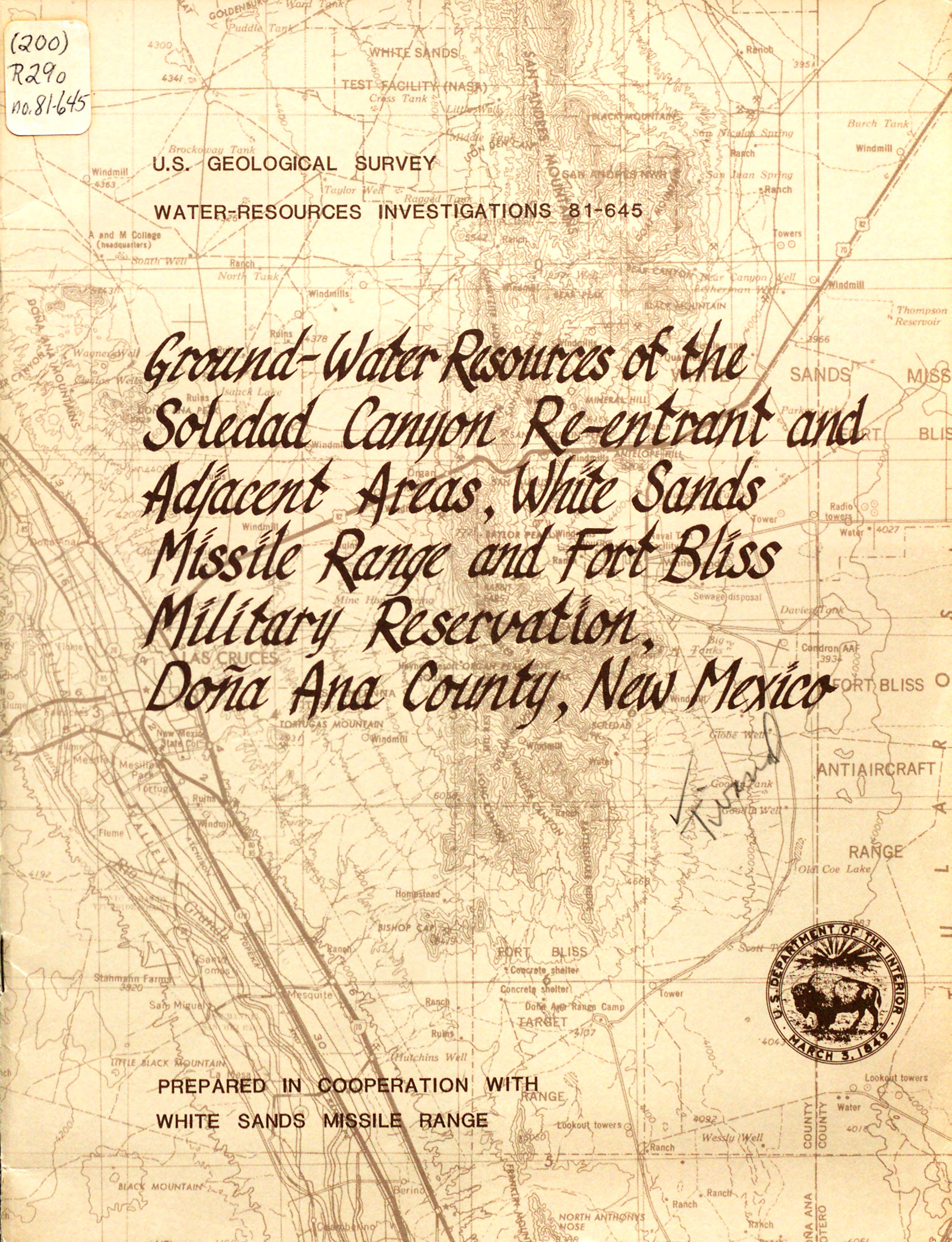
U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS 81-645

Ground-Water Resources of the Soledad Canyon Re-entrant and Adjacent Areas, White Sands Missile Range and Fort Bliss Military Reservation, Doña Ana County, New Mexico



PREPARED IN COOPERATION WITH
WHITE SANDS MISSILE RANGE

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BY C. A. WILSON AND R. G. MYERS

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MAY 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

In this report figures for measurements are given in inch-pound units only. The following table contains factors for converting to metric units.

Multiply inch-pound units	By	To obtain metric units
foot	0.3048	meter
foot per day	0.3048	meter per day
foot squared per day	0.0929	meter squared per day
acre-foot	1,233	cubic meter
square mile	2.590	square kilometer
gallon per minute	3.785	liter per second
inch	25.4	millimeter

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

GROUND-WATER RESOURCES OF THE SOLEDAD CANYON RE-ENTRANT AND ADJACENT AREAS, WHITE SANDS MISSILE RANGE AND FORT BLISS MILITARY RESERVATION, DOÑA ANA COUNTY, NEW MEXICO

BY C. A. WILSON AND R. G. MYERS

ABSTRACT

The Soledad Canyon re-entrant and adjacent areas are located on White Sands Missile Range and Fort Bliss Military Reservation in south-central New Mexico. Geologically, the area consists of outcropping Precambrian to Tertiary metamorphic, sedimentary, and igneous rocks in the west, and Quaternary and Tertiary bolson-fill deposits and surficial alluvium in the east. The bolson-fill deposits consist of alternating and interfingering lenses of clay, silt, sand, and gravel. The saturated section of these deposits forms an aquifer that contains water varying in quality from fresh to saline. No continuous units of sand or clay can be traced between test wells.

The zone of freshwater (dissolved-solids concentration less than 1,000 milligrams per liter) underlies the re-entrant and adjacent areas and pinches out toward the east. Toward the west, the base of the freshwater in the Soledad Canyon re-entrant is at the contact between the bolson deposits and bedrock. Freshwater grades into saline water below the zone toward the east, northeast, and southeast. The freshwater generally meets the accepted quality standards for municipal use, although a few samples contained excessive fluoride. Additional sampling will be necessary to determine selected metallic ion, radioactivity, and chlorinated hydrocarbon concentrations. Approximately 8.7 million acre-feet of freshwater is in storage in the aquifer with an estimated 2.3 million acre-feet available to pumping. Estimated annual recharge to the aquifer from the Soledad Canyon watershed is 750 acre-feet.

Three supply wells, about 700 feet deep and spaced about 1¼ miles apart, each producing 750 gallons per minute for 12 hours each day, could produce about 1,800 acre-feet per year of freshwater. The preferred location of the supply wells is along a line about ½ to 1 mile west of Firing-Line Road where the deepest part of the freshwater aquifer occurs. The maximum saturated thickness at this location is almost 2,200 feet. Should this area be excluded due to use as a gunnery range, the best alternate supply-well locations would be along Firing-Line Road. The saturated thickness of the freshwater aquifer at this location is about 1,200 feet.

INTRODUCTION

The purpose of this report is to evaluate the ground-water resources of the Soledad Canyon re-entrant and adjacent areas as a possible supplemental potable-water source. The study area is located on White Sands Missile Range and Fort Bliss Military Reservation in south-central New Mexico (fig. 1). In this report, the Soledad Canyon re-entrant is defined as that area of bolson deposits immediately east of the Soledad Canyon watershed where the land-surface contours "V" toward the mouth of the canyon. This study is done in cooperation with the Department of the Army, White Sands Missile Range, Facilities Engineering Directorate.

The public water supply for the Post Headquarters area of White Sands Missile Range is obtained from 11 wells located within and immediately north of the Headquarters area. The alluvial aquifer furnishing potable water to the wells is bordered on the south, west, and north by bedrock of the Organ Mountains and on the east by saline water in the sediments of the Tularosa Basin. Saline water and bedrock lie below the potable-water aquifer. Water levels are declining in the vicinity of the well field.

The Water Resources Development Plan for White Sands Missile Range recommends the development of a well field in the alluvial-fan facies located immediately east of the Soledad Canyon watershed as one of several alternatives to increase the public water supply for the Headquarters area (Department of the Army, 1978, p. 123 and 137). The report recommends that by 1981 an agreement be reached with the Fort Bliss Military Reservation, which controls the land south of White Sands Missile Range, on the use of the Soledad Canyon re-entrant area and adjacent land for location of the well field.

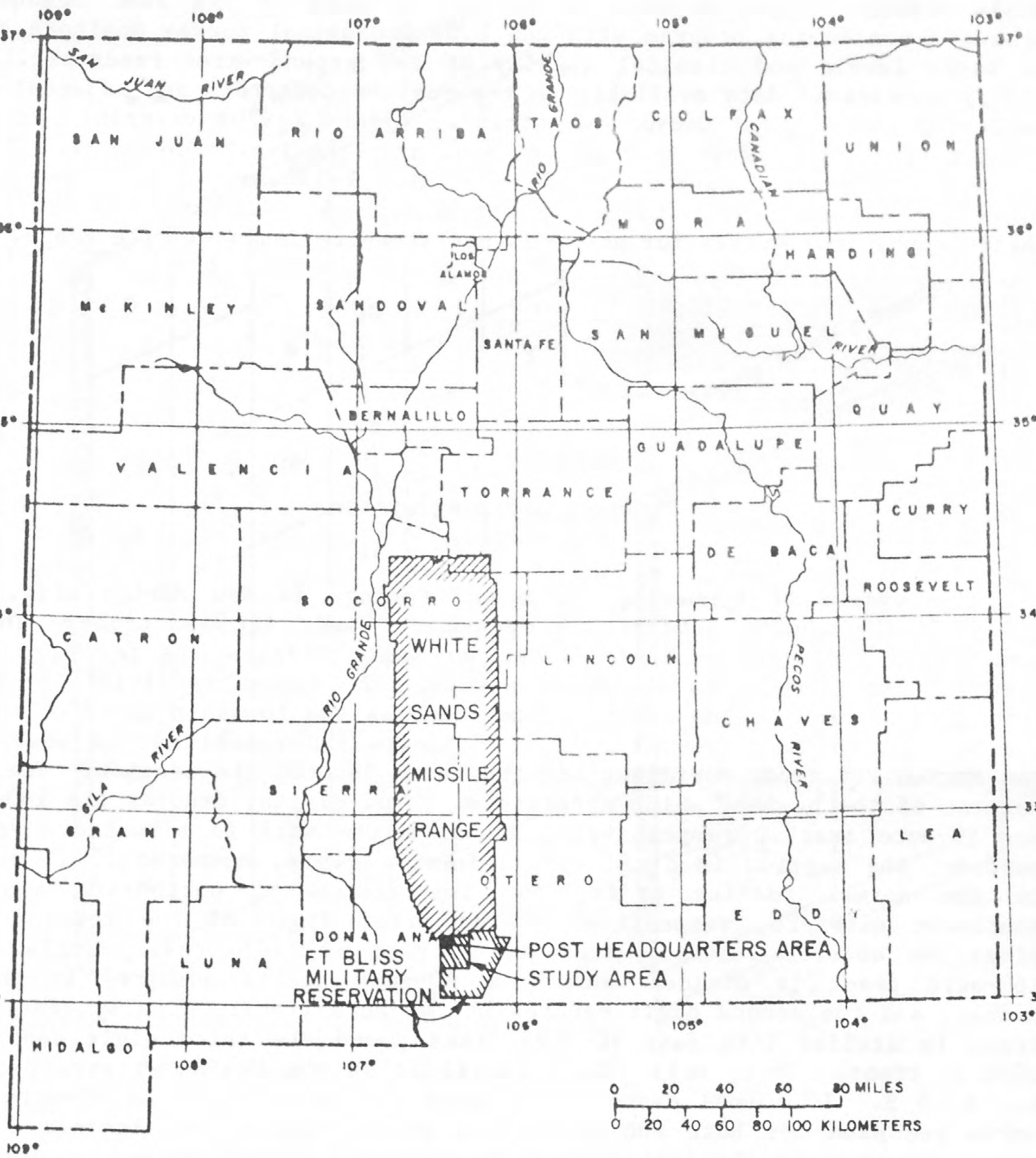

Figure 1. Location of the Soledad Canyon study area.

Many studies have been conducted on the water resources of the White Sands Missile Range, especially in the vicinity of the Post Headquarters area. A continuing program with the U.S. Geological Survey monitors changes in water levels and chemical quality of the ground-water reservoir. Kelly (1973) summarized data available in the Post Headquarters and adjacent areas, including the Soledad Canyon re-entrant. Lyford (1970) described in detail the construction of four test wells in or near the re-entrant area. The land south of the Soledad Canyon area is described by Knowles and Kennedy (1958). Zohdy and others (1969) included part of the Soledad Canyon re-entrant in their geophysical survey for ground water at White Sands Missile Range.

Well-numbering system

The system of numbering wells and springs in New Mexico (fig. 2) is based on the common subdivision of public lands into sections. The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land network. The number is divided by periods into four segments. The first segment denotes the township north or south of the New Mexico Base Line; the second denotes the range east or west of the New Mexico Principal Meridian; and the third denotes the section. The fourth segment of the number, which consists of three digits, denotes the 160-, 40-, and 10-acre tracts, respectively, in which the well is situated. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4 in the normal reading order, for the northwest, northeast, southwest, southeast quarters, respectively. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. Similarly, the 160-acre tract is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 23S.5E.24.342 is in the NE¼SE¼SW¼ sec. 24, T. 23 S., R. 5 E. If a well cannot be located accurately within a 40-acre tract, zeros are used for both the second and third digits. The letters a, b, c, etc., are added to the last segment to designate succeeding wells in the same 10-acre tract.

Where sections are irregularly shaped, the well is located on the basis of a regular square section grid that is superimposed on the irregular section with the southeast corner and eastern section lines matching. The well is then numbered by its location in the superimposed square grid.

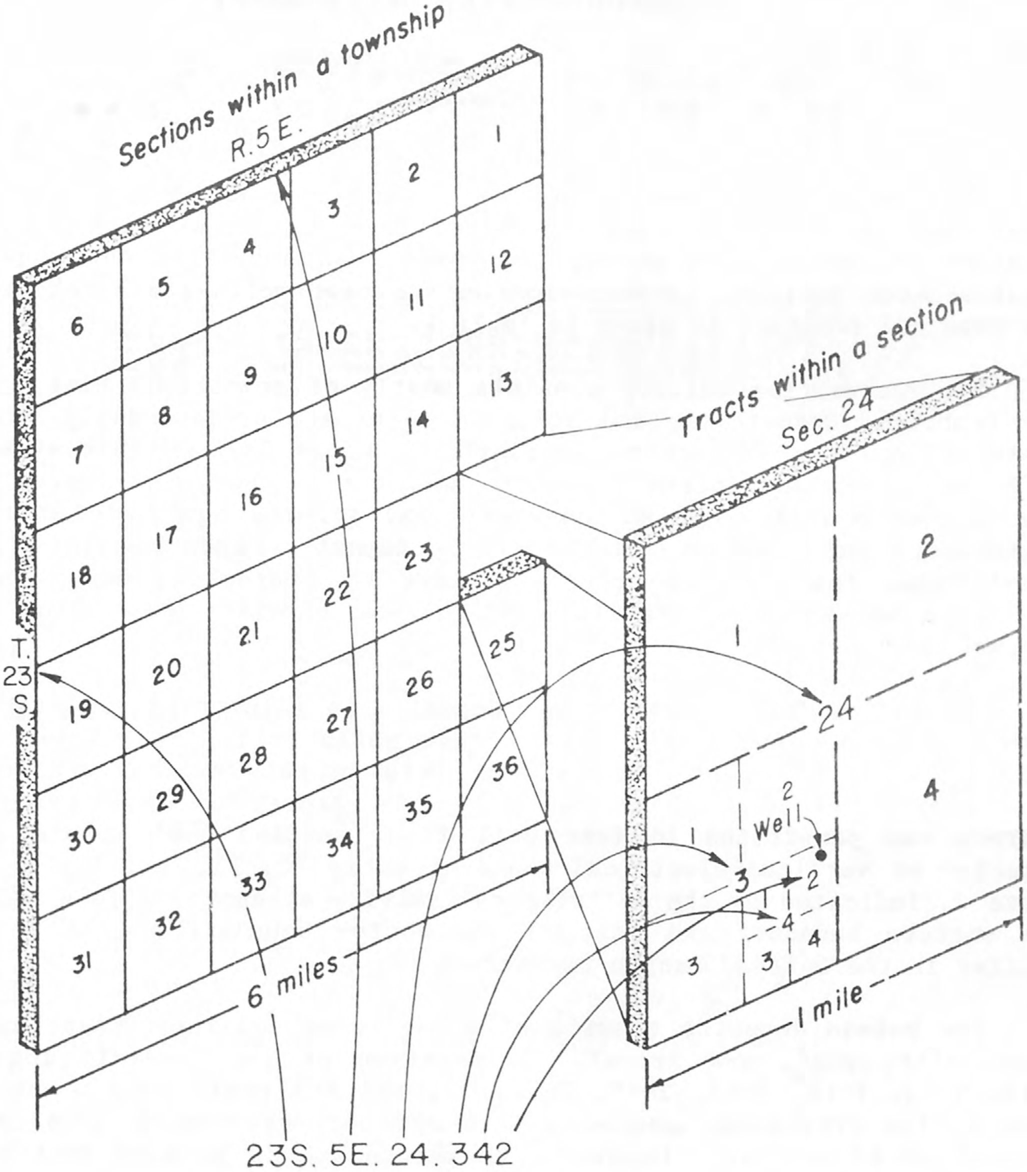

Figure 2.--System of numbering wells and springs in New Mexico.

GROUND-WATER HYDROLOGY

Geology

The geology of Soledad Canyon and adjacent areas and the altitude of the water table are shown on plate 1. Hydrologic sections on plate 2 show the relation of the bedrock geology to the bolson deposits that constitute the potable-water aquifer. Information on the test wells and boreholes shown on the maps and sections is given in table 1.

The Precambrian outcrop consists mostly of granite, schist, and gneiss. The Cambrian, Ordovician, and Silurian rocks are predominantly limestone and shale. The Upper Cretaceous and Tertiary rocks include extrusive rhyolite, tuff, andesite, and intrusive quartz monzonite. The rocks listed above form the bedrock boundary (or basement complex) for the aquifer that consists of Quaternary and Tertiary bolson-fill deposits and surficial alluvium. Considerable faulting has occurred (plate 1); bedrock is exposed on most of the upthrown sides of faults, and bolson deposits cover the downthrown blocks.

The composition of the bolson deposits is illustrated on plate 2 by the lithologic and geophysical logs of test wells T-15, T-16, T-17, T-18, F-1, F-3, F-5, G-1, and L-1. The well numbers in this report correspond to the well numbers used by White Sands Missile Range and in previous reports. Bedrock was penetrated in test well T-18 (section B-B', plate 2) and was detected at vertical-electrical-sounding sites 70, 71, and 73 (section C-C', plate 2, indicated by the infinite resistivity at depth). This bedrock forms the western boundary and part of the bottom boundary of the potable-water aquifer in the Soledad Canyon re-entrant.

The bolson deposits consist of alternating and interfingering lenses of clay, silt, sand, and gravel. Examination of the electric logs for test wells T-15, T-16, T-17, T-18, F-1, F-3, and F-5 indicates the percentage of sand in the freshwater aquifer (plate 2) to range from 48 to 82 percent and to average 61 percent. However, the percentage of sand in that part of the aquifer nearest the Soledad Canyon re-entrant is about 54 percent based on logs from T-16, T-17, and F-1. No continuous, individual units of sand or clay can be traced between test wells. Generally, gravel is common in the upper parts of test wells located near the bedrock outcrop (T-15, T-17, T-18, F-5). Sandy clay or sand and clay intermixed seems more prevalent toward the bottom of test wells (T-15, T-17, L-1).

Table 1.—RECORDS OF SELECTED WELLS AND BOREHOLES IN THE SOLEDAD CANYON AREA
(Cooper, 1970; Cruz, 1978, 1979, 1980; Kelly, 1973; Knowles and Kennedy, 1958)

NAME	LOCATION NUMBER	DATE COMPLETED	ALTITUDE OF LAND SURFACE (FEET)	DRILLED WELL DEPTH (FEET)	PRESENT WELL DEPTH (FEET)	CASING DIAMETER (INCHES)	WATER LEVEL DEPTH BELOW LAND SURFACE (FEET)	DATE MEASURED	REMARKS
windmill	23S.5E.5.311	unknown	4,120	-	-	6	104.10	1-30-80	
OWF3	22S.5E.32.321	unknown	4,115	-	381	-	dry	1-31-53	
							227.23	8-6-79	
OWF6	22S.5E.32.312	6-46	4,104	338	318	-	235.58	1-31-53	
							237.48	8-6-79	
OWF7	22S.5E.32.323	5-46	4,084	-	304	-	237.06	1-31-53	
							232.61	8-6-79	
OWF9	22S.5E.31.424	6-46	4,128	348	348	-	234.00	9-10-47	
							250.39	8-6-79	
B4	22S.5E.28.233	3-71	4,017	260	251	2	200.73	3-9-72	
							197.84	2-79	
							198.00	8-79	
B5	22S.5E.33.223	3-71	3,996	-	243	2	189.63	3-9-72	
							188.14	2-79	
							188.18	8-79	
B6	23S.5E.1.113	3-71	3,929	200	183	2	131.38	3-7-72	
							134.04	2-79	
							134.18	8-79	
B44	23S.6E.20.313	6-71	3,972	260	-	2	196.46	2-3-72	Destroyed.
B45b	23S.5E.24.133	12-71	3,962	270	254	2	181.40	1-27-72	
							186.97	8-78	
B48	22S.6E.31.422	12-71	4,007	300	286	2	203.94	3-9-72	
							204.32	2-79	
							204.49	8-79	

Table 1.—RECORDS OF SELECTED WELLS AND BOREHOLES IN THE SOLEDAD CANYON AREA - concluded
(Cooper, 1970; Cruz, 1978, 1979, 1980; Kelly, 1973; Knowles and Kennedy, 1958)

NAME	LOCATION NUMBER	DATE COMPLETED	ALTITUDE OF LAND SURFACE (FEET)	DRILLED WELL DEPTH (FEET)	PRESENT WELL DEPTH (FEET)	CASING DIAMETER (INCHES)	WATER LEVEL DEPTH BELOW LAND SURFACE (FEET)	DATE MEASURED	REMARKS
B51	22S.5E.26.312	2-72	3,946	400	321	2	141.90	3-9-72	
							146.88	2-79	
							146.73	8-79	
B56	22S.5E.30.424	12-71	4,162	350	344	2	-	-	
							280.16	2-79	
							280.34	8-79	
T11	22S.5E.29.232	11-66	4,087	1,808	575	8	279.65	11-16-66	Cement plug
							273.34	2-79	at 780 ft.
							273.51	8-79	
T15	22S.5E.33.244	12-68	3,990	2,034	455	8	179.25	6-24-69	Cement plug
							178.55	2-79	at 670 ft.
							178.54	8-79	
T16	23S.5E.10.413	2-69	3,980	2,007	549	8	186.85	6-24-69	Cement plug
							186.20	2-79	at 710 ft.
							185.61	8-79	
T17	23S.5E.27.142	5-69	4,020	2,500	457	8	242.16	6-24-69	Cement plug
							242.24	2-79	at 564 ft.
							242.47	8-79	
T18	23S.5E.5.321	5-69	4,065	894	638	8	257.20	7-23-69	Cement plug
							240.21	2-79	at 704 ft.
							240.40	8-79	
F1	23S.5E.35.333	1953	3,937	1,200	-	-	165.1	4-4-53	
F3	24S.5E.20.334	1953	4,136	1,205	-	-	381.0	6-27-53	
F5	24S.5E.28.244	1953	4,015	580	-	-	256.7	4-4-53	
G1	23S.6E.35.211	1953	4,081	650	-	-	287.5	3-29-53	
L1	25S.6E.4.121	1953	4,052	1,208	-	-	300.3	3-31-53	

Quality of the ground water

In this report, ground water containing less than 1,000 milligrams per liter of dissolved solids is referred to as fresh; slightly saline water contains between 1,000 and 3,000 milligrams per liter of dissolved solids; and saline water contains more than 3,000 milligrams per liter of dissolved solids. Samples of formation water from specific zones in the alluvial deposits were collected by the use of packers during drilling of the test wells and boreholes. The results of these chemical analyses are given in table 2.

The dissolved-solids concentration of samples ranges from 207 to 33,000 milligrams per liter (table 2). The major cations in freshwater from most test wells are sodium and calcium, usually present in about equal amounts. However, freshwater from test well F-3 contains much more sodium than calcium. The major anion in the samples of freshwater is bicarbonate. The saline water contains large amounts of chloride.

The water samples listed in table 2 that have a dissolved-solids concentration of less than 1,000 milligrams per liter generally meet the requirements of the Environmental Protection Agency (1976), except for the amount of fluoride in samples from test wells T-18 and F-3 (3.1 to 8.0 milligrams per liter), which exceeds the recommended limit.

Additional sampling of the freshwater in the aquifer would be necessary to determine the concentrations of other inorganic chemicals that have maximum contaminant levels established by the Environmental Protection Agency (1976). These chemicals include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The Environmental Protection Agency has also established radioactivity levels for radium-226, radium-228, gross alpha-particle activity, beta-particle activity, and photon radioactivity. Samples could also be analyzed for organic chemicals such as the chlorinated hydrocarbons. The additional sampling could be better accomplished by pumping water from the test wells rather than by taking the samples "in-place" using a wire-line sampling tool.

The freshwater aquifer

Sections A-A', B-B', C-C', and D-D' on plate 2 delineate zones in the bolson deposits containing fresh, slightly saline, and saline water. The freshwater zone in the deposits generally corresponds to that part of the aquifer referred to by the Department of the Army (1978) as the "potable aquifer". The thin, slightly saline zone is about equivalent to the "potable/saline interface" described by the Department of the Army (1978).

Table 2.—CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS AND BOREHOLES IN THE SOLEDAD CANYON AREA
(chemical constituents in milligrams per liter)
(Cooper, 1970; Cruz, 1977; Knowles and Kennedy, 1958)

NAME	LOCATION NUMBER	COLLECTION DATE	SAMPLE DEPTH (FEET)	SILICA (SiO_2)	IRON (Fe)	CAL-CIUM (Ca)	MAG-NESIUM (Mg)	SODIUM (Na) + POTAS-SIUM (K)	MAN-GANESE (Mn)	BICAR-BONATE (HCO_3)	CAR-BONATE (CO_3)	SULFATE (SO_4)	CHLORIDE (Cl)
T15	22S.5E.33.244	12-29-68	1,620-1,642	13.0	0.13	1,700	379.0	10,200	-	43	0	3,600	17,100
		1-3-69	714-736	26.0	0.09	47	4.7	63	-	93	0	112	54
		12-14-76	400	1.5	0.01	31	0.9	99.5	0.03	24	0	99	130
T16	23S.5E.10.413	3-11-69	1,360-1,382	33.0	18.00	1,280	683.0	1,450	-	102	0	3,360	13,300
		3-12-69	628-650	28.0	4.00	27	1.8	47	-	104	0	59	20
		3-28-69	310-700	38.0	0.56	34	5.6	33	-	127	0	48	16
T17	23S.5E.27.142	4-25-69	1,709-1,731	29.0	0.09	465	83.0	1,970	-	57	0	720	3,540
		4-26-69	1,023-1,045	27.0	0.33	22	0	78	-	141	0	66	26
		5-10-69	440-544	28.0	0.05	30	1.7	34	-	113	0	42	11
T18	23S.5E.5.321	5-24-69	505-527	23.0	0.07	46	5.1	103	-	201	0	128	36
		5-29-69	506-684	32.0	0.09	38	1.9	98	-	153	0	119	42
F1	23S.5E.35.333	4-4-53	404-452	58.0	0	36	3.9	24.6	-	104	0	35	17
		4-5-53	470-510	58.0	0.08	35	4.2	28.3	-	104	0	42	19
		4-9-53	636-660	34.0	0	31	6.4	29.2	-	102	0	37	24
		4-10-53	715-744	32.0	0.02	28	4.9	34.9	-	106	0	38	23
		4-12-53	827-865	32.0	0.01	29	3.5	48.7	-	107	0	59	26
		5-3-53	962-1,012	34.0	0	42	3.8	48.0	0	94	0	59	54
		5-6-53	1,162-1,216	32.0	0	640	57.0	435	0.65	54	0	541	1,550
F3	24S.5E.20.334	6-27-53	520-560	23.0	0.06	16	5.0	146.2	0	226	0	66	74
		6-28-53	685-721	26.0	0.37	12	3.8	124.7	0	212	0	49	56
		6-30-53	786-826	13.0	0.15	10	2.5	137.5	0	232	0	42	66
		7-1-53	842-882	17.0	0.03	13	4.1	124.1	0	221	0	37	60
		7-3-53	895-935	14.0	0.14	11	4.8	139.2	0	241	0	48	59
		7-8-53	1,155-1,205	16.0	0.14	14	4.2	138.1	0	408	0	39	53
F5	24S.5E.28.244	4-4-53	408-433	9.8	0	155	8.3	134.0	-	31	0	71	425
		4-4-53	465-505	24.0	0.01	602	20.0	287	-	27	0	159	1,410
		4-5-53	505-580	25.0	0.02	1,480	77.0	531	-	22	0	201	3,500
G1	23S.6E.35.211	3-30-53	423-450	-	-	-	-	-	-	41	0	1,410	6,710
		3-30-53	584-650	-	-	-	-	-	-	35	0	1,460	8,010
L1	25S.6E.4.121	3-31-53	489-514	24.0	0	1,250	282.0	824	-	36	0	1,210	3,390

Table 2.—CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS AND BOREHOLES IN THE SOLEDAD CANYON AREA - concluded

(chemical constituents in milligrams per liter)
(Cooper, 1970; Cruz, 1977; Knowles and Kennedy, 1958)

NAME	FLUORIDE (F)	NITRATE (NO_3)	PHOSPHATE (PO_4)	BORON (B)	DISSOLVED SOLIDS (sum)	CARBONATE HARDNESS	NON-CARBONATE HARDNESS	SPECIFIC CONDUCTANCE (micromhos at 25°C)	pH	TEMPERATURE (°C)	REMARKS
T-15	1.4	1.8	-	-	33,000	5,800	5,760	45,600	6.9	33	Other
	0.4	4.2	-	-	357	137	61	567	7.7	27.5	analyses
	0.9	0.01	-	0.04	375	81	61	688	8.5	24.0	available.
T-16	0.7	1.7	-	-	26,000	6,000	5,920	36,700	7.5	25	
	0.4	3.1	-	-	239	75	0	354	8.2	26	
	0.6	3.2	-	-	240	108	4	355	8.1	25	
T-17	1.2	0.1	-	-	6,840	1,500	1,450	11,200	6.9	32	
	1.1	0.2	-	-	290	55	0	450	7.8	30	
	0.6	4.0	-	-	207	82	0	301	7.8	27	
T-18	3.9	0	-	-	444	136	0	698	7.8	31	
	3.1	0.2	-	-	409	103	0	641	7.4	32	
F-1	0.6	5.0	-	0.02	238	106	-	308	7.7	-	
	0.6	4.2	-	0.08	246	105	-	324	7.6	-	
	0.5	4.2	-	0.21	217	104	-	334	7.9	-	
	0.5	4.3	-	0.06	218	90	-	326	7.7	-	
	0.5	4.2	-	0.10	256	87	-	388	7.8	-	
	0.5	4.0	0	0.04	299	120	-	471	7.4	-	
	0.1	1.5	0	0.40	3,280	1,830	-	5,440	7.0	-	
F-3	8.0	1.0	0.01	0.11	458	60	-	761	7.7	-	
	5.0	1.5	0.02	0.15	384	46	-	628	8.2	-	
	4.0	1.5	0.01	0.16	395	36	-	669	8.1	-	
	6.0	1.0	0.01	0.16	371	50	-	631	8.1	-	
	6.0	0.5	0.02	0.30	402	47	-	670	8.2	-	
	8.0	1.0	0.01	0.16	408	52	-	675	8.0	-	
F-5	0.4	4.0	-	0.05	823	420	-	1,630	6.9	-	
	0.1	1.5	-	0.06	2,520	1,580	-	4,620	6.8	-	
	0	-	-	-	5,830	4,010	-	10,200	6.8	-	
G-1	-	-	-	-	-	7,950	-	19,000	6.5	-	
	-	-	-	-	-	8,950	-	22,500	6.6	-	
L-1	0	-	-	-	7,000	4,280	-	11,000	6.7	-	

The delineation of the three water-quality zones of the sections on plate 2 was based on chemical analyses of water samples taken during drilling of the test wells and on the resistivity value of the electric logs. The resistivity curve for the electric logs on plate 2 represents that curve on the original log that had the better capability of evaluating the true resistivity of the formation fluids (either the long normal or deep induction logs). A resistivity value of about 17 to 20 ohm-meters squared per meter usually represents fresh-quality formation water while a resistivity of about 7 to 9 ohm-meters squared per meter is indicative of slightly saline water. Saline water normally has a resistivity of less than 5 ohm-meters squared per meter.

The approximate altitude of the base of the freshwater zone is shown on plate 3. Toward the west, the base is formed by the bedrock-bolson deposits contact (section B-B' and C-C', plate 2); to the northeast, east, and southeast, the base is represented by a water-quality change to slightly saline (plate 2). The top of the aquifer is the water table. The axis of the freshwater aquifer trends north-south and generally parallels the surface contact of the bedrock-bolson deposits (plate 1). The deepest part of the aquifer, about 2,500 feet below land surface, occurs near vertical-electrical-sounding 73 (section C-C', plate 2).

The saturated thickness of the freshwater aquifer is shown on plate 4. The thicker part of the aquifer is located about 3 miles east of the surface contact of the bedrock and bolson deposits. The maximum saturated thickness is almost 2,200 feet.

The volume of freshwater in the Soledad Canyon re-entrant and adjacent areas is calculated from that portion of the saturated thickness (plate 4) located south of a line extending from T-18 to vertical-electrical-sounding 40 and north of the trace of section D-D' (plate 2). The western edge is the bedrock contact, and the eastern edge is the estimated eastern extent of freshwater. The enclosed area covers about 54,000 acres and contains about 29 million acre-feet of sediments in the freshwater aquifer.

The volume of freshwater in the area described above is estimated to be 8.7 million acre-feet, based on an assumed porosity of 30 percent. The amount of freshwater that might be available to pumping is estimated to be 2.3 million acre-feet, based on an assumed specific yield of 15 percent (Kelly and Hearne, 1976, p. 37) and an estimate that 54 percent of the aquifer is permeable sand or gravel.

The results of an aquifer test on test well T-11 are reported by Kelly (1973). Lyford (1970) reported test results for wells T-16, T-17, and T-18; however, the results for T-18 were not considered valid by Lyford and are not presented here. The following summary gives the transmissivities from these reports and the calculated hydraulic conductivity of the sand or gravel units contributing to the perforated interval:

Test well	Transmissivity (feet squared) per day)	Type of aquifer test	Net sand thickness (feet)	Hydraulic conductivity (feet per day)
T-11	1,700	unknown	159	10.8
T-16	5,020	drawdown	171	29.4
T-16	4,790	recovery	171	28.0
T-17	2,190	drawdown	91	24.1
T-17	2,380	recovery	91	26.2

The average hydraulic conductivity of the sand and gravel units (using a single average value for each well) is 21.6 feet per day if T-11, T-16, and T-17 are considered, and 26.9 feet per day if only T-16 and T-17 are considered. The hydraulic conductivity calculated for T-11 does not appear to be representative, but the values for T-16 and T-17 are similar to values calculated for other wells in the area. Based on information given in Kelly (1973, p. 15-17) and Wilson, White, Roybal, and Gonzales (1978, p. 16 and 31), the average hydraulic conductivity of supply wells SW-10a, SW-12, SW-13, SW-14, SW-15, SW-16, SW-17, SW-18, SW-19, SW-21, and SW-22 is 26 feet per day.

Recharge

The watershed and adjacent bolson-fill deposits in the Post Headquarters well-field area cover about 52 square miles (Kelly and Hearne, 1976, p. 38). Kelly and Hearne (1976, p. 39-40) estimated that about 3 percent of the precipitation (average of 16 inches per year) that falls on the bolson deposits or on the bedrock mountain areas forming the watershed for the Post Headquarters area will reach the aquifer as recharge. They estimated the annual recharge to the aquifer in the Headquarters re-entrant to be about 1,300 acre-feet. This amount of recharge is approximately 60 percent of the current annual pumpage from the Headquarters well-field.

The area of the Soledad study area bounded on the west by the Soledad watershed boundary and Rattlesnake Ridge, on the east by the 4,200-foot contour line, on the north by the Soledad watershed boundary and a line extending to T-18, and on the south by a horizontal line through a point approximately 3 miles south of vertical-electrical-sounding site 73 is about 36 square miles. The average precipitation on this area is probably less than the 16 inches used in the recharge calculation of Kelly and Hearne because it is at a lower altitude. Assuming an average annual precipitation of 13 inches over the area and that 3 percent of this moisture reaches the aquifer as recharge, about 750 acre-feet of recharge is received annually on this area.

CRITERIA FOR ESTABLISHMENT OF A WELL FIELD IN THE SOLEDAD CANYON AREA

A report by the the Department of the Army (1978, p. 123 and 138) recommends construction of three supply wells in a 1- by 2-mile area located in the Soledad re-entrant approximately 3 miles west of T-17. However the preferred location for future supply wells is about ½ to 1 mile west of Firing-Line Road (plate 1), where the greatest thickness of sediments containing freshwater occurs. The report also recommends construction of about eight test and observation wells around the well field. Presently, Fort Bliss uses the Soledad area for a gunnery range for tanks and artillery. It is possible that the location of any supply wells by White Sands Missile Range on the Fort Bliss Military Reservation will have to be along or east of Firing-Line Road (plate 4). At this location, the wells would be east of the thickest part of the freshwater aquifer. The average saturated thickness east of Firing-Line Road is about 1,200 feet (plate 4). Firing-Line Road lies about 5 to 6 miles west of the line marking the estimated eastern extent of freshwater.

A well field located along Firing-Line Road in the Soledad area would be generally similar to the situation in the Post Headquarters well field. The Headquarters well field is located about 4½ to 5 miles west of the maximum eastern extent of freshwater (Kelly, 1973, fig. 31). The thickness of sediments containing freshwater in the Post Headquarters well field may extend to a depth of about 1,600 feet (Department of the Army, 1978, plate 3-1, p. 32).

It is probable that withdrawal of freshwater by wells located along Firing-Line Road in quantities considerably less than those currently being withdrawn in the Post Headquarters well field would not cause a rapid encroachment of saline water into the Soledad field. Increases in the concentration of dissolved solids in water pumped by the proposed supply wells would probably be very gradual, on the order of a few milligrams per liter per year.

If three supply wells are drilled and constructed in the bolson deposits located east of the Soledad Canyon re-entrant and each well is pumped at a rate of 750 gallons per minute for 12 hours per day, about 1,800 acre-feet per year of water can be produced. The construction of three wells would allow flexibility in the pumping schedule when water is needed, such as during the summer. Supply wells at White Sands Missile Range are usually pumped only 12 hours per day, during the time that electrical demand is low.

A depth of 700 feet for supply wells in the Soledad area would allow about 400 feet of saturated thickness at each well site. This amount of saturated thickness would allow about 800 feet between the bottom of the well and the underlying slightly saline zone. The average transmissivity of 400 feet of aquifer in the area would be about 4,600 feet squared per day, assuming that the average hydraulic conductivity is 21.6 feet per day and that 54 percent of the saturated thickness is permeable sand and gravel.

Theoretical drawdowns at various distances from a well discharging 750 gallons per minute for selected periods of pumping are shown in figure 3. The aquifer is assumed to have a transmissivity of 4,600 feet squared per day and a storage coefficient of 0.15. No correction to the transmissivity was made for reduced saturated thickness due to drawdown. While theoretical, such a graph is useful in planning the location of production and observation wells.

Drawdown at the water table becomes very small at distances about 1 mile away from a pumping well, assuming a pumping period of 100 days (fig. 3), which might be representative of a period of heavy summer pumpage. If wells are spaced far enough apart, the interference between the cones of depression created around the pumping wells will be minimized. If mutual interference between cones of depression is minimized, there will be smaller changes in the gradient of the water table (plate 1), resulting in minimal encroachment of saline water from beneath or from the east.

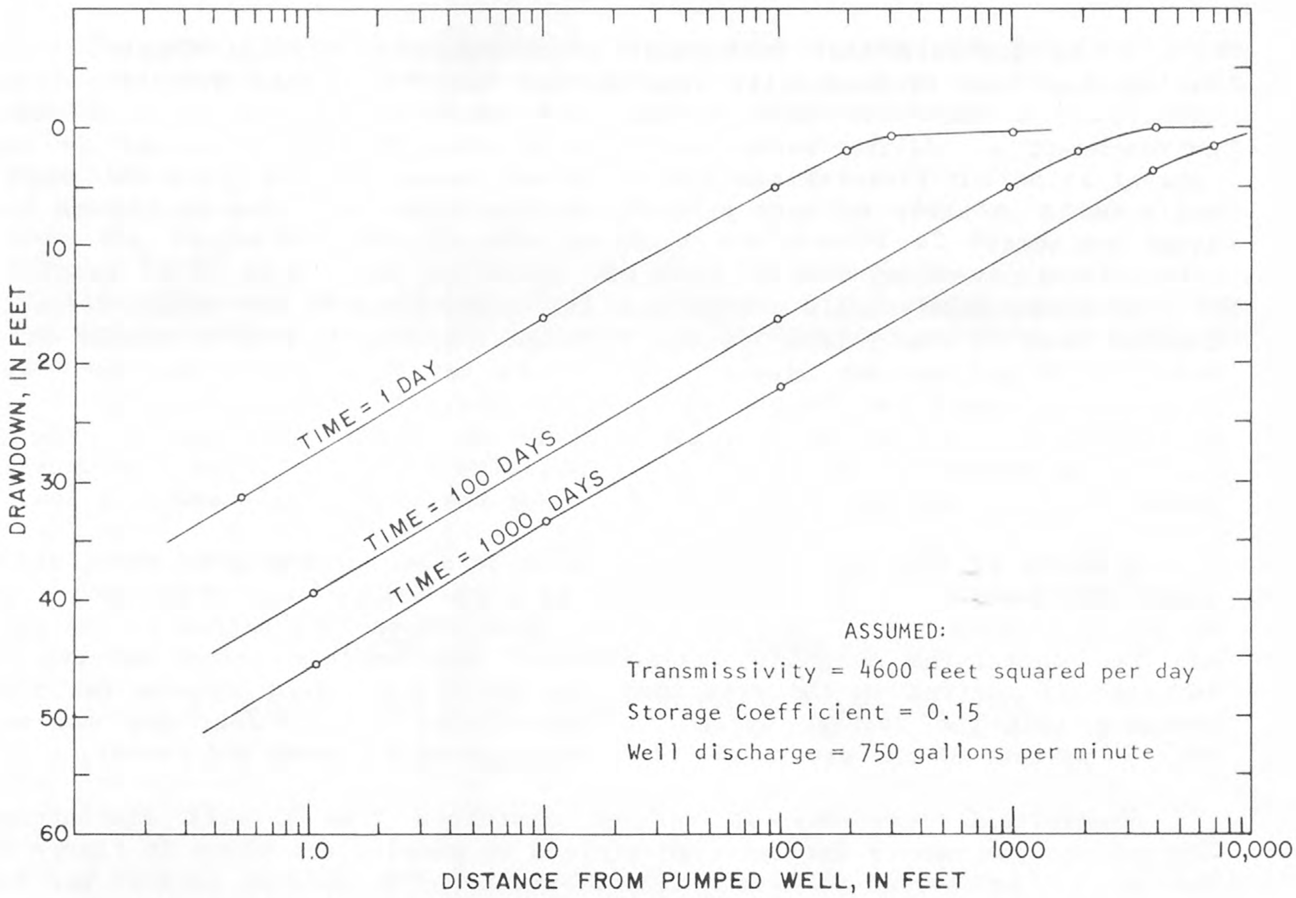

Figure 3. Theoretical relation of drawdown to time and distance as a result of pumping.

The preferred location to minimize boundary effects for the three supply wells would be in the thickest part of the freshwater aquifer (plate 4) and at distances greater than 1 mile from the contact of the bedrock and bolson deposits. Possible locations for three supply wells with respect to existing test wells are shown in figure 4. One well could be located near vertical-electrical-sounding 73, the second well could be located about 1¼ miles north of vertical-electrical-sounding 73, and the third well located about 1¼ miles south of vertical-electrical-sounding 73. The exact locations could be selected at the time of drilling, when more information may be available. Fort Bliss may require the supply wells to be located east of Firing-Line Road; possible alternate locations for the three wells are shown in figure 5.

If test wells to monitor water-level and chemical-quality changes that may occur due to pumpage are constructed before the supply wells, the hydrologic information obtained could be used in refining the site selection and design of the supply wells.

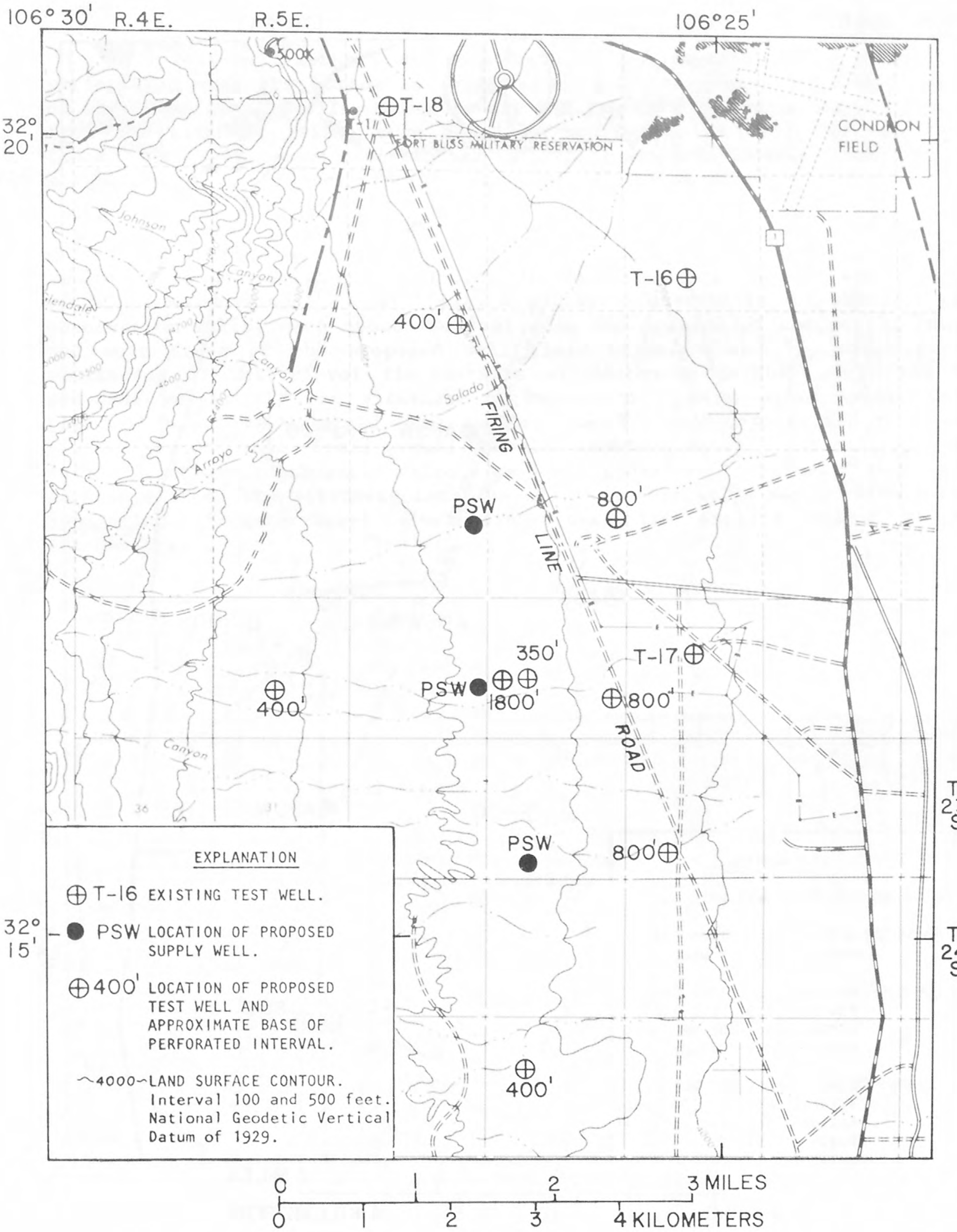

Figure 4. Locations of proposed supply and test wells.

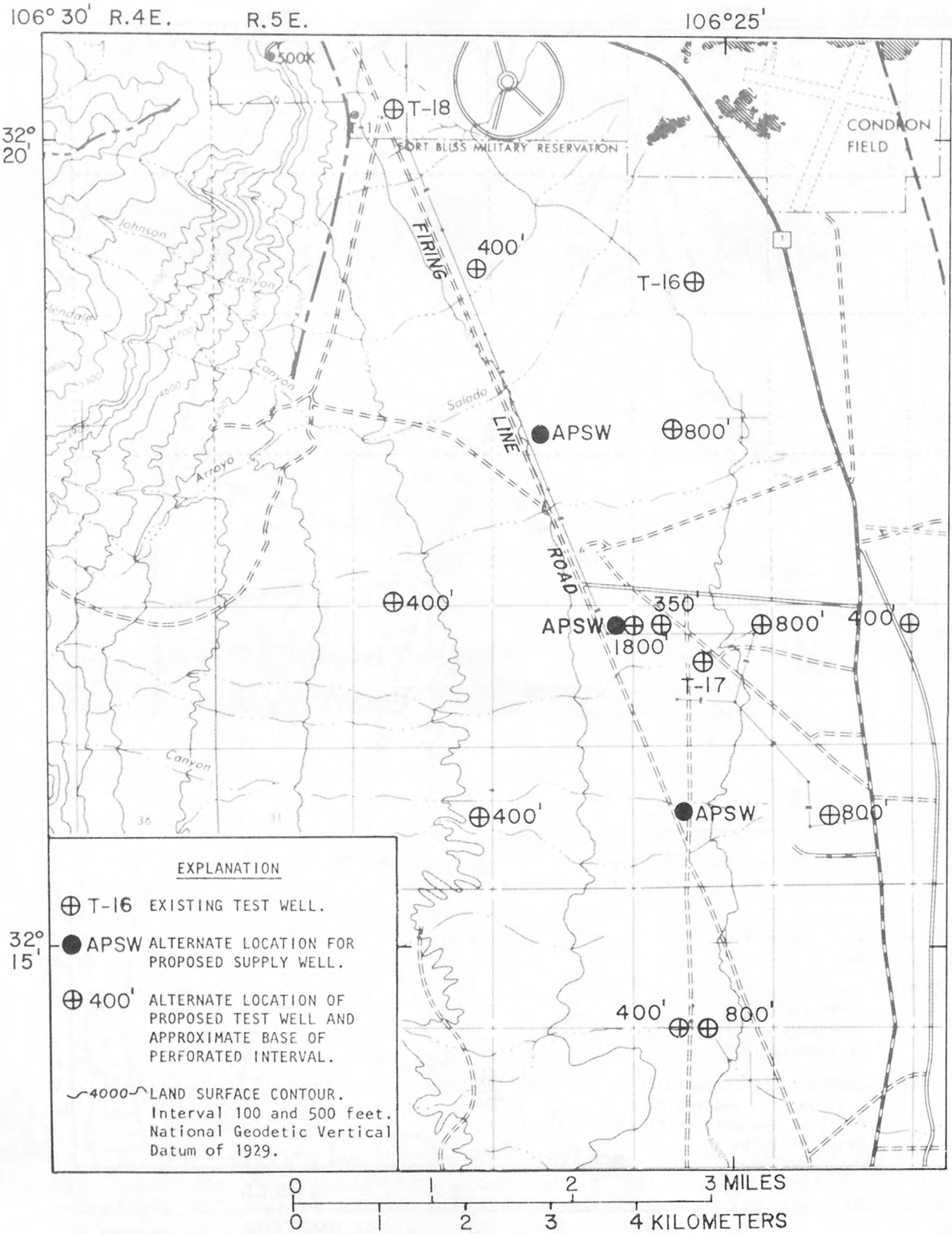

Figure 5. Alternate locations of proposed supply and test wells.

If a test well about 1,600 to 1,800 feet deep with a single interval of perforation near the bottom is constructed near the center or slightly east of the three supply wells, water levels and possible upward movement of water from the slightly saline zone could be monitored. A shallower test well (about 350 feet deep) constructed at this central location would allow monitoring of water levels in the upper part of the aquifer.

Construction of three 800-foot-deep test wells, each with perforations near the bottom and each located about 1 mile east of a proposed supply well, would permit monitoring of water-level fluctuations and possible encroachment of saline water from the east (figs. 4 and 5). Construction of three or four observation wells, each about 400 feet deep and located on the north, south, and west sides of the proposed well field (figs. 4 and 5), would permit monitoring of water-level fluctuations at distances farther away from the proposed wells. If the alternate locations for the proposed supply wells (fig. 5) would be selected, the construction of an 800-foot-deep test well south of the well field would permit improved monitoring of possible saline-water encroachment. Also, an additional 400-foot-deep test well located east of the alternate location of the supply wells would allow closer monitoring of water-level fluctuations near the eastern extent of the freshwater.

SUMMARY

The Soledad Canyon and adjacent areas consist of outcropping Precambrian to Tertiary metamorphic, sedimentary, and igneous rocks in the west and Quaternary and Tertiary bolson-fill deposits and surficial alluvium in the east. The bolson-fill deposits, consisting of alternating and interfingering lenses of clay, silt, sand, and gravel, form the aquifer for White Sands Missile Range. No continuous units of sand or clay can be traced between test wells.

The results of chemical analyses made on water samples taken while drilling test wells showed that the concentrations of dissolved solids of the formation water ranged from 207 to 33,000 milligrams per liter. The freshwater part of the aquifer (dissolved-solids concentration less than 1,000 milligrams per liter) generally complies with the Environmental Protection Agency's maximum contaminant-level requirements. Some samples from wells T-18 and F-3 exceeded the fluoride level. Further sampling of the freshwater could be conducted to determine the amounts of arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, radioactivity, and chlorinated hydrocarbons.

The base of the freshwater zone in the Soledad Canyon re-entrant is at the bedrock-bolson deposits contact toward the west and is marked by a quality degradation to slightly saline and saline water below the zone and toward the east, northeast, and southeast. The approximate volume of freshwater stored in the Soledad Canyon re-entrant and adjacent areas under consideration is estimated to be 8.7 million acre-feet. However, the amount of freshwater that might be available to pumping is estimated to be 2.3 million acre-feet, assuming no mixing with the saline water. The estimated annual recharge from the Soledad Canyon watershed is 750 acre-feet.

A gunnery range on the Fort Bliss Military Reservation may limit the location of a potential well field to the east side of the thickest part of the freshwater aquifer. The average saturated thickness of the freshwater aquifer in this area is approximately 1,200 feet. Three supply wells about 700 feet deep, spaced about 1¼ miles apart, each pumping 750 gallons per minute for 12 hours per day, could produce about 1,800 acre-feet per year of freshwater. If several test and observation wells are constructed, water-quality changes and water-level fluctuations could be monitored.

REFERENCES CITED

Cooper, J. B., 1970, Summary records of supply wells and test wells in the Post Headquarters area, White Sands Missile Range, New Mexico: U.S. Geological Survey open-file report, 202 p.

Cruz, R. R., 1977, Annual water-resources review, White Sands Missile Range, New Mexico, 1976--a basic-data report: U.S. Geological Survey Open-File Report 77-330, 27 p.

———1978, Annual water-resources review, White Sands Missile Range, New Mexico, 1977: U.S. Geological Survey Open-File Report 78-553, 31 p.

———1979, Annual water-resources review, White Sands Missile Range, New Mexico, 1978: U.S. Geological Survey Open-File Report 79-985, 23 p.

———1980, Annual water-resources review, White Sands Missile Range, New Mexico, 1979: U.S. Geological Survey Open-File Report 80-753, 25 p.

Dane, C. H., and Bachman, G. O., 1965, Geologic map of New Mexico: U.S. Geological Survey, scale 1:500,000, 2 sheets.

Dunham, K. C., 1935, The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 11, 272 p., 35 figs.

Kelly, T. E., 1973, Summary of ground-water data at Post Headquarters and adjacent areas, White Sands Missile Range: U.S. Geological Survey open-file report, 66 p., 33 figs., 3 tables.

Kelly, T. E., and Hearne, G. A., 1976, The effects of ground-water development on the water supply in the Post Headquarters area, White Sands Missile Range, New Mexico: U.S. Geological Survey Open-File Report 76-277, 97 p., 18 figs., 6 tables.

Knowles, D. B., and Kennedy, R. A., 1958, Ground-water resources of the Hueco Bolson northeast of El Paso, Texas: U.S. Geological Survey Water-Supply Paper 1426, 186 p., 25 figs., 6 tables.

Lyford, F. P., 1970, Test wells T-15, T-16, T-17, T-18, and RC-3, White Sands Missile Range, Dona Ana and Sierra Counties, New Mexico: U.S. Geological Survey open-file report, 46 p., 14 figs., 11 tables.

U.S. Department of the Army, White Sands Missile Range, 1978, Water resources development: analytical report 210-20, annex 1, U.S. Army, White Sands Missile Range, New Mexico, 151 p.

REFERENCES CITED - CONCLUDED

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: EPA-570/9-76-003, 159 p.

Wilson, C. A., White, R. R., Roybal, R. G., and Gonzales, J. L., 1978, Drilling, construction, and testing of water-supply wells 21 and 22, White Sands Missile Range, Dona Ana County, New Mexico: U.S. Geological Survey Open-File Report 78-172, 34 p., 14 figs., 5 tables.

Zohdy, A. A. R., Jackson, D. B., Mattick, R. E., and Peterson, D. L., 1969, Geophysical survey for ground water at White Sands Missile Range, New Mexico: U.S. Geological Survey open-file report, 144 p., 17 figs.


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Water
Angostura
4030
South Well
SIERRA LUNA
COUNTY COUNTY
Windmill
ATCHISON TOPEKA AND SANTA FE
Ranch
Corral
LUNA COUNTY
DOÑA ANA COUNTY
4705
4471
Windmills
HORSE CANYON
6294
SIERRA DE LAS UVAS
BROAD CANYON
TAILHOLT MTN
BUCKLE BAR CANYON
Buckle Bar Well
FOSTER CANYON
FAULKNER CANYON
LOOKOUT PEAK
Leasburg
Radium Springs
Fort Selden
Ruins
ROBLEDO MOUNTAIN
5876
ROUGH AND READY HILLS
SLEEPING LADY HILLS
MASON DRAW
Tower
Box Canyon Dam
4648
4400
4536
Las Cruces Municipal
4454
Water
4379
4640
5365
4600
5455
Akela
Cambray
Doña Siding
4554
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180
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Aden
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Quarries
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Kenzin
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5080
WEST POTRILLO
ADEN CRATER
THE MALPAIS
New Tank
Lava
Norwood Well
Afton
4216
4265
4288
MERIDIAN
PRINCIPAL