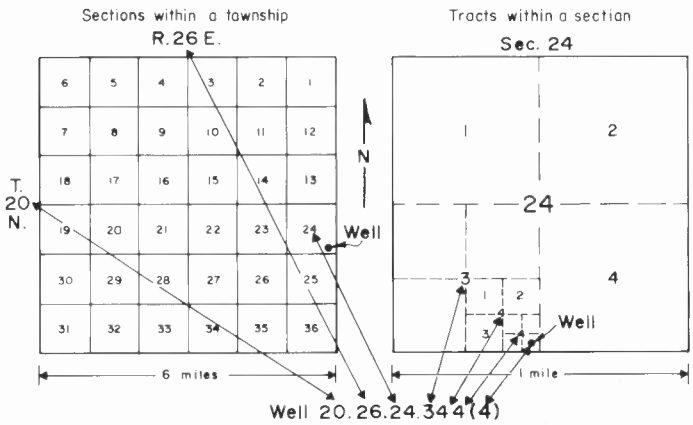


FIGURE 2. System of numbering wells in New Mexico.

TABLE 2. Driller's logs of selected wells in the vicinity of Roy, Harding County, New Mexico. Logs of wells listed in this table show the type of rock materials penetrated by the well. These logs, excerpted from Galloway (1958), were obtained from owners and drillers, and the description of the rocks is the terminology of the driller. Consequently, the terms used to describe the rock materials do not have the same meaning in all the logs; in some logs the terms depart from standard usage. Driller's terms believed not to have been used in the regular sense are placed in quotations, and the possible or probable proper rock type or term is enclosed in brackets. Stratigraphic designations shown in the well logs were made by the authors on the basis of comparison of the driller's log data with the known sequence of rocks in the vicinity of the well. The depths of wells indicated in the logs may not be the same as the measured depths given in Table 1. Wells are subject to sanding and caving, even though cased, and the original depth seldom remains unchanged.

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Well 19.27. 9.311 Mary Hern		
Tertiary:		
Ogallala Fm. (To):		
Caliche	0- 10	10
Sand and clay	10- 20	10
Sand and gravel (2½gpm @ 30)	20- 30	10
Cretaceous:		
Graneros Shale (Kg):		
Shale	30- 52	12
6-inch galvanized casing to total depth of 52 feet; completed November 16, 1954, by H. L. Judy.		
Well 19.27.21.400 Southern Pacific Railraod		
Quaternary:		
Alluvium (Qal):		
Soil	0- 2	2
Tertiary:		
Ogallala Fm. (To):		
"Lime" and clay	2- 22	20
Brown sand	22- 32	10
Sand and clay	32- 40	8
Brown sand rock	40-108	68
Sand and "lime" rocks	108-128	20
Conglomerate	128-133	5
Cretaceous:		
Romeroville Sandstone (Kdr):		
Sand rock (pure)	133-143	10
Sand rock	143-163	20
Pajarito Shale (Kp):		
Blue shale	163-201	38
Mesa Rica Sandstone (Km):		
"Soapstone" {hard dry clay?}	201-221	20
Very hard rock	221-276	55
White sand rock	276-307	31
Tucumcari Shale (Kt):		
Blue clay	307-323	16
Morrison Fm. (Jm):		
Very hard rock	323-331	8
Hard rock and shale	331-340	9
Dark hard rock	340-351	11
Black hard rock	351-356	5
Red non-grit rock	356-368	12
Black hard rock	368-371	3
"Soapstone" {hard dry clay}	371-378	7
Sticky blue clay	378-412	34
Black non-grit rock	412-420	8
Hard grit rock	420-425	5
Sand rock	425-433	8
"Soapstone" and sand {hard dry clay?}	433-445	12
"Soapstone" {hard dry clay?}	445-453	8
Hard rock	453-460	7
White sand rock	460-482	22
"Volcanic deposit" {?}	482-491	9
Hard sand rock	491-498	7
Clay	498-530	32
Bell Ranch (Jbr):		
Sand rock	530-552	22
Non-grit clay	552-645	93
Exeter Entrada (Je):		
Hard rock	645-682	37
Hard clay and sand	682-686	4
Hard rock	686-705	19
Triassic:		
Redondo Fm. (Rr):		
Red sand rock	705-819	114
Chinle Fm. (Rc):		
Red clay	819-838	19
Red claystone	838-869	31
Red clay	869-873	4
Red claystone	873-926	53
494 feet of 9 5/8-inch casing and 271 feet of 8 1/4-inch casing; completed Oct. 1, 1906, by O. E. Lindholm.		
Well 20.26.10.441 J. A. Craig		
Quaternary:		
Alluvium (Qal):		
Top soil dark loam	0- 10	10
Tertiary:		
Ogallala Fm. (To):		
White sand	10- 20	10
Brown sand	20- 85	65
Gravel sand (water)	85- 90	5
Cretaceous:		
Carlisle Shale (Kg):		
Gray clay	90-100	10
Black clay	100-120	20
Gray clay and gravel	120-130	10
Gray clay (water)	130-140	10
Black and gray clay and "soapstone" {hard dry clay?}	140-156	16
6-inch galvanized casing to total depth of 156 feet. Completed July 27, 1955, by H. L. Judy.		
Well 20.26.24.312 Nick Martinez		
This hole not found, 1985		
(Missing-includes Ogallala Fm.)	0-100	100
Cretaceous:		
Carlisle Shale, Greenhorn Limestone and Graneros Shale: (Kg)		
Unconsolidated sand-some calcareous cementing material and light gray limestone	100-125	25
As above; larger grains of sand	125-135	10
Conglomerate w/quartz and yellow limestone grains in gray shale	135-140	5
Fine grained micaceous quartz sandstone; well cemented, dense. Trace dead oil.	140-147	7
As above w/pyrite and trace gray fibrous calcite	147-150	3
Dark gray to black fissile shale	150-155	5

TABLE 2 (continued).

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Romeroville Sandstone (Kdr):		
Light gray sandstone, medium grained partly unconsolidated; little porosity, slight stain.	155-172	17
As above w/fair porosity and oil stain	172-180	8
Light gray sandstone, fine grained, consolidated, little porosity.	180-185	5
As above w/less porosity; oil stain	185-190	5
As above with trace of pyrite	190-205	15
Light gray to white, micaceous quartz sandstone, little porosity; oil stain, loosely cemented.	205-215	10
Light gray quartz sandstone, more tightly cemented, less porosity, oil stain, streak dark gray shale.	215-225	10
Dark gray sandstone, hard and dense	225-228	3
Pajarito Shale (Kp):		
As above w/coarser grains and intermixed gray shale, slight stain.	228-230	2
Gray sandstone (water sand), intermixed pyrite and black shale, loosely cemented	230-235	5

Well 20.26.24.312, continued

Mesa Rice Sandstone (Kdm):		
Light to dark gray sandstone, tightly cemented	235-245	10
As above w/dary gray shale streaks	245-247	2
Hard, dense, quartz sandstone, light gray	247-250	3
Dark gray sandstone, tightly cemented w/black carbonaceous material, streak dark gray shale	250-255	5
Light gray to white quartz sandstone, medium grained and mostly translucent, loosely cemented	255-259	4
As above	259-269	10

6-inch casing to 260 feet; oil test completed in 1955 by Kelly-Moore and Rador Oil & Mining Co.; Morad-Martinez No. 1. (Reference to residues of oil should be considered with some skepticims-author.)

Well 20.26.26.112 Lloyd Gambrel

Quaternary:		
Alluvium (Qal):		
Soil and sand	0- 10	10
Tertiary:		
Ogallala F. (To):		
Sand and caliche	10- 40	30
Caliche	40- 65	15
Soft red sand	65-100	35
Coarse sand gravel	100-145	45
Water sand red gravel	145-150	5
Cretaceous:		
Carlisle Shale, Greenhorn Limestone (Kg) and Graneros Shale:		
Gray shale	150-155	5
Black shale	155-160	5
Black shale and "lime"	160-165	5
"Shells"	165-170	5
Romeroville Sandstone (Kdr):		
Brown sand and "lime"	170-175	5
Brown sandy "shell"	175-180	5
Hard shale and "shell"	180-185	5
Hard gray "lime"	185-195	10
Brown shale	195-200	5
Hard "lime"	200-210	10
Pajarito Shale (Kp):		
Gray shale	210-215	5
Brown sandy shale	215-220	5
Mesa Rica Sandstone (Kdm):		
Sandy "lime"	220-225	5
Gray shale, "lime"	225-230	5
Hard gray "lime"	230-245	15
Shale and "lime shells"	245-255	10
Hard sandy "lime"	255-260	5
Sand and "lime shells"	260-265	5
Soft "lime"	265-275	10
White hard sand	275-370	95
Fine sand	370-375	5
Tucumcari Shale (Kt):		
Brown shale	375-385	10
Jurassic:		
Morrison Fm. (Jm):		
Hard sand rock	385-395	10
Soft sand rock	395-400	5
Soft rock	400-405	5
Sandy shale	405-410	5
Brown shale	410-415	5
"Lime" shale	415-420	5
Brown shale	420-430	10
Blue shale	430-440	10
Hard "lime" & shale	440-455	15
Hard sand "lime"	455-460	5
Shale and "lime shells"	460-465	5
Brown sandy shale	465-470	5
Gray sand	470-475	5
Soft sand	475-490	15
Blue "lime"	490-500	10
Sandy "lime"	500-505	5
"Shells"	505-515	10
Brown shale	515-520	5
Hard blue sand "lime"	520-530	10
Shale and "lime"	530-535	5
Brown hard shale	535-540	5
Brown sandy shale	540-555	15
Gray "lime"	555-560	5
Sand and "lime shells"	560-575	15
Hard gray sand	575-600	25
Sand "lime"	600-605	5
Sandy shale	605-610	5
Sand "lime" and "shells"	610-620	10
Hard sand	620-675	55
Sandy shale	675-680	5

TABLE 2 (continued).

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Jurassic:		
Bell Ranch (Jbr):		
"lime shells"	680-685	5
Dark sandy "lime"	685-690	5
"Lime"	690-695	5
Sandy shale	695-700	5
Sand and "lime"	700-705	5
Hard gray sand	705-715	10
Exeter (Je):		
Sand and gravel	715-735	20
Sand and gravel	735-778	43
Sandy shale	778-790	12
Sand	790-795	5
Entrada (Je):		
Sandy "lime"	795-805	10
Hard gray sand (Water level at about 820 ft. according to neutron log)	805-840	35
Soft sand (oil)	840-850	10
Sandstone	850-860	10
Sand and gravel (795-875:Oil show very strong; free oil in good proportion)	860-875	15
Triassic:		
Redondo Fm. (Rr):		
Red sandy shale	875-905	30
Sand and gravel	905-915	10
Sandy shale	915-935	20
Chinle Fm. (Rc):		
Hard white "lime"	935-945	10
"Lime"	945-950	5
Red shale and "lime"	950-1045	95
Brown shale	1045-1055	10
Blue shale	1055-1060	5
Blue sandy shale	1060-1070	10
Oil show free oil, gray sand with hard streaks with 3 ft of red shale	1070-1145	75
Gray sand with show of free oil	1145-1210	65
Red shale with "lime shells"	1210-1211	1

Total depth 1211 feet. Log furnished by G.J. Stumpff, Box 278, Aurora Branch, Denver 8, CO through Mr. R.C. Kiersey. (references to occurrences of oil should be considered with some skepticism-author) See gamma and neutron logs, Appendix A. The gamma and neutron logs indicate different intervals for geologic separation of beds and probably should be considered more reliable than the driller's log. The terms "lime" and "shell" as used by the driller are not interpretable in geologic terms and what was meant is not known.

Well 20.26.36.333 Village of Roy

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Tertiary:		
Ogallala Fm. (To):		
Sand, clay, etc.	0- 95	95
Sand, loose, no water	95-107	12
*Blue shale, dry	107-170	63
*Blue shale, dry, some sand and rock fragments	170-185	15
*Blue shale, dry	185-197	12

*These notations considered unreliable

Test well drilled under supervision of W.C. Powell in 1946; log is believed to be incomplete since note indicates that driller expected to hit hard "sandrock" at 250 ft.

Well 20.27.22.410 R. E. Hicks

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Quaternary:		
Alluvium (Qal):		
Top soil	0- 10	10
Cretaceous:		
Carlisle-Graneros shale (Kg):		
Black shale	10- 55	45
Romeroville Sandstone (Kdr):		
Sand (water)	55- 73	18

6-inch steel casing to total depth of 73 ft. Completed Feb. 22, 1956, by J.L. Garrison.

Well 21.25.24.433 F. U. Exum

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Quaternary:		
Alluvium (Qal):		
Surface dirt	0- 10	10
Tertiary:		
Ogallala Fm. (To):		
Sand	10- 50	40
Gray sand rock	50- 80	30
Cretaceous:		
Carlisle Shale, Greenhorn Limestone (Kg):		
Shale (in excess of 15 gpm @ 90)	80- 90	10
Alternating shale and rock	90-113	23

6-inch steel casing to total depth of 113 feet; completed Dec. 8, 1956, by H.L. Judy.

Well 21.25.25.344 P. M. Hooper

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Quaternary:		
Alluvium (Qal):		
Surface dirt	0- 10	10
Tertiary:		
Ogallala (To);		
Sand	10- 50	40
Sand rock (10gpm ± @ 60)	50- 60	10
Cretaceous:		
Carlisle Shale (Kg):		
Black shale	60- 78	18

6-inch galvanized casing to total depth of 78 feet; completed Aug. 24, 1956, by H. L. Judy.

Well 21.26.29.223 L. V. Shurbet

Stratigraphic Unit	Interval (ft)	Thickness (ft)
Tertiary:		
Ogallala Fm. (To):		
Caliche	0- 10	10
Sand	10- 40	30
Shale	40- 60	20
Sand and gravel (6 gpm @ 65)	60- 65	5
Sand and gravel	65- 85	20

TABLE 2 (continued).

Stratigraphic Unit	Interval (ft)	Thickness (ft)
6-inch galvanized casing to total depth of 85 feet; completed Aug. 20, 1954, by H. L. Judy.		
Well 21.27.32.123 Thomas Rigoni		
Tertiary:		
Ogallala Fm. (To):		
Caliche	0- 10	10
Sand	10- 50	40
Cretaceous:		
Carlisle Shale, etc. (Kg):		
Shale	50-110	60
Romeroville Sandstone (Kdr):		
Alternating shale and rock (1gpm @ 140; 3gpm @ 190)	110-210	100
6-inch galvanized casing to total depth of 210 feet; completed April 28, 1955, by H.L. Judy.		

20.26.24.344 is in the SE¼ SE¼ SW¼, sec. 24, T20N, R26E. Letters a, b, c, etc. are added to the last part of the well number to designate the second, third, fourth and succeeding wells listed in the same 10-acre tract. If the scale of the map permits, a fourth, or fifth number, instead of a letter, may be added to the last part to allow closer location within the 10-acre tract. The well numbers in Table 1 are not given in full for each well. The wells are grouped by townships and ranges for easier reading, and the full well number is used only for the first well in each township and range. The last two parts of the well number, showing the section and location within the section, are given for other wells in that township and range.

GEOGRAPHIC FEATURES OF THE AREA

The area is a part of the Raton section of the Great Plains physiographic province as defined by Fenneman (1931). The Raton section in general is characterized by volcanic cones and dissected lava-capped plateaus, mesas and buttes. However, the Roy-Solano area lies at the southern margin of the Raton section, south of all exposed volcanic rocks, and at the western edge of a broad, southeastward sloping plateau of low relief. The Canadian River bounds the plateau on the west and courses some 1,000 ft lower in altitude than the Town of Roy (elevation: 5,892 ft). The plateau is bounded on the east by Tequesquite and Ute Creeks, 900 to 1,000 ft below the rim of the plateau.

The surface of the plateau slopes at about two degrees per mi toward the southeast. Except along the margins of the plateau, where deeply incised canyons work headward, the relief generally is less than 30 ft between major drainages which commonly are separated by distances of three to five mi. The surface of the plateau is dotted with small, round-to-oval-shaped depressions, commonly called sinks. A few are as much as a mi or more across in their long dimension. These sinks frequently contain small ponds during the summer rainy season. Some are reputed by long-time residents to have contained water the year-round in the period 1900 to 1920. Chicosa Lake, northeast of Roy, is in one such sink.

Drainage channels are relatively well defined over most of the plateau surface but are not deeply incised anywhere in the immediate study area. Many relatively short shallow drainages terminate in the sinks as mentioned above. At least three such sinks, one large, can be noted on Figure 3 in the area between the town of Roy and city well-field in Weisdorfer Draw.

According to local residents, Weisdorfer and La Pompa Draws flow only occasionally as a result of heavy rains. Such flood flows can be extreme but are rare. Mr. Bennie Kirksey (oral commun., 1985) states that Weisdorfer and La Pompa Draws, where they cross his ranch just west of the well-field, commonly will contain runoff to some degree about once or twice a year, but not every year, and that flows are seldom large. The floor of La Pompa Draw, through the well-field, shows little evidence of heavy flow, being only slightly channeled at intervals.

General geology

The rocks underlying the surface of the plateau in the vicinity of Roy are all of sedimentary origin of a depth of at least 2,000 ft according to available records of various exploratory wells drilled for oil and gas in the general area (Dixon et al., 1954). The oldest rocks exposed in the vicinity of Roy are those of the Chinle Formation of Triassic age. They crop out at stream level in the canyon of the Canadian River southwest of Roy and in the valley of Tequesquite and Ute Creeks east of Roy. The youngest rocks are the thin deposits of alluvium of Recent age found in some drainageways and the clay and silt deposits found underlying the floors of the various sinks and dry lake beds.

All the sedimentary deposits underlying the area are essentially flat-lying but have a generally southeastward slope of about two degrees. Unconformities exist between some formations, but there appears to have been only minor deformation of beds and only minor faulting in the area since Triassic time. The sandstones, siltstones and shales deposited during the Triassic, Jurassic and Cretaceous Periods resulted in a sequence of clastic sediments some 3,000 ft thick being deposited in the region. Erosion in post-Cretaceous time removed the upper one-third of the deposits leaving some 2,000 ft of Triassic to Cretaceous sediments to be covered by the Ogallala Formation of Tertiary age.

A regional structural feature of importance to the hydrology of the Roy area is the Bravo dome—an anticlinal structure of broad dimensions. The axis of the anticline lies east of Roy and trends northwest across the northeast corner of the county. The Sierra Grande arch, another broad regional structure lies west of the Canadian River and trends northeast. The two structures merge in the region of the Raton-Capulin volcanic field. The broad synclinal structure between the Sierra Grande arch and the Bravo dome contains a low anticlinal arch that trends northwest. This structure is referred to in this paper as the Roy anticline.

The axis of the Roy anticline parallels or coincides with the western margin of the outcrop of the Ogallala Formation and State Highway 89 in the Mosquero-Roy-Mills area. Dips of beds are gently west and east from the axis. The significance of this structure is that it elevates the permeable Exeter/Entrada sandstone and underlying Chinle/Redonda shale and mudstone sequence of rocks several hundred ft above the level of the Canadian River in the Roy area. As a consequence, although the river crosses the outcrop of the Exeter/Entrada Sandstone, the sandstone is not recharged.

The course of the Canadian River is along the axis of the synclinal trough trending more-or-less north-south from near Springer to its junction with the Mora River. This structure is referred to in this paper as the Mills syncline. The eastern limb of the Mills syncline is the western limb of the Roy anticline. Ground water cannot move eastward from the river because of the Roy anticline. In the valley of the Canadian River, west of Roy, the Exeter/Entrada must discharge water.

The sequence of rocks to be found in drilling in the vicinity of Roy includes only a few that may be considered worthy of exploration for municipal water supply. The following discussion summarizes the water-bearing characteristics of the various formations; for a more detailed discussion, see Kilmer (1987, this guidebook).

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

Triassic System

Chinle Formation

The rocks consist of purplish-red to orange-red and variegated (red and green) beds of clay, shale and siltstone of low permeability. They are not known to have produced any water of consequence in the plateau area.

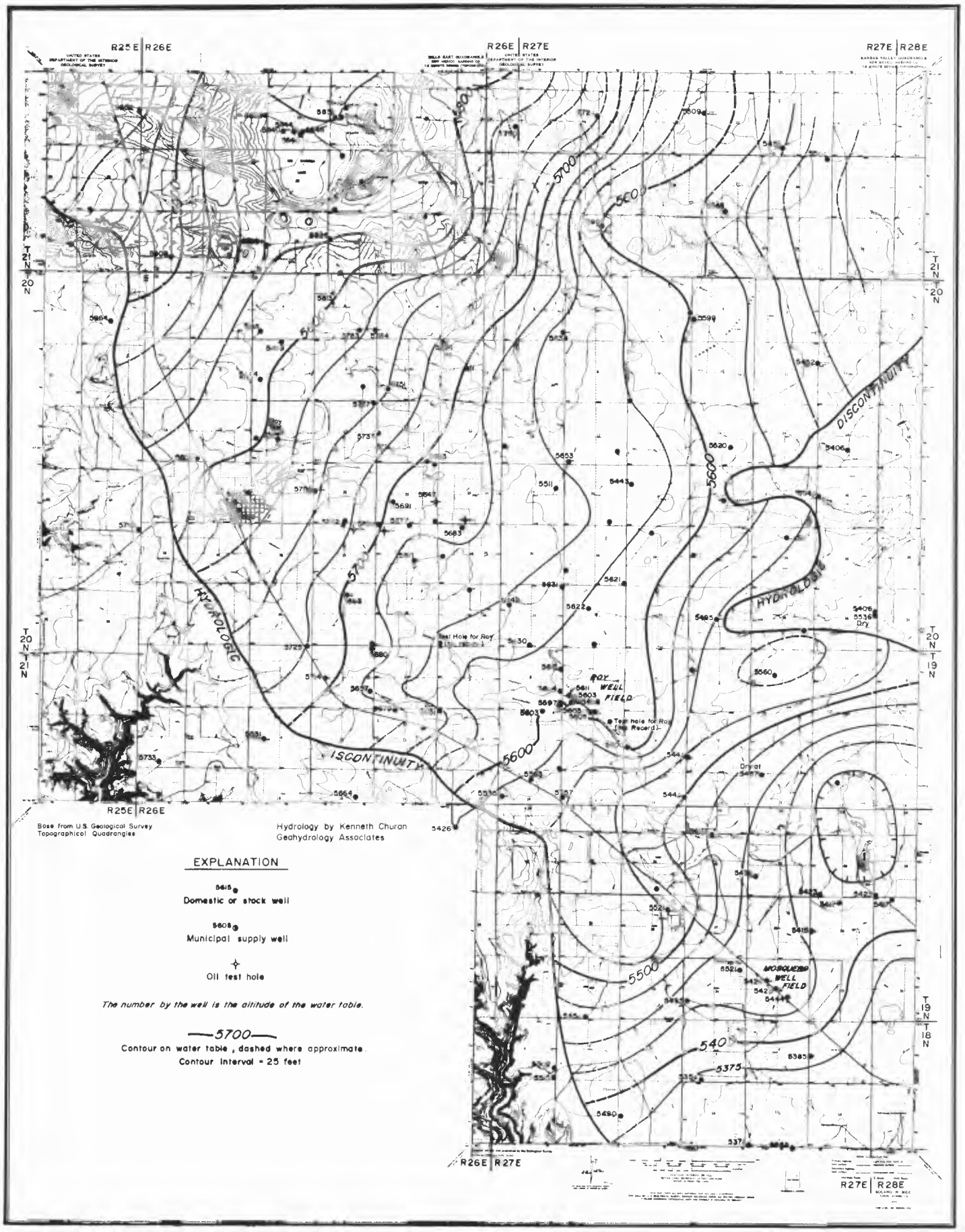


FIGURE 3. Map showing location of selected wells and test holes, and water-level contours for the Ogallala aquifer, Roy area, Harding County, New Mexico.

Jurassic System

Exeter/Entrada Sandstone

The Exeter/Entrada Sandstone is a sequence of mostly fine to very fine, soft, yellowish gray to white, moderately calcareous but poorly cemented beds of quartz sand (Trauger and Bushman, 1964, pp. 17–20). No water wells are known to penetrate the Exeter in the vicinity of Roy, but several wells obtain good supplies of water from the Exeter in the valley of Tequesquite Creek, adjacent to State Highway 65. The oil test well 1.25 mi east of Roy (20.26.26.1123) penetrated an estimated 90 to 100 ft of deposits presumed to be the Exeter/Entrada beds. The gamma and neutron logs (Fig. 4A, B) for this well indicate the static water level in the well is at a depth of about 816 ft in the Exeter/Entrada.

Bell Ranch and Morrison formations

The Bell Ranch and Morrison formations consist of a thick sequence of thinly-bedded sandstone similar to the Exeter, red and green variegated clay and shale and interbeds of gray shale and sandstone. The rocks of the Bell Ranch and Morrison formations generally are poor aquifers. The sandstones are mostly fine-grained and well cemented. The shales and mudstones also are relatively impermeable. No wells in the area are known to develop water in these rocks.

The clean white sandstone found locally at the base of the Mesa Rica Sandstone, and considered by Trauger et al. (1972, p. 20) a possible correlative of the Cheyenne Sandstone, may, in fact, be a unit at the top of the Morrison according to Holbrook and Wright (1987, this guidebook). In the absence of sample material for examination, the shale horizon indicated in the middle of the Mesa Rica in the gamma ray and neutron logs for well 20.26.26.114 (Fig. 4) could well be the Tucumcari Shale, thus making the Cheyenne Sandstone (?) the uppermost unit of the Morrison.

Cretaceous System

The Cretaceous System in the Roy area includes the following formations, from oldest to youngest: Tucumcari Shale, Mesa Rica Sandstone, Pajarito Shale, Romeroville Sandstone, Graneros Shale, Greenhorn Limestone and Carlile Shale. The Mesa Rica, Pajarito and Romeroville formations are considered to be units of the Dakota Group (see Lucas and Kues, 1987, this guidebook). The Tucumcari and Pajarito shales are not everywhere present. They are exposed locally and are found in oil-test drill holes and a few water wells that fully penetrate the Romeroville and Mesa Rica sandstones. The Carlile, Greenhorn and Graneros are more commonly found in wells drilled in the northern part of the area because they overlie the Romeroville Sandstone and underlie the Ogallala. The rocks of the Cretaceous System in general yield only negligible amounts of water, and that commonly of poor quality. The shales are considered to be the likely source of the high fluoride content found in the well water at Chicosa Lake State Park. Only the Mesa Rica and Romeroville are of importance as aquifers in the Roy-Solano area.

Mesa Rica and Romeroville sandstones

The Mesa Rica and Romeroville sandstones consist of a 165- to 210-ft-thick sequence of massive to coarsely-bedded sandstones with local thin interbeds of shaley sandstone and siltstone. The sequence is about 190 ft thick in the oil-test well in sec. 26 east of Roy (Fig. 4A, B). Distinguishing the Romeroville from the Mesa Rica is difficult in well cuttings as they are of similar character. The overlying Romeroville Sandstone commonly is lighter in hue, and may be nearly white in places. The Pajarito Shale, where present, lies between the Romeroville and underlying Mesa Rica and commonly is yellowish-gray.

The Romeroville-Mesa Rica Sandstone sequence furnishes small amounts of water to many wells in the Roy area. It must be considered an important aquifer because where the Ogallala is dry (above the water table), the Romeroville-Mesa Rica sequence is the *only* aquifer. Only small yields, 1/2 to 5 gpm, can be expected from wells tapping either unit. The best that can be said is that the greater the penetration, the more likely a well would be to develop a supply adequate for domestic and stock use.

Tertiary System

Ogallala Formation

The Ogallala is the principal aquifer of the study area, and in most places it will supply adequate water for domestic and stock use. Yields to 100 or more gallons per minute have been obtained locally. The Ogallala underlies the surface of nearly all the plateau area. It is a sequence of poorly-sorted to well-sorted sand and gravel generally more-or-less cemented with calcium carbonate. The more densely cemented masses usually are referred to as "caliche" and have been quarried extensively for road surfacing.

The formation ranges in thickness in the area from as little as 5 to 10 ft on the western margin of the outcrops, just west of Roy, to as much as 220 ft in the vicinity of the Roy well-field. About 116 ft of Ogallala are indicated in the geophysical logs for the oil-test well. The Ogallala is thickest in those places where it filled shallow valleys and drainageways developed on the pre-Ogallala surface. Outcrops and well-log data indicate that the pre-Ogallala surface in the Roy area had a low relief, probably rarely over 30 to 40 ft.

The carbonate (caliche) development generally increases greatly upward in the formation and commonly forms a capping that may be several tens of ft thick. The water-bearing and transmitting capability of the Ogallala Formation decreases greatly with increased alteration and calcification. At depth, where the calcification is poorly developed or absent, the sand and gravel beds are highly permeable and have a high storage capability with respect to water. Such unaltered beds generally are found only where the Ogallala is thickest, that is, in the old buried stream channels.

Quaternary System

An appreciable area in the vicinity of Roy is underlain by alluvium, wind-blown silt and sand and lake deposits. The alluvium and wind-blown material generally is thin, at most about 5 to 10 ft. It overlies the Ogallala everywhere in the area but may be disregarded as a source of water. The lake deposits are found underlying the beds of all the sink depressions large enough to have contained water for any appreciable length of time. The deposits are mostly very fine sand to silt and clay. Some thin beds of coarser material may occur locally, especially near the points where stream channels entered the lakes during earlier pluvial cycles.

The maximum thickness of the deposits in the larger lake beds, known as Chicosa or Kansas Valley, is not known, but they may be as much as 30 to 50 ft, or possibly more. A few stock wells obtain water from the lake deposits, but none in the area are known to yield more than a few gallons per minute. Two wells in Black Lake Basin, northeast of Mosquero, reportedly are about 50 ft deep and produce 20 to 55 gpm from sands. It is not certain the sands are lake deposits—they could be Ogallala.

The water from one of these wells was considered for public supply in about 1969 for the town of Mosquero, but when tested the water was found to have much too high a mineral content for human consumption. Such is commonly the case with lake-basin sediments. A high mineral content may be expected of any water developed in the lake beds where the lakes did not have an outlet. Kansas Valley Lake, the largest sink in the vicinity of Roy, and probably the largest on the plateau, had an outlet during much of Pleistocene time, and it is possible that any gravel and sand deposits at the mouths of entering streams would yield water of good quality.

GENERAL HYDROLOGY

Ground water in the various formations occurs under water table conditions in the vicinity of Roy. Slight barometric pressure-change effects noted in water levels in some wells during the pumping test are attributed to differential response in the interfingering beds of gravel,

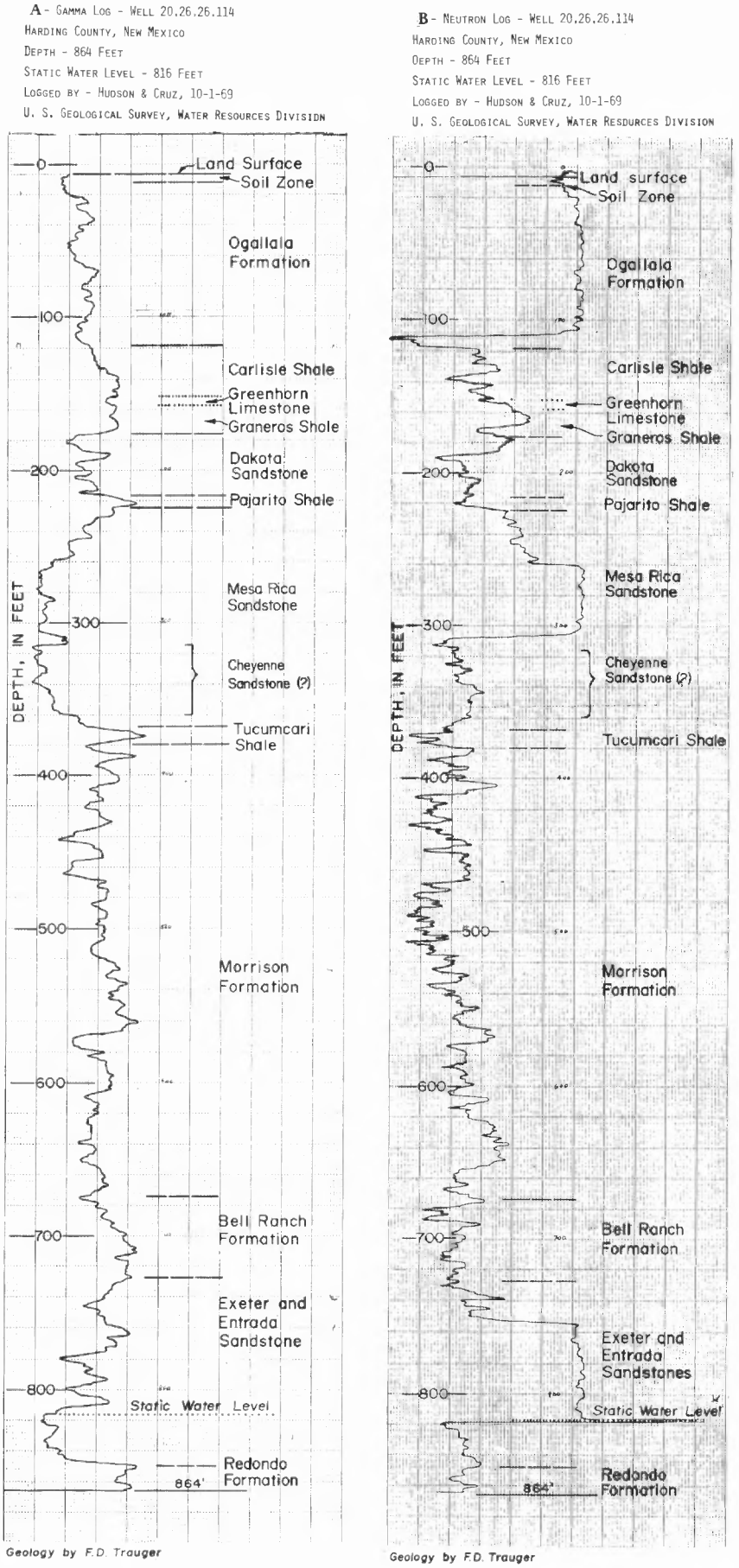


FIGURE 4. Geophysical logs of oil-test wells in section 26 east of Roy, Harding County, New Mexico.

sand, silt and clay that comprise the Ogallala Formation. Such fluctuations result from relatively rapid changes in barometric pressure. When the atmospheric pressure stabilizes, water levels return to the static unconfined position. The term "semi-confined" is sometimes used to describe such occurrences.

There are two essentially different water tables in the vicinity of Roy because of the elevated position of the plateau upon which Roy is situated, and because of the rather extreme differences in water-bearing characteristics of the various rock formations. The two water bodies may not be perfectly separated, but for practical purposes one may be recognized in the Ogallala Formation and another in the Mesa Rica-Romeroville sandstone sequence underlying the Ogallala. When water levels are noted on the water-table contour map (Fig. 3), it may be seen that the levels in some wells are as much as a hundred or more ft deeper than those in nearby wells. The deeper levels are in wells finished in the Romeroville-Mesa Rica sequence. The shallow water levels are in the Ogallala-alluvial deposits.

The water in the Ogallala and alluvium may be considered to be perched in those places where remnants of the Graneros-Greenhorn-Carlile shale and limestone sequence separate the Ogallala from the Romeroville. The shales are virtually impermeable and hold up water in the Ogallala. When these beds are absent, the water is not perched, the Ogallala may be "dry," and only small amounts of water can be developed in the Romeroville-Mesa Rica sandstones at appreciably greater depths.

Movement of ground water in the plateau area generally is from northwest to southeast. A ground-water divide roughly parallels State Highway 39 and follows more-or-less the western margin of the Ogallala outcrop in the study area. Ground water west of the divide thus moves west-to-southwest in the pre-Ogallala rocks.

The topography west of the highway in general has much greater relief than to the east. Runoff is rapid, and infiltration (recharge) is negligible because of the relatively impermeable character of the rocks. So-called "gully washers" are common during the summer rainy season. East of the highway, runoff is commonly slower due to lower gradients. As a result, some recharge occurs whenever precipitation is adequate to wet the ground to below the soil-depth and the level of root development. That does not happen often; thus, while recharge does occur it is in only small increments at infrequent intervals.

RECHARGE AND DISCHARGE

In a generally accepted study of recharge on the southern High Plains area of New Mexico, Theis (1937) determined that probably less than half an inch, or about three percent of the average annual precipitation in that area, became ground water. The topography there is about the same as in the Roy area, and the surface there also is underlain generally by rocks of the Ogallala Formation.

Havens (1966), as a result of studies in northern Lea County, New Mexico, reported an annual rate of recharge of about 0.8 inches per year or five percent of the average annual precipitation of 16 inches (Tatum area). More recent studies (Brown and Signor, 1973; Stone, 1984; Stone and McGurk, 1985) have suggested much lower rates of infiltration of precipitation. Stone and McGurk (1985, p. 334), utilizing the so-called chloride method for determining the recharge, indicated an average rate of about 0.2 to 0.3%—an order of magnitude less than Theis and Havens. The Stone and McGurk study, however, evaluated precipitation on upland surfaces and infiltration through playa beds, but did not include recharge by stream channel infiltration. They further stated that recharge values for the playas might "not fully reflect playa recharge." They considered only recharge through the playa floors and did not evaluate recharge through the much more permeable annular area adjacent to the floor, recharge that Wood and Osterkamp (1984) concluded was responsible for most of the recharge on the Llano Estacado in Texas.

Trauger (1972, p. 105) noted the rapid loss by bank infiltration of water caught in new stock tanks where only the floors had developed clay seals. Numerous studies made in recent years of infiltration pits constructed for recharge stress that lateral infiltration through the walls of the pits, not the floors, accounts for a large percentage of the infiltrated water. Infiltration through the annular area of the sinks probably is as important, or perhaps more important, than recharge resulting from channel infiltration. Channel infiltration is appreciable in the area of Roy where stream gradients are low. The apparent recirculation of water after about four and one-half days of discharge to the channel adjacent to Roy Municipal Well No. 1 during test pumping (see Kelly, 1987, this guidebook) testifies to the importance of channel infiltration in considering recharge to a shallow aquifer.

As pointed out by Stone and McGurk, the chloride method utilized for recharge determination in Quay and Curry Counties "should be applied to other areas only with considerable caution" (Stone and McGurk, 1985, p. 334). If recharge in the area of the Roy well-field was of the magnitude determined by Stone and McGurk for Quay and Curry Counties, the annual recharge at Roy would amount to about 16 acre-ft per year. Water levels in the well-field, at withdrawal rates of 50 to 60 acre-ft per year, would have shown sharp declines over the past ten years. That water-level declines have not occurred, and water levels have in fact risen, indicates that recharge to the Roy well-field must be at least in excess of the annual withdrawal from wells.

Because the Theis and Havens studies were based on methods that tended to integrate the various effects of unequal increments at different times, places and conditions, and involved calculations of ground-water flow and net changes in water levels, they include recharge from precipitation on the upland surfaces, infiltration in stream channels and playa beds and annual area infiltration; thus these studies are considered to be the more appropriate index of recharge to the Roy well-field.

The precipitation that infiltrates past the soil and root-zone to become ground water tends to move down-gradient toward the major drainages: the Canadian River on the west and Tequesquite and Ute Creeks on the east. Water in the Ogallala is in some places discharged by way of seep springs where gullies and canyons have cut through the Ogallala to the underlying rocks of the Graneros Shale or Romeroville Sandstone. The seeps, where they occur, are found mostly around the margins of the plateau. In similar fashion, water in the Romeroville and Mesa Rica sandstones may discharge at the contact of the sandstones over shales of the underlying Tucumcari Shale or Morrison Formation. One such point of discharge may be observed just below the rim-rock where the Mills Canyon road descends from the plateau.

Chicosa Lake is a ground-water lake developed in a sink hole in the Ogallala. The floor of the sink is below the water table. The rise or fall of the level of the lake is an indication of fluctuations in the annual rate of recharge and discharge to and from the ground-water body in the Ogallala.

AMOUNT OF RECHARGE

The question of the amount of recharge annually to the ground-water reservoir (Ogallala aquifer) is important to later discussions in this paper. The location of the village well-field at the western margin of the eastward-sloping plateau, and the fact that the Ogallala aquifer can receive no recharge except from precipitation and runoff, would suggest that the supply of water available to recharge the city well-field is closely dependent on the vagaries of the climate (and it is). The question then, is how much recharge occurs annually? As mentioned earlier, Theis' work, verified by many subsequent studies, indicates that an average of about three percent of the annual precipitation infiltrates to the water table.

A planimeter survey of the saturated thickness of the Ogallala aquifer shows an area of about 6.7 mi^2 contributing to the city well-field. If the mean annual precipitation at Roy is taken at 15.06 inches (1.25 ft) (Trauger, 1987, this guidebook), then precipitation on each mi^2 (640 acres) is about 800 acre-ft. At a three percent recharge rate, 24 acre-ft per square mile would be recharged. The well-field basin (6.7 mi^2) would receive a minimum of about 160 acre-ft of recharge during a year of normal precipitation.

The estimate is considered minimal because the area of the drainage basin of Weisdorfer and La Pompa Draw is greater than the underlying area of the Ogallala aquifer assumed to constitute the well-field. Some

precipitation falling on the drainage basin outside the 6.7 mi² area of the well-field basin must surely recharge the basin eventually. This study considers that recharge to the 6.7 mi² area of the well-field basin is available in the relatively short period of one to three years, or more-or-less "immediately."

If the recharge to the well-field is about 160 acre-ft in a year of normal precipitation (15 inches), it may be assumed to be proportionally larger in wetter years. However, it could be considerably less than proportional in drier years. In dry years soil moisture would be depleted, and it is probable that appreciably less than three percent would infiltrate to become recharge. The well-field may thus be assumed to be particularly vulnerable to prolonged periods of drought, as during the period 1933 to 1957 when some 19 of 25 years had below-average precipitation (see Trauger, 1987, this guidebook).

USE OF WATER AND WATER AVAILABILITY

Pumpage by city

Galloway's (1958) report on the Roy water supply summarized the development of the town water system and included a table showing operational data for the period July 1957 through August 1958 (Galloway, 1958, p. 19). The monthly pumpage for that period together with pumpage figures for the years 1984 and 1985 are shown in Table 2. It is clear from Table 2 that water use by the town has increased sharply since 1958. The increase has occurred in spite of a sharp decline in population. United States census data furnished by the University of New Mexico Bureau of Business and Economic Research show the population as being 1,138 persons in 1940; 1,074 in 1950; 633 in 1960; 476 in 1970; 381 in 1980; and it was estimated to be 316 in 1984.

The increase in water use is attributed to a greatly expanded sewer system, increased use for landscaping and much greater use over the past thirty years of water-dependent facilities and appliances, such as showers, dishwashers, automatic washing machines and garbage disposals. It is believed unlikely that further large increases in daily per capita use will occur unless some new continuing demand for large amounts of water should develop.

Water-level changes

Water-level change records in Harding County have been kept by the USGS since about 1966 when an observation well net was established in conjunction with a county-wide study of water resources. The records show that water levels in wells in the vicinity of Roy have fluctuated within a relatively narrow range and have neither risen nor fallen greatly. Most of the observation wells have been either abandoned stock or domestic wells. Two of the city wells have been monitored on a regular basis. One of the abandoned wells (20.27.31.344) measured at intervals is about a mi from the well-field but within the same part of the aquifer tapped by the city wells.

The graphs of the water-level fluctuations in selected observation wells near Roy and in city well No. 5, shown in Figure 5, indicate there has been no appreciable decline in regional water levels, or in the well-field over the past twenty years. In fact, water levels in village Well No. 5 indicate a rise of about two ft between January 1967 and January 1983.

An examination of the precipitation and accumulative departure curve (Fig. 5) show that water levels in general should have been rising from about 1968 to 1972, declining through 1978, and rising again from 1978 to the present time. That water levels in the city wells have not declined appreciably since 1972 is encouraging as it indicates no general depletion of the aquifer, or conversely, that annual recharge has been adequate to maintain water levels against sharply increased annual rates of withdrawal from the well-field. However, somewhere, down-gradient from the well-field, water levels must be affected by the increased withdrawals.

Water in storage available to the well-field

An important, perhaps critical, question is how much water is in storage in that part of the Ogallala aquifer tapped by the village well-

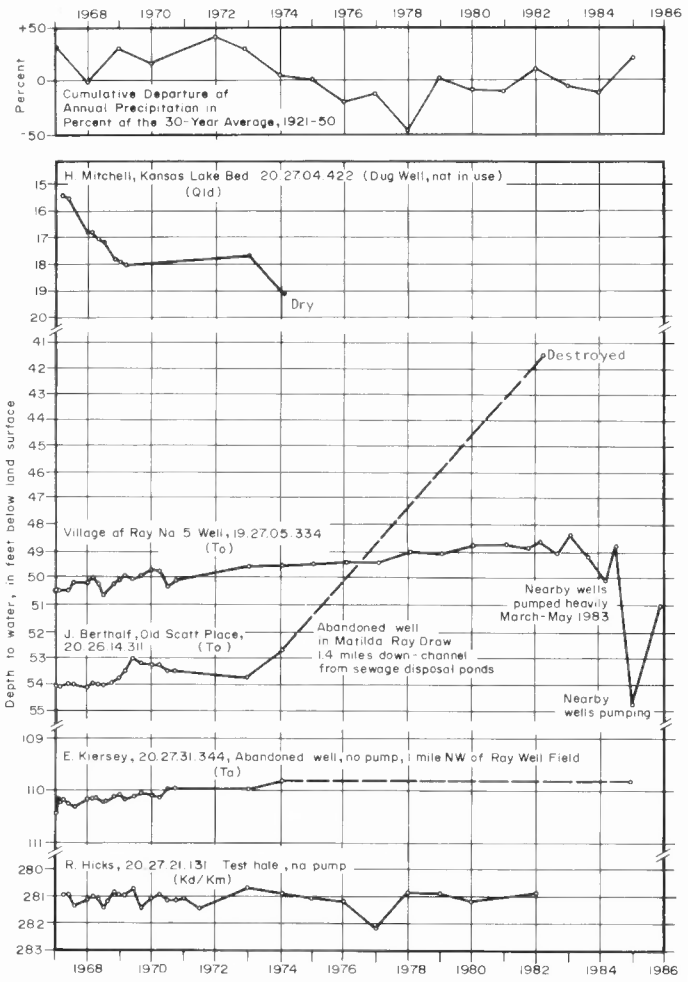


FIGURE 5. Hydrographs of selected wells in the vicinity of Roy, Harding County, New Mexico.

field? To answer that question, a contour map was constructed showing the saturated thickness of the Ogallala in the vicinity of the well-field. The data used to draw the contours were derived in part from some assumptions. Thus, the result is only approximate, but is considered accurate enough to serve the purpose of this study.

The lack of good well logs showing the character of the rocks penetrated made it necessary to assume that most wells penetrated the Ogallala fully and bottomed at the Dakota. Enough logs (Table 2) and verbal reports from drillers are available to indicate the assumption is, in general, valid. It is obvious that where most wells in an area are from 50 to 150 ft deep and produce 5 to 100 gpm, a well 200 to 400 ft deep producing no more than 1 to 3 gpm has not tapped the same aquifer. The assumption is strengthened when knowledge of the geologic formations indicates the Ogallala rarely is over 150 ft thick, and generally is less than 100 ft.

A map is first constructed contouring the base of the Ogallala (Fig. 6) using data obtained from available well logs and the well canvass. Well depths for wells suspected of tapping the Dakota Group were not used, nor were water levels from such wells. The water-level contour map (Fig. 3) shows unconfined water levels assumed to be in the Ogallala aquifer. Water levels obviously at variance with probable occurrence in the Ogallala were not used even though the character of the aquifer supplying that well was not known. The combination of the two contour maps, base of the Ogallala, and water levels, made possible the determination of the saturated thickness. The difference in elevation at any point on the two superimposed maps yielded the saturated thickness at that point. Subsequent contouring using those figures resulted in a saturated thickness map (Fig. 7).

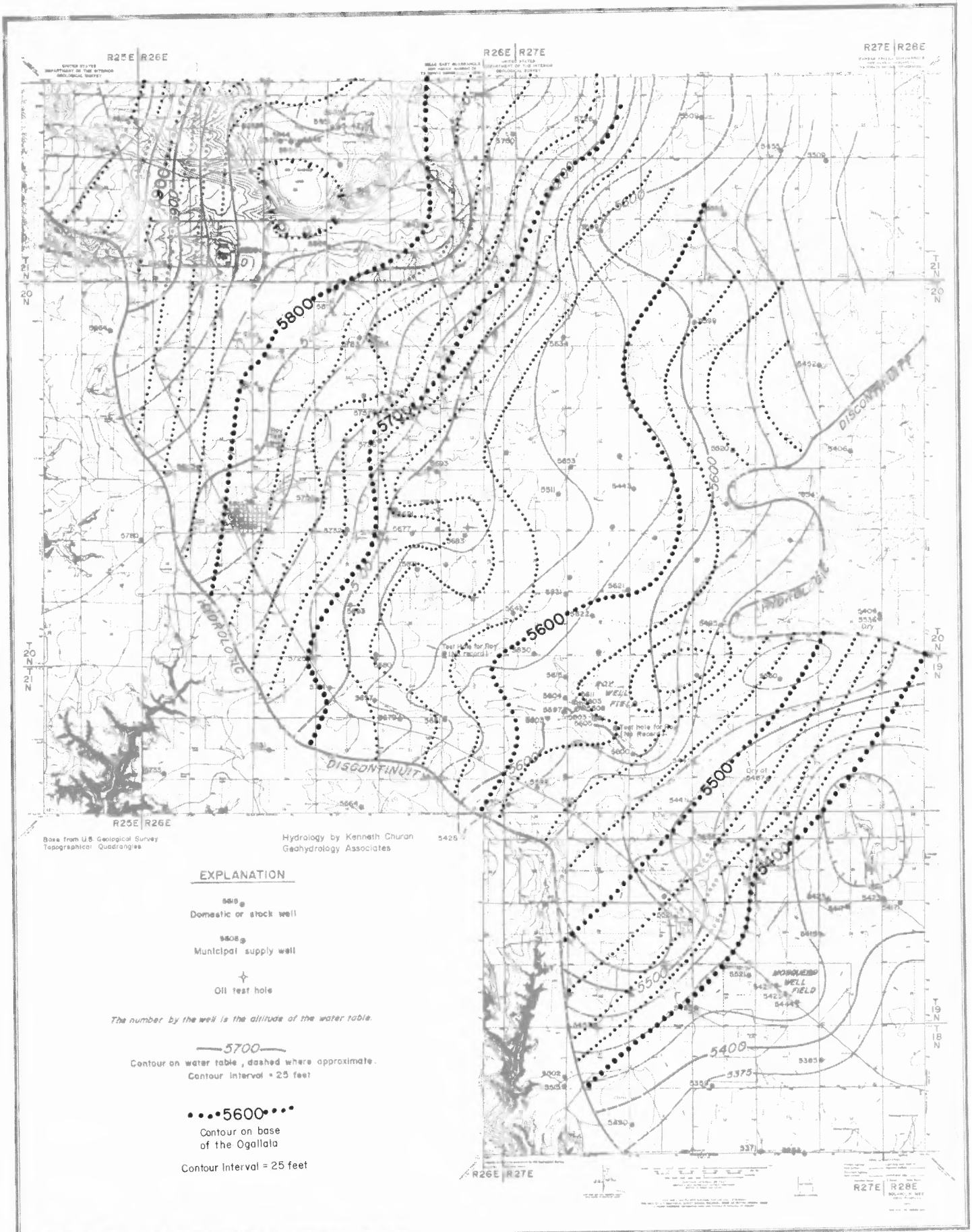


FIGURE 6. Map showing location of wells, water-level contours and contours on the base of the Ogallala aquifer, Roy area, Harding County, New Mexico.

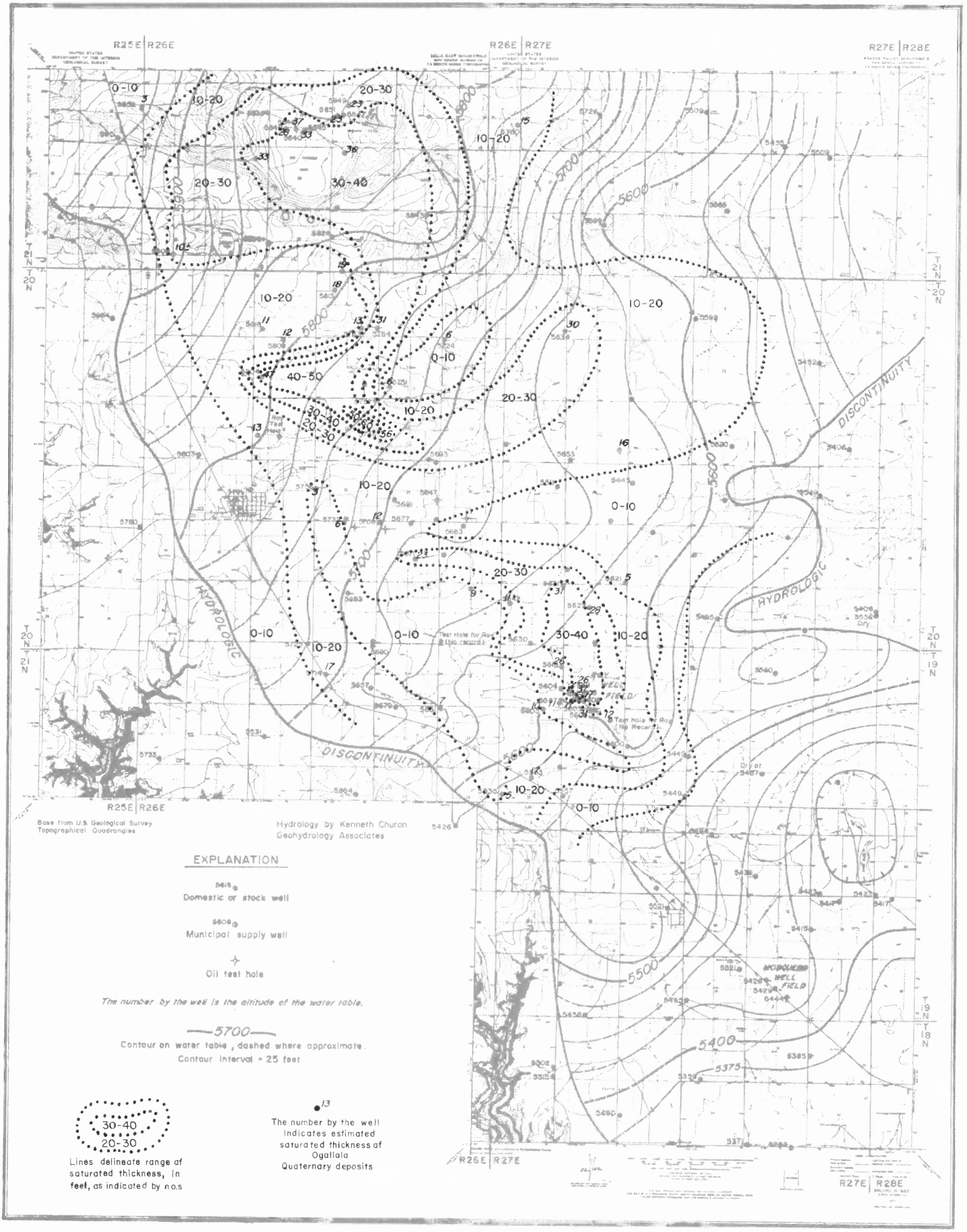


FIGURE 7. Map showing location of wells, water-level contours and saturated thickness of the Ogallala aquifer, Roy area, Harding County, New Mexico.

As expected, the saturated-thickness contour map delineated clearly those areas in which the saturated thickness indicates high yields from wells might be expected. The village well-field lies at the eastern end of a roughly oval area of about 6.7 mi^2. The Ogallala Formation in this area filled a shallow valley developed in the Romeroville Sandstone. The sides of that valley sloped gently toward the axis, or stream bed, of that valley. As a consequence, the cross sections of that valley, east-to-west, and north-to-south, define an asymmetric oval-shaped basin. By assuming ten-ft sectional increments, as indicated in the following diagram (Fig. 8), and a storage coefficient of 0.03 as determined from the pump test, the approximate volume of water in storage in the basin can be calculated. From these calculations it can be estimated that the basin supplying water to the well-field contains about 2,100 acre-ft of water in storage.

It should not be assumed that all the water in storage is available. It is probable that not more than 50% of the water in storage could be recovered through wells. That figure might be considered optimistic under normal hydrologic conditions, but the location of the well-field at the east apex of the oval-shaped basin, at the natural exit point of ground water moving down-gradient and out of the basin, enhances the probability for a relatively high percentage of recovery. At the annual pumpage rate of about 60 acre-ft (1984), the recoverable water in storage, estimated at about 1,000 acre-ft, would last some 16 years, assuming no annual recharge.

It has been shown that annual recharge to the basin in a year of normal precipitation probably is about 160 acre-ft. In a really dry year having no periods of heavy precipitation, recharge could be essentially zero. Assuming no recharge half the time, the average rate of recharge would be 80 acre-ft, or still more than the annual 60 acre-ft of pumpage. However, to carry conjecture further, in unusually dry years, withdrawals probably would be greater than 60 acre-ft, approaching, or possibly exceeding, the rate of recharge. In that event, a decline in water levels in the well-field probably would be noted. Monitoring of water levels in the well-field and in a nearby observation well should provide early warning of possible aquifer depletion in times of prolonged drought. It is unlikely that periods of less than three to five years of deficient precipitation would result in marked depletion of the aquifer at present rates of withdrawal by the village.

Effects of withdrawal at various rates of annual pumpage

Pumping from the village well-field at an annual rate of 60 acre-ft will, of course, have an appreciable effect on water levels in the immediate area of the pumped wells. These effects can be monitored in the observation wells, as mentioned above. The levels will fluctuate seasonally as withdrawal rates vary with seasonal usage, and the levels may decline sharply if withdrawals are appreciably greater than average. This effect was noted on water levels in village Well No. 5 during the period 18 March through 30 October 1983, during and after the time when water was furnished to A&S Construction Company for work on the State Highway (Fig. 5).

In the seven-week period from 9 March 1983, through 29 April 1983, approximately 1,447,500 gallons of water (4.4 acre-ft) were delivered



0-10 ft. contour interval - 4,288 ac. x 10 = 42,880 ac.ft.
10-20 ft. contour interval - 2,112 ac. x 10 = 21,120 ac.ft.
20-30 ft. contour interval - 704 ac. x 10 = 7,040 ac.ft.
71,040 ac.ft.

70,000 ac.ft. x 0.03 = 2,100 acre feet of water

FIGURE 8. Method of calculating water in storage in the Roy well-field.

TABLE 3. Monthly pumpage, town of Roy (in gallons).

Year	1957[a]	1958[a]	1984	1985
Population		1,100	316 (est.)	300 (est.)
January		831,395	1,000,000 (est)	1,074,000 ('86)
February		552,011	850,000 (est)	884,500
March		606,848	1,134,400	989,400
April		583,757	1,407,300	1,692,900
May		634,209	1,857,000	1,685,800
June		696,992	2,312,100	2,314,400
July		909,236	2,549,400	3,556,700
August		1,028,027	2,328,400	2,182,900
September	1,216,850		1,781,200	1,901,100
October	1,664,263		1,097,400	1,233,500
November	871,612		907,600	1,972,900
December	538,250		1,160,300	
GALLONS/YEAR		10,133,450	18,385,100	19,697,900
ACRE-FEET/YEAR		31	56	60
AVERAGE PUMPING RATE, GAL/MIN		19	35	37
GALLONS PER DAY PER PERSON		25	159	180

[a] from Galloway, 1958

to the construction company. That is equal to a steady discharge of about 20 gpm. Water was at the same time being delivered to residents at the estimated rate of 30 gpm, steady flow, making a total steady pumping rate of about 50 gpm from the well-field. Some increase in the rate of water-level decline would have occurred normally as pumping increased with the advent of spring, but the average daily decline of about 0.012 ft through 2 May is attributed mostly to the added stress on the aquifer of pumpage for the construction company. The extra draft ended 29 April, but declines continued through May, then leveled off, picking up again in mid-July as the effects of normally heavy June pumping for city use were manifested. The normally heavy summer water usage sent the level in the well down through September. As use tapered off, levels rose. Measurements made by city personnel show that by 15 March of the following year, water levels in No. 5 well had recovered to a level higher than on 18 March 1983, when pumping to supply A&S Construction began.

This discussion is presented to show that temporary heavy drafts on the aquifer need not be cause for concern. In periods of normal precipitation, annual recharge apparently is adequate to restore water levels to pre-draft conditions.

To illustrate the theoretical effect of pumping from the well-field on water levels in the field, and on wells in the vicinity, projections were made assuming no recharge to the aquifer, a worst-possible scenario that could happen only if a drought worse than that of the 1930–1955 period should develop and last for a longer time. Hydrologic coefficients for the Ogallala aquifer used to make the projections were those determined from data collected during the test pumping of City Well No. 1 (Kelly, 1987, this guidebook). The effects after 40 years of pumping at continuous rates of 60, 90 and 150 gpm are shown on Figure 9. The 60 gpm rate represents pumpage at about 30% greater than for 1985. It may be seen that water levels in the center of the well-field would be lowered about eight ft, and about 2.5 ft at a distance of 2,000 ft after 40 years. Such declines would appear to be of little concern, and it is most unlikely that precipitation would be so deficient that no recharge would occur in that time. Should such an event happen, it is more likely the village would be out of people before being out of water.

Pumping at a continuous rate of 150 gpm would lower the water levels excessively and probably could not be sustained for 40 years as

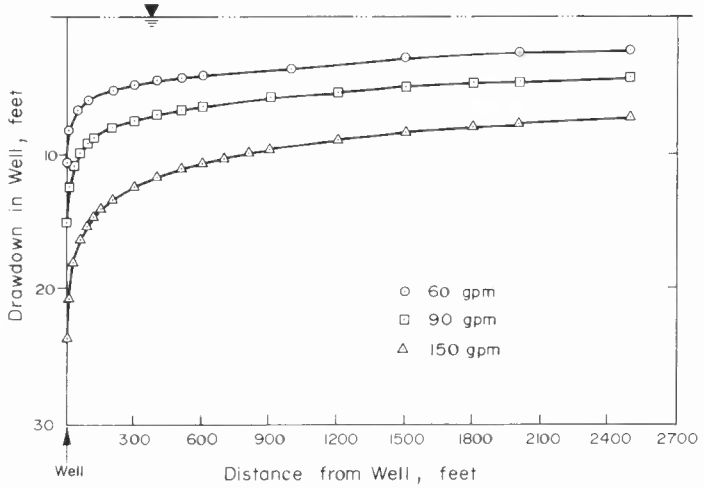


FIGURE 9. Projected drawndown after 40 years of pumping from the Roy well-field at various rates of discharge.

indicated by the graph (Fig. 9). The saturated thickness of the aquifer in the well-field is only about 40 ft at most, and a 24-ft decline in the static water level at the well would result in greatly diminished yield. Transmissivity decreases as the saturated thickness decreases, and reduction of the saturated thickness of an aquifer by as much as 50% may be considered as warning of impending aquifer failure.

Quality of water

The chemical suitability of ground water for various uses depends on the type and quantity of dissolved matter. The chemical suitability is independent of the biological suitability. A water may be of excellent chemical quality for human use yet contain bacteriological matter that makes it unsuitable for domestic use. This study considers only the chemical suitability of ground water in the Roy area. Concentrations of common constituents are reported in Table 4 in milligrams per liter (mg/l). Milligrams per liter are approximately the same as parts per million (ppm) for concentrations up to 7,000 units. For example, one pound of calcium dissolved in one million pounds (120,000 gallons) of water would yield water having 1 ppm of calcium. Standards for judging the chemical quality of public-supply water for human consumption are under the jurisdiction of the New Mexico Environmental Improvement Division (EID) (Water Supply Program) of the Health and Environment Department. The standards are set forth in the department manual, "Regulations governing water supplies."

Ground water in the vicinity of Roy is, in general, suitable for domestic, livestock, irrigation and most industrial uses. The village wells produce water suitable in all respects for domestic use. Although generally of good quality, all ground water in the area is hard to very hard (Table 4). Water having a carbonate hardness, as $CaCO_3$, of more than 120 ppm usually is considered to be hard, and under 60 ppm, soft. Water from the village wells has a hardness of about 190 ppm. No sampled wells in the area had a hardness less than 140 ppm. The only troublesome constituent commonly present in ground water in the Roy area is fluoride. Some wells sampled had concentrations as high as 3.2. The concentration in the village wells was from 1.8 to 2.0 ppm. According to the EID standards, the permissible upper limit for a public water supply in the Roy area would be 2.4 ppm, on the basis of the mean annual temperature of 52.0 degrees (F) (Kunkel, 1984, p. 154). The EID currently is considering raising the permissible limits for fluoride to 4.0 ppm, in line with proposals suggested by the U.S. Environmental Protection Agency (EPA) in the Federal Register, dated Thursday, 14 November 1985, part 2. If the permissible limit is raised to 4.0 ppm, water from test wells drilled for the village in the Chicosa Lake area, and rejected because of excessive fluoride content, would be acceptable for public supply.

Standards for public-supply water have commonly set a total dissolved

TABLE 4. Chemical analyses of water from wells in the Roy area, Harding County, New Mexico. Analyses by U.S. Geological Survey. Chemical constituents are in milligrams per liter, which are approximately equivalent to parts per million for water having a specific conductance less than 10,000, or having less than 7,000 parts per million dissolved solids. Location number: see explanation in text. Stratigraphic sequence: Kdr, Romeroville Sandstone; Kdm, Mesa Rica Sandstone; Jm, Morrison Formation; Qal, alluvium; To, Ogallala Formation.

Location number	Owner, tenant, or name	Depth of well (feet)	Stratigraphic unit	Date collected	Temperature (°F)	Temperature (°C)	Silica (SiO_2)	Iron (Fe) In solution	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) + Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Milligrams per liter (mg/l)	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
18.27.14.111	Thompson and Lane	16	Kdr	08-27-69			26	0	110	60	80	370	280	62	2.2	3.0	81.0		520	220	1230	7.7
18.27.14.212	Thompson and Lane	197	Kdm	08-27-69			34	0	39	27	19	210	45	13	1.9	3.1	290	.20	210	36	467	8.5
19.26.15.234	T. A. Weathers	44	Kdm	04-01-69			25	20	64	40	26	170	180	30	3.2	.60	450		320	190	712	7.3
19.27. 5.331	Village of Roy, No. 2	808	To	07-30-58	60	15.5						208	97	22					250	78	565	7.6
19.27. 5.334	Village of Roy, No. 1	718	To	07-30-58	58	14.5	28	10	41	21	27	198	47	13	1.8	5.1	286	.39	189	16	443	8.5
				04-16-60					42	21	28	202		16	2.0	2	282		192		488	8.3
				08-07-70	62	17.0	29		38	22	25	220	44	10	1.8		280	.38	190	8	458	8.1
20.26. 3.141	D. Linder	90	To	04-04-67	56	13	25	10	39	29	34	210	53	37	1.6	7.2	330		220	48	558	7.7
20.26.20.244	L. Payton	4298	Jm	07-24-58	66	19.0	24		50	34	131	302	232	34	1.8	10	666	.91	265	14	1010	7.6
20.26.20.414	J. Grady	116	To	08-02-58	65	18.5	33		49	34	41	228	85	32	1.6	35	423	.58	262	76	670	7.6
20.26.23.323	J. M. Beard	191	To/Kdr	07-31-58	60	15.5	31		50	25	38	167	64	44	1.2	26	384	.48	228	91	601	7.5
20.26.23.424	L. Gambrel	250R	Kdm	07-24-58	59	15.0	8.9		26	18	13	142	27	12	1.6	1.9	180	.25	140	22	308	7.5
20.26.26.411	L. Gambrel	135	To/Kdr	08-02-58	50	10.0	25		40	15	17	190	15	16	.6	5.1	232	.31	162	4	378	7.6
20.27.34.322	Anderson	245	Kdm	08-22-70	61	16.0	15	30	66	51	190	350	370	57	1.8		930	1.3	370	89	1460	8.2
20.27.36.242	State of New Mexico	152R	To/Kdr	08-22-70			10	10	58	52	228	320	500	15	2.4		1000	1.4	360	99	1530	8.0
20.27.36.244	State of New Mexico	14	Qal/To	08-22-70			39	10	22	31	22	270	31	59	1.9		390	.53	310	88	673	7.3
21.26.21.413	W. Fluhman	52	Qal/To	05-02-60	56	13.5															568	
				05-03-60	56	13.5															561	
				05-05-60	56	13.5	28		58	28	23	260	45	26	3.1	1.0	340		260	47	569	7.6
23.26.24.422	U. S. Government	18	To	07-09-70	59	15.0			210	69		410	1100	18	1.4				810	470	2700	7.8

solids limit of 1,000 ppm but allow up to 4,000 ppm if no better water is available, and providing the total is not elevated by an unusual concentration of a single constituent that might prove harmful in high concentrations. Only one sample (Table 4) showed a total dissolved solids concentration above 1,000 ppm. The 1,800 ppm dissolved solids in that sample was the result largely of a concentration of 1,100 ppm of sulfate. The upper limit for sulfate for human consumption is set at 250 ppm by the EPA, but regulations permit the state to allow a higher limit where no better water is available.

Two wells show moderately high concentrations of nitrate, a constituent commonly considered indicative of pollution. The concentrations, 35 and 26 ppm, are within limits generally considered safe for adult consumption but higher than the limits of 10 ppm generally recognized as suitable for infants under three months of age. As a consequence of the low tolerance of nitrate by infants, the state regulations consider 10 ppm the upper limit for public water supplies.

Available analyses of water from wells in the vicinity of Roy do not show the presence of constituents other than those mentioned that might make the waters unfit for human consumption. In brief, ground water in the area is a bicarbonate water—hard to very hard—but of otherwise good quality suitable for general use by humans and livestock.

POTENTIAL FOR DEVELOPING ADDITIONAL SUPPLIES OF GROUND WATER

New well-fields

Data available indicate the possibility of developing additional well-fields in two areas in the vicinity of Roy. The area about one mi west of Chicosa Lake State Park has been shown to have the potential to supply relatively large amounts of water. The USGS files in Albuquerque contain a water analysis card for well 21.26.21.413 in the Chicosa Lake bed showing an analysis for a water sample collected 5 May 1960. The analysis card indicates the owner of the well was the "Town of Roy," that the well was drilled and cased in 1960 to a depth of 57 ft, and that the water-bearing formation was sand and gravel from 22 to 57 ft. The static water level was reported to be 16.3 ft below land surface. The card states that the well was pumped for about 70 hours at an average rate of 116 gpm. No record of the drawdown data for this test could be found in the USGS files. The location number given on the card designates the location of the eastern well of the three shown on the USGS topographic map. Mr. Allen Floersheim reported that the wells were rejected for city supply because of the chemical quality of the water produced. Under present-day water quality standards, the fluoride concentration indicated in the analysis would be sufficient cause to have rejected the wells.

If new fluoride standards are adopted, the three wells in the S1/2, sec. 21 represent a potentially excellent source of additional water for the village. The drainage basin of Leonard Draw which empties into the Big Chicosa Lake bed, just north of the three wells, is more extensive than that of La Pompa and Weisdorfer Draws and so would likely contribute as much or more annual recharge to a well-field. The sands and gravels reported as being the water-bearing formation may in part have been deposited in the basin by prehistoric flow in Leonard Draw.

Another desirable aspect of the Big Chicosa Lake area as a well-field is the matter of pumping lift. The pumping water-levels in the well-field probably would be about 30 ft below land surface, or at an altitude of 5,835 ft. The high point on State Highway 120, between the village and the proposed well-field, is at an altitude of about 5,935 ft. The ground elevation at the town water tank is about 5,890 ft, or about 45 ft lower. The lift from the well-field on the transmission line would be about 100 ft, and from that point, water would flow by gravity to town, and a water tower might not be necessary. The lift from pumping levels in the present well-field to town, plus the lift to the water tower, is about 260 ft. An appreciable savings in pumping costs could be realized by pumping from a well-field at Big Chicosa Lake.

An area closer to town than either the present well-field or the Big Chicosa Lake bed that might be explored for water is between Ivey and Matilda Roy Draws, about 2.25 mi northeast of town. No records could be found to indicate that any test wells had been drilled in the NE1/4, sec. 15, T20N, R26E, where the saturated thickness contours (Fig. 7) indicate the saturated thickness of the Ogallala may be as much as 60 ft. That is even greater than in the present well-field in Weisdorfer Draw.

Galloway (1958, p. 21) indicated that an 8-inch test well (20.26.16.322) was drilled in John Draw to a depth of 419 ft in 1958 but reportedly produced only 10 gpm, presumably from the Romeroville Sandstone. The hole would not have been in the area of high productivity suggested by the saturated thickness contours. Admittedly, the triangular area in secs. 9, 10, 15 and 16 indicated as being underlain by 30 to 60 ft of saturated Ogallala is postulated on insufficient data to be conclusive. More data points would be desirable. However, the area would seem to be worthy of at least one or two test holes to the base of the Ogallala which should be at a depth of about 100 ft. Pumping lifts into town from wells in the NE1/4, sec. 15 probably would be about 140 to 150 ft, less than from the present well-field but greater than from the Chicosa Lake area. Geologic conditions in the vicinity of Roy would seem to preclude the likelihood of obtaining additional supplies of water from well-fields closer to the village than the areas described above.

Expansion of present well-field

The potential for expanding the present village well-field in Weisdorfer Draw to increase the city water supply is conditional. The present wells, Nos. 1, 2, 3 and 5, are too closely spaced for efficient operation. The effect of pumping these wells simultaneously to get more water is to create mutual interference and excessive drawdown in the center of the field, thus decreasing the already thin, saturated thickness, resulting in decreased yield per well. Furthermore, it is not feasible to drill additional wells at greater distances, as between No. 1 and No. 4, because to do so would require the new wells to be at the margin of the areas of greatest saturation. A test hole drilled in sec. 8 (19.27.8.21), southeast of Well No. 4 was abandoned, and a test hole in sec. 36, T20N, R26E, northwest of the well-field, failed to produce over 15 gpm (Galloway, 1958, pp. 12–13).

The contours showing the saturated thickness of the Ogallala in the vicinity of the present well-field indicate the present wells are located at the southern margin of the area of greatest saturation. Any test holes put down east, west or south at distances of 1,500 ft—the theoretical optimum spacing for minimal interference between pumping wells—from the present wells, would be in areas of appreciably less saturated thickness. The saturated thickness map (Fig. 5) would seem to indicate that a test hole drilled in sec. 5, north of the present well-field, might penetrate 30 to 40 ft of saturated Ogallala. Thus, if no other area development is feasible, and it is desired to try to expand the present well-field, a test hole should be drilled about 1,500 ft northeast of Well No. 5.

It is probable the basin could sustain a moderate increased yield if new wells are not located close to the present wells. Previous discussions have indicated that annual recharge to the basin supplying the village wells is appreciably in excess of annual withdrawal, and that pumping effects decrease rapidly away from a pumped well. It is repeated for emphasis, that the greatest danger in over-pumping from wells in the present well-field lies in reducing appreciably the already thin, saturated thickness of the Ogallala aquifer in the immediate vicinity of well Nos. 1, 2, 3 and 5.

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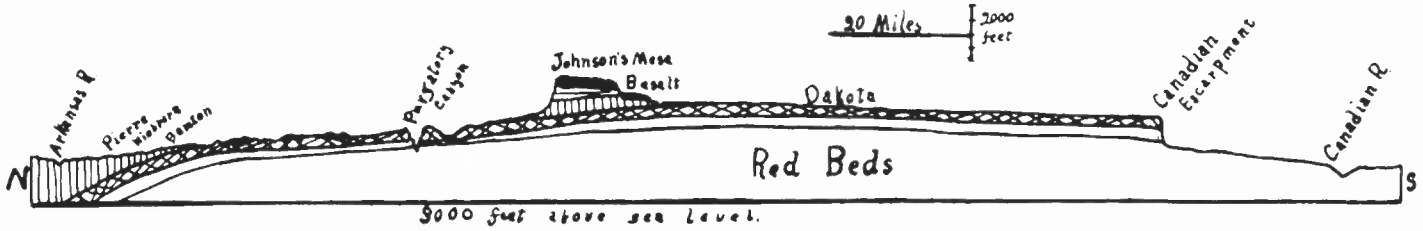


FIG. 11. *A North-South Section from the Arkansas River to the Canadian River along the 103th Meridian.*

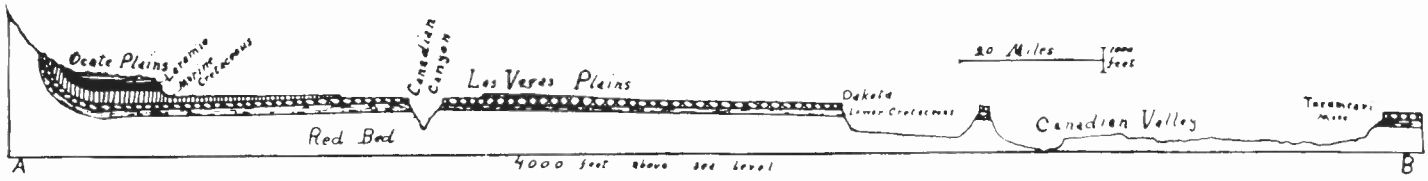


FIG. 12. *Section from the Mountains southeastward to the Staked Plains along the broken line A B of Fig. 1 (page 65), illustrative of the relation of geographic form to geographic structure.*

Geological cross sections in and around the Raton Basin. From Lee, W. T., 1903, The canyons of northeastern New Mexico: Journal of Geography, v. 2, pp. 63–82.