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GEOLOGICAL SURVEY
Water Resources Division

WATER RESOURCES AT MARINE CORPS SUPPLY CENTER BARSTOW, CALIFORNIA FOR THE 1969 FISCAL YEAR

By

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WATER RESOURCES AT MARINE CORPS SUPPLY CENTER, BARSTOW, CALIFORNIA FOR THE 1969 FISCAL YEAR

By J. H. Koehler

SUMMARY

The water supply for the Marine Corps Supply Center, Barstow, Calif., is obtained from wells in the Barstow and Yermo ground-water subunits of the Mojave River basin.

Recharge to the ground-water subunits depends almost entirely on seepage from floodflow in the Mojave River. In the 1969 water year the total flow at the gage at Barstow was 146,000 acre-feet which resulted in about 60,000 acre-feet of recharge to the ground-water subunits. Between March 1968 and April 1969 the water levels rose an average of 1.2 feet in the Yermo supply wells and 10.1 feet in the Nebo supply wells.

Pumpage at Yermo is expected to decrease slightly in 1969. Pumpage at Nebo (Barstow subunit) is expected to decrease from 1,321 acre-feet in 1968 to an estimated 1,200 acre-feet in 1969.

The chemical quality of water from the Yermo supply wells is within the U.S. Public Health Service recommended limits for dissolved chemical constituents. The quality of water from the new well, 9N/1E-3P2 (Yermo 5), is excellent; the sample taken in July 1969 had a dissolved-solids content of 267 mg/l (milligrams per liter). Both the average fluoride and average dissolved-solids contents, in eight samples from the Nebo supply wells, exceed the recommended limits. The quality of water from the new well at Nebo, 9N/1W-14B3 (Nebo 6), is as good as or better than that of the other supply wells.

Pumping tests were made of nine supply wells in the summer of 1969. The test of well 9N/1W-14B3 (Nebo 6), drilled in June 1969, indicates that this well could be pumped at a sustained yield of about 1,500 gpm (gallons per minute) and still maintain an acceptable efficiency. The pumping test of well 9N/1E-3P2 (Yermo 5), drilled in July 1969, indicates that this well could be pumped at a sustained yield of at least 2,500 gpm.

INTRODUCTION

The Marine Corps Supply Center, Barstow, is in the eastern part of the Mojave River basin. The supply center headquarters is near Nebo, a rail siding 2 miles east of Barstow, south of the Mojave River; the Yermo annex is 5 miles downstream on the north side of the river (fig. 1).

This report, covering the 1969 fiscal year, is the third in a series of annual appraisals of the water resources at the Marine Corps Supply Center, Barstow, Calif. It follows a comprehensive report for the supply center by Miller (1969). This report was prepared by the U.S. Geological Survey at the request of the Department of the Navy.

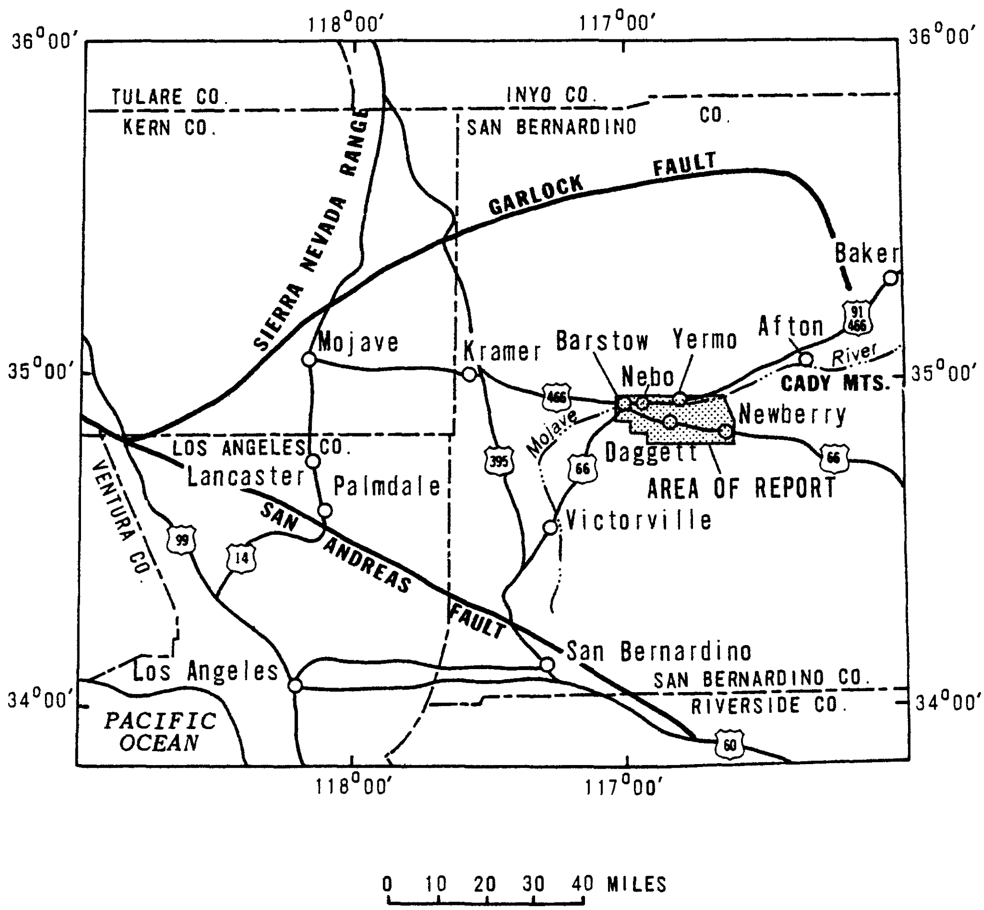
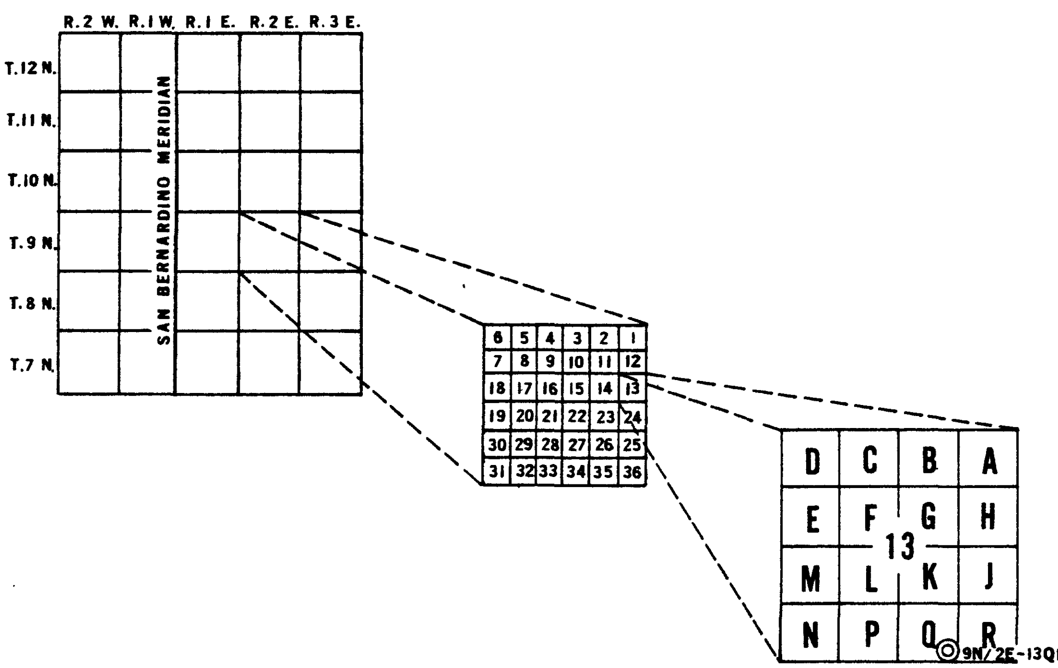


FIGURE 1.--Area of this report.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. As shown by the diagram, that part of the number preceding the slash, as in 9N/2E-13Q1, indicates the township (T. 9 N.); the number following the slash indicates the range (R. 2 E.); the number following the hyphen indicates the section (sec. 13); the letter following the section number indicates the 40-acre subdivision according to the lettered diagram. The final digit is a serial number for wells in each 40-acre subdivision. The area covered by this report lies east and west of the San Bernardino meridian and north of the San Bernardino base line.

The letter Z, substituted for the letter designating the 40-acre tract, indicates that the well was plotted from unverified descriptions; the described locations of such wells were visited, but no evidence of a well could be found.



Purpose and Scope

The purpose of the continuing appraisal is to collect and analyze water-resources data and to advise the Marine Corps on hydrologic conditions that may affect the water supply at the center.

The scope of the study includes:

1. Making annual water-level measurements in wells to determine the change in water level and the direction of ground-water movement.

2. Monitoring pumpage to determine the effect on the ground water in storage.

3. Annually determining the condition of the center's supply wells from Southern California Edison Co. pump-efficiency tests.

4. Evaluating the chemical analyses of water to determine changes or trends.

5. Preparing an annual report evaluating the water resources at the supply center.

This report was prepared by the U.S. Geological Survey, Water Resources Division, under the immediate supervision of J. L. Cook, chief of the Garden Grove subdistrict, and under the general supervision of R. Stanley Lord, district chief in charge of water-resources investigations in California.

WATER RESOURCES

Surface Water

Recharge to the ground-water subunits depends almost entirely on seepage from infrequent floodflow in the normally dry Mojave River.

Total flow in the Mojave River, recorded at the gage at Barstow, in the 1969 water year (October 1, 1968, to September 30, 1969) was about 146,000 acre-feet,[1] the wettest year of record. This is about three times greater than the total flow recorded for the previous 20 years (fig. 2). Flow was recorded from January to May of 1969. During this time, two major flood peaks occurred. The first peak occurred January 26 and had a maximum discharge of 28,000 cfs (cubic feet per second).[2] The second major peak occurred February 25 with a maximum discharge of 30,000 cfs.

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[1]An area of 1 acre covered to a depth of 1 foot equals 1 acre-foot, about 325,850 gallons.

[2]A flow of 1 cfs equals about 2 acre-feet per day; a flow of 43,560 cfs equals 1 acre-foot per second.

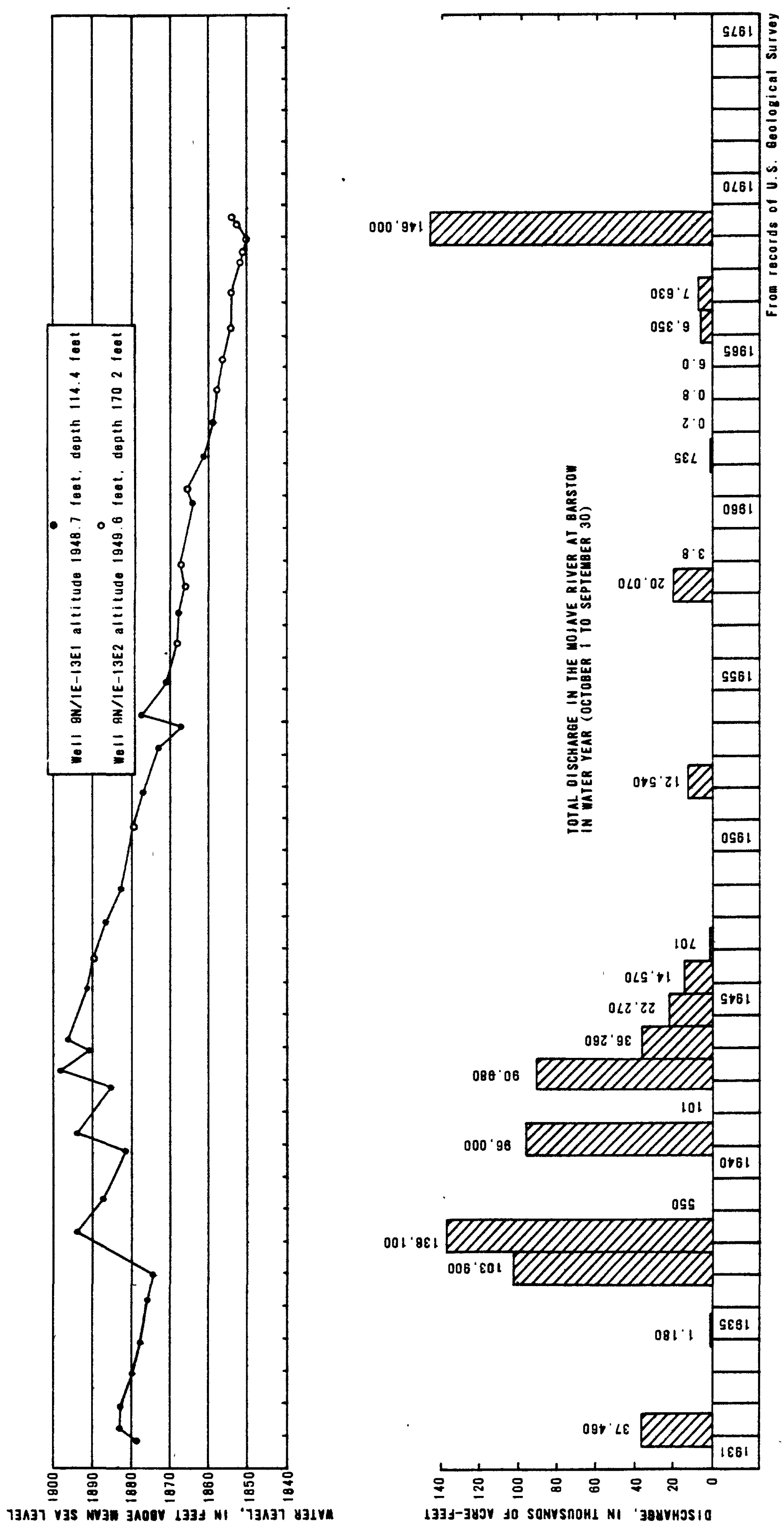

FIGURE 2.--Water-level fluctuations in two wells and total discharge at Barstow.

Recharge to the Barstow and Yermo ground-water subunits can be estimated by using the method described by Miller (1969, p. 27). Using Miller's formula: total annual recharge equals 85 percent of the difference between total annual discharge at Barstow and total annual discharge at Afton[1] minus estimated evaporation loss; the total computed annual recharge to the Barstow and Yermo subunits during the year was about 60,000 acre-feet.

Ground Water

The surface geology of the area, as described by Miller (1969, p. 21-23), is characterized in the highlands by outcrops of a basement complex of pre-Tertiary crystalline rocks and of sedimentary rocks of Tertiary age (fig. 3). Most of the lowland areas contain unconsolidated deposits of Quaternary age overlying the older rocks.

The basement complex and sedimentary rocks generally yield little or no water to wells. The unconsolidated deposits generally yield moderate to large quantities of water to wells.

The ground water utilized by the supply center is stored in two ground-water subunits (fig. 3), the Barstow subunit and the Yermo subunit. The water supply for the center is obtained from wells that penetrate the permeable water-bearing deposits of sand and gravel in these subunits.

Water Levels

Water-level measurements were made in about 80 wells in the Yermo and Barstow ground-water subunits in April 1969. In addition to these measurements, water levels were measured in selected wells in October 1968 and in July 1969. A continuous water-level recorder is operated in well 9N/1E-13E2 in the Yermo ground-water subunit (fig. 3).

Considerable recharge to the ground-water subunits resulted from floodflow in the Mojave River in the 1969 water year. This recharge is reflected in the ground-water contours in figure 3 and the hydrograph of well 9N/1E-13E2 (fig. 2).

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[1]The Afton gaging station is about 50 miles downstream from Barstow.

The ground-water contours show a recharge mound along the Mojave River while the contours farther away from the river show little or no recharge. The recharge mound will subside as the recharge water spreads to areas farther away from the river.

The greatest measured change in water level was in well 9N/1W-13B1. In March 1968 the water level was 61.01 feet below land surface, a level comparable to that of most measurements in the well in recent years. The water level rose to 12.27 feet below land surface by April 1969. The water level in well 9N/1E-13E2 rose from 99.50 feet below land surface in October 1968 to 95.50 feet below land surface in May 1969.

Water levels in the Yermo supply wells have declined an average of about 1.8 feet per year since 1947. The average water-level rise between March 1968 and April 1969 was 1.2 feet.

The Nebo supply wells are in the Barstow subunit. The average annual decline of water levels in the Nebo supply wells during the period 1943 to 1968 was about 0.5 foot. Water levels in the Nebo supply wells rose an average of 10.1 feet between March 1968 and April 1969.

Pumpage

The annual metered pumpage at Nebo and Yermo for the years 1957 through 1969 is shown in figure 4. The pumpage for the 1969 calendar year is estimated on the basis of records for the first half of the year. Table 1 gives the total pumpage and the percentage contributed by each well in 1968.

The total pumpage at Yermo in 1968 was 357 acre-feet. This is a decrease of about 18 percent from the previous year and a decrease of about 47 percent since 1962 when pumpage was at an alltime high. The pumpage is expected to decrease only slightly in 1969.

The pumpage at Nebo is expected to decrease from 1,321 acre-feet in the 1968 calendar year to an estimated 1,200 acre-feet in 1969. Pumpage at Nebo has decreased every year since 1966 when a high of 1,439 acre-feet was recorded.

The expected changes in pumpage in 1969 will have little or no effect on the overall water levels in the ground-water subunits. Hydrologic data indicate that adequate ground water remains in storage to provide the center with a dependable water supply for many years.

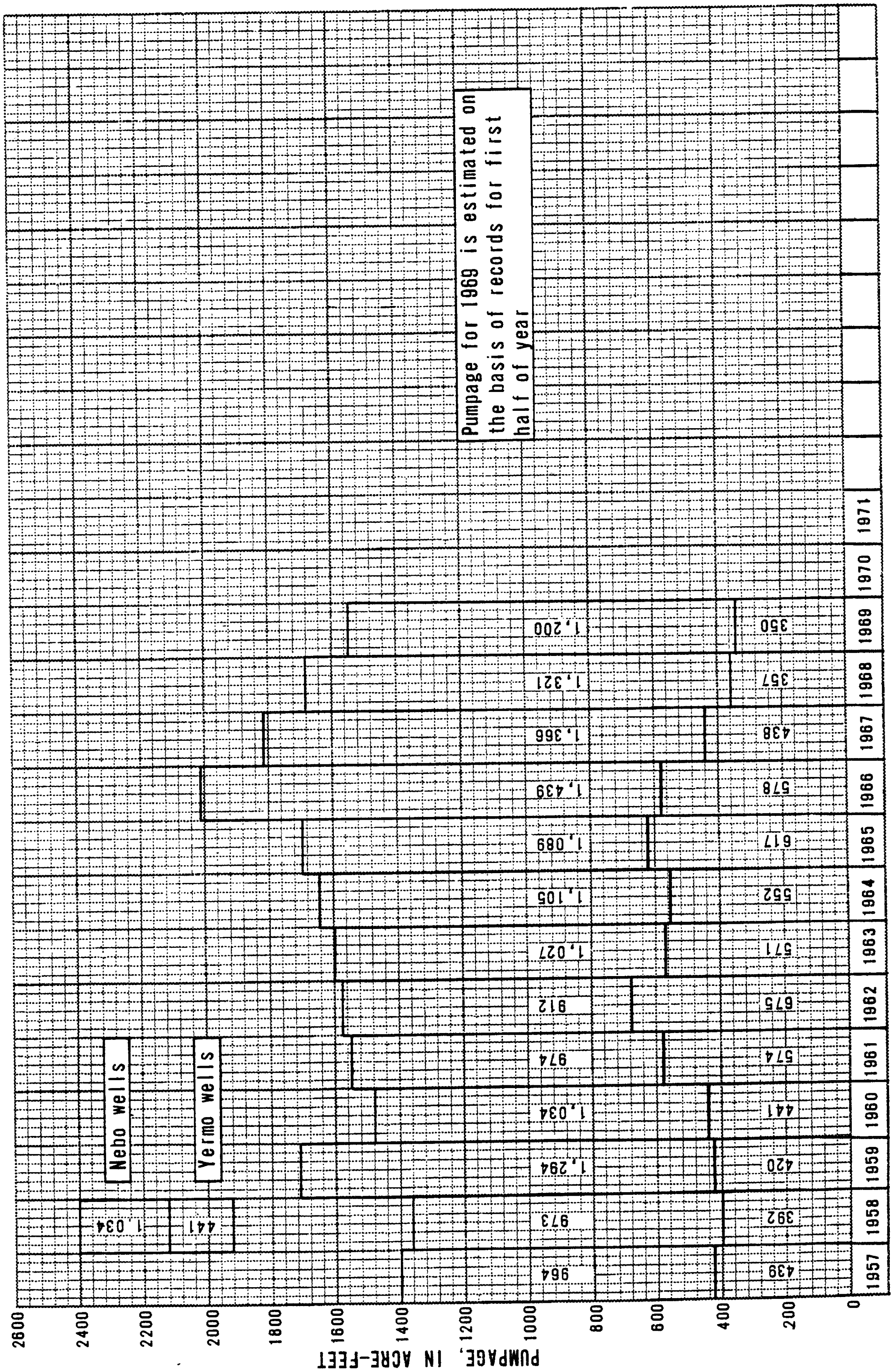

FIGURE 4.--Annual pumpage from supply wells.

TABLE 1.--*Data on supply wells*

Well number		Year drilled	Depth (feet)	Casing diameter (inches)	Normal pump-ing rate	Specific capacity[1] June 1969	Static water level June 1969 (feet)	Pumpage in 1968		Dissolved solids March 1968 (mg/l)
USMC	USGS							Acre-feet	Percent of total	
Nebo 1	9N/1W-14B1	1942	192	16	770			109.5[2]	8.3	516
Nebo (new) 2	14A2	1958	407	12	880	57	58.7[3]	342.1	25.9	760
Nebo 3	14B2	1947	280	16	390			168.1	12.7	456
Nebo 4	13E1	1954	348	16	1200	135	59.4[3]	459.4	34.8	520
Nebo 5	13E2	1960	450	16	630	9.3	62.0[3]	242.2	18.3	568
Nebo 6	14B3	1969	336	16		83	47.3			
						Total, Nebo:		1,321.3	100.0	
Yermo 1	9N/1E-4J1	1942	296	12	190	12	114.0[3]	30.8	8.6	296
Yermo 2	4R1	1942	174	12	220	26	115.3[3]	41.6	11.7	312
Yermo 3	10L1	1942	214	12	940	58	100.8[3]	110.2	30.9	212
Yermo 4	4J2	1961	350	14	1000	76	111.0[3]	174.2	48.8	324
Yermo 5	3P2	1969	400	16		197[4]	104.4[4]			
						Total, Yermo:		356.8	100.0	

[1]Yield, in gallons per minute, divided by drawdown, in feet.
[2]Well taken out of service in June 1968.
[3]Measured from center of discharge pipe to water surface.
[4]Data for July 1969.

Water Quality

The U.S. Public Health Service (1962) recommended limits for certain chemical constituents in drinking-water supplies. The recommended limits are shown in the heading of table 2.

Water samples were collected from six of the 11 supply wells on the Marine Corps Supply Center in 1969. The analyses of these samples are shown in table 2.

Four water samples were collected from two of the supply wells at Yermo in 1969. The results of the analyses of these and other samples are given in table 2. None of the chemical constituents exceeds the recommended limit. The dissolved-solids content of water from well 9N/1E-10L1 (Yermo 3) decreased from 248 mg/l (milligrams per liter) in January 1969 to 188 mg/l in March 1969. This well is near the Mojave River, and the decrease is probably due to the dilution effects caused by the better quality recharge water from floods on the Mojave River entering the ground-water subunit. The dissolved solids increased to 252 mg/l in the sample taken in July 1969. The quality of water from the new well, 9N/1E-3P2 (Yermo 5), is excellent; the sample taken in July had a dissolved-solids content of 267 mg/l.

Eight water samples were collected from four supply wells at Nebo for chemical analysis (table 2) in 1969. The average fluoride and dissolved-solids content exceed the recommended limit for drinking water supplies (U.S. Public Health Service, 1962).

The average fluoride content in water from the Nebo supply wells for the period of record, from 1952 to 1969, is 1.1 mg/l. The average computed for the eight samples collected in 1969 was 0.95 mg/l. The recommended limit for fluoride is 0.8 mg/l (U.S. Public Health Service, 1962). Under Public Health Service standards the maximum allowable concentration of fluoride may be twice the recommended optimum of 0.7 mg/l, which would be 1.4 mg/l. Recommended limits for fluoride concentrations vary with climatic zones. Those cited are appropriate to the warm, dry Mojave Desert region.

The dissolved solids in each of the samples from the Nebo wells exceeded the recommended limit of 500 mg/l. The average of the eight samples was 590 mg/l. Well 9N/1W-14B2 (Nebo 3) was sampled just before the floods in the Mojave River of January and February 1969 and again a few weeks after the floods. The sample taken before the floods contained 676 mg/l dissolved solids; the sample taken after the floods contained 524 mg/l dissolved solids. This reduction in dissolved solids is attributed to the dilution of the ground water by better quality recharge water from the floods. A similar decrease in dissolved solids occurred after the floods of 1958 and 1966 (Miller, 1969, fig. 9). The improvement in water quality is substantiated by the reduction of dissolved solids in water samples from well 9N/1W-14A2 (Nebo new 2). The dissolved-solids content decreased from 760 mg/l in March 1968 to 560 mg/l in March 1969. A water sample taken in July 1969 indicated an increase to 672 mg/l.

TABLE 2.--*Chemical analyses of water*

Values for dissolved solids indicate the residue on evaporation.

Laboratory and sample number: GS, U.S. Geological Survey, Sacramento, Calif.
N, Sanitary Engineering Laboratory, Eleventh Naval District, San Diego, Calif.

Well number	Date of collection	Depth of well (feet)	Water temperature (°C)	Results in milligrams per liter																Percent sodium	Specific conductance (micromhos at 25°C)	pH	Laboratory and sample number
				Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$				
U S Public Health Service drinking-water standards (1962)					0.3							250	250	0.8	45		500						
9N/1W-14A2 (Nebo new 2)	3-20-69	407		28	0.0	72	14	118	2.6	151	17	210	84	1.0	1.8	0.45	560	236		52		8.3	N
	7-15-69			28	.0	73	18	116	2.7	256		165	98	.8	2.2	.28	672	256		49		7.9	N
9N/1W-14B2 (Nebo 3)	6-19-68	280		21	.0			116	2.6			195	98	1.3		.48	652	242				8.6	N
	1- 8-69			23	.0	73	17	118	2.6	210		195	98	.8	4.4	1.2	676	252		50		8.1	N
	3-20-69			25	.0	69	9.8	114	2.7	132	19	225	80	1.0	4.0	.61	524	212		54		8.4	N
9N/1W-13E1 (Nebo 4)	1- 8-69	348		24	.0	61	11	130	2.7	215		150	118	.8	8.0	.9	572	196		60		8.0	N
9N/1W-14B3 (Nebo 6)	6-26-69	336	22	26	.72	68	13	101	2.4	257		112	75	.9	.3	.33	530	223	12	49	861	7.4	GS 58897
	a6-26-69		22	26	.71	66	13	105	2.9	257		109	75	1.0	.0	.56	538	218	7	51	884	7.2	GS 58895
9N/1W-14B5	6-26-69	126		26	.72	68	14	102	2.5	262		110	77	.9	2.2	.33	524	227	12	49	864	7.7	GS 58896
9N/1E-10L1 (Yermo 3)	1- 8-69	212		19	.0	30	6.3	48	1.8	149		44	24	.6	6.6	.91	248	100		50		8.3	N
	3-20-69			22	.0	33	3.4	39	1.3	83	19	64	18	.7		.3	188	96		46		8.4	N
	7-15-69			21	.1	30	6	46	2.0	144		48	24	.6	.0	.0	252	109		49		8.0	N
9N/1E-3P2 (Yermo 5)	7-14-69	500		22	.0	31	5.5	53	2.0	171	0	42	24	.1	3.6	.15	267	100	0	53	435	8.0	GS 58989

a. Thief sample from 290-foot depth.

The quality of water from the new well at Nebo, 9N/1W-14B3 (Nebo 6), is as good as or better than that of the other supply wells. The dissolved-solids content in June 1969 was 530 mg/l. A better comparison can be made when all the wells are sampled at the same time.

The water quality in the aquifer near well 9N/1W-14B3 (Nebo 6) may become poorer with depth. This is suggested by the electric log of the well, which records a progressive drift to the left of both the spontaneous potential and the resistivity below about 200 feet (fig. 5). Water samples representing water from different depth zones were collected during the test. A thief sample was taken at a depth of about 290 feet. Another sample was collected from well 9N/1W-14B5. Well 14B5 is a 2-inch pipe set in the gravel pack of the supply well Nebo 6 at a depth of 126 feet. Also, a composite sample from the supply well Nebo 6 was collected. This last sample probably represents the quality of water within the aquifer interval 120 to 150 feet. The analyses of these samples indicated no significant difference in quality within the depth zones sampled.

Another 2-inch pipe (well 9N/1W-14B4) has been set in the gravel pack of Nebo 6 at a depth of 399 feet below land surface. This well will be sampled to determine the water quality in the lower part of the aquifer.

In the future if local contamination, pollution, or deterioration of water quality in any of the supply wells is to be detected, at least one water sample from each well should be collected annually to monitor such changes; otherwise changes in chemical quality could conceivably go undetected for several years. If water-quality deterioration should occur, the source or cause could more readily be detected by observing its onset as reflected in periodic water samples. For the above reasons we suggest that all the supply wells be sampled at least once a year or preferably twice a year. Samples should be taken from each well in December or January when pumpage is minimal and again in the summer when pumpage is at its peak.

YIELD AND CONDITION OF SUPPLY WELLS

Pumping tests were made on nine of the center's supply wells in the summer of 1969. Tests were by the Southern California Edison Co. except for wells 9N/1W-14B3 (Nebo 6) and 9N/1E-3P2 (Yermo 5), which were made by the U.S. Geological Survey. The results of those tests and previous pumping tests are given in table 3. Wells 9N/1W-14B2 (Nebo 3) and 9N/1W-13E2 (Nebo 5) consistently show a comparatively low specific capacity.[1] This is reflected in greater drawdown and thus greater pumping lift. As the lift increases the cost of pumping water also increases. Southern California Edison Co. tests made in September 1968 indicate an expenditure of 211 kwhr (kilowatthours) per acre-foot of water for well Nebo 3 and 287 kwhr per acre-foot for well Nebo 5. This is considerably greater than wells 9N/1W-14A2 (Nebo 2) and 9N/1W-13E1 (Nebo 4), both of which require 151 kwhr per acre-foot. Thus, the power requirements per acre-foot were almost twice as great for well Nebo 5 than for either well Nebo 2 or Nebo 4. These figures may vary because of factors other than lift such as pump efficiency and pressure in the discharge line. Because of the higher kilowatthours per acre-foot factors, wells Nebo 3 and 5 should probably be used only when the remaining wells cannot meet peak water demand.

The specific capacity of well 9N/1E-4J2 (Yermo 4) has been decreasing gradually since 1964. If this trend continues, this well should probably be redeveloped by treating with a polyphosphate and surging, after which any accumulated sand should be removed. The polyphosphate will help remove material that may be clogging the perforations and thus may increase the yield.

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[1]Specific capacity: Measure of well performance obtained by dividing discharge (yield), in gallons per minute, by drawdown, in feet.

TABLE 3.--*Pumping tests*

Well number	Depth of well (feet)	Date tested	Pumping rate (gpm)	Static water level (feet)	Drawdown (feet)	Specific capacity (gpm/ft)
9N/1W-14A2 (Nebo (new) 2)	407	6- -58	930	62.7	17.6	53
		1-20-59	1,035	64.0	15.0	69
		11- 3-61	964	67.0	15.0	64
		4-23-63	940	68.0	14.0	67
		1964		69.8	15	52
		5- 4-67	862	69.1	14.3	60
		9-11-68	862	72.6	14.0	62
		6-24-69	880	58.7	15.5	57
9N/1W-14B2 (Nebo 3)	280	1947	420	60	35	12
		1949	410	61	34	12
		11- 4-50	399	70.6	30.5	13
		1951	391	71	15	26
		1954	327	63	32	10
		5-23-56	346	63.4	32.6	11
		11- 2-61	745	61.5	86.5	8.6
		1964	325	69.6	9.4	35
		5- 4-67	380	67.9	47.2	8.0
		9-11-68	386	70.7	50.0	7.7
9N/1W-13E1 (Nebo 4)	348	1954	670	68	10	67
		1956	675	63	7	96
		1959	1,053	63.0	7	150
		11- 2-61	1,047	68.0	5.0	209
		4-26-63	1,033	67.0	6.0	172
		1964	940	71.2	11	85
		5- 4-67	1,149	67.9	7.2	160
		9-11-68	967	75.5	8.0	121
		6-24-69	1,176	59.4	8.7	135
9N/1W-13E2 (Nebo 5)	450	1961	500		148	3.4
		4-26-63	670	68.0	80.0	8.4
		1964	550	62.0	80	5.7
		5- 4-67	656	64.1	70.9	9.2
		9-11-68	516	76.4	---	---
		6-24-69	628	62.0	67.4	9.3
9N/1W-14B3 (Nebo 6)	336	6-26-69	575	47.3	5.3	108
		6-26-69	1,450	47.3	17.5	83
		6-26-69	2,570	47.3	35.1	73

Well number	Depth of well (feet)	Date tested	Pumping rate (gpm)	Static water level (feet)	Drawdown (feet)	Specific capacity (gpm/ft)
9N/1E-4J1						
(Yermo 1)	296	6-17-43	241	68.65	10.2	24
		10-10-50	242	82.5	9.7	25
		11- 2-61	310	---	24.88	12
		1964	200	106.9	25	8
		5- 5-67	142	111.0	21.9	6.4
		9-12-68	---	112.2	15.0	---
		6-25-69	187	114.0	15.5	12
9N/1E-4R1						
(Yermo 2)	174	1942	175		9	19
		6-17-43	314	72.75	4.2	75
		1- 9-59	302	100.0	10.0	30
		11- 2-61	262	106.0	9.0	29
		4-26-63	227	108.0	8.5	27
		1964	208	110.8	8.0	26
		5- 5-67	206	115.5	7.8	26
		9-12-68	214	117.7	8.3	26
		6-25-69	218	115.3	8.3	26
9N/1E-10L1						
(Yermo 3)	214	8-25-49	730	69	15	49
		10-10-50	734	74.2	9	82
		5-16-56	280	85.0	2.5	112
		12-16-58	540	86.0	7.0	77
		1-14-59	803	86.0	10.0	80
		1964	920	98.9	8.3	111
		5- 5-67	826	103.5	30.0	28
		7- -68	826	103	31	27
		9-12-68	978	106.1	---	---
		6-25-69	943	100.8	16.2	58
9N/1E-4J2						
(Yermo 4)	350	6- 8-60	1,173	98.1	12.9	91
		11- 3-61	1,068	102.0	12.0	87
		4-26-63	1,047	106.0	10.5	100
		1964	1,000	109.3	8.6	117
		5- 5-67	1,041	111.1	10.2	102
		9-12-68	973	112.9	10.3	94
		6-25-69	1,035	111.0	13.7	76
9N/1E-3P2						
(Yermo 5)	400	7-14-69	450	104.4	2.1	214
		7-14-69	1,420	104.4	7.2	197
		7-14-69	2,720	104.4	15.8	172

NEW SUPPLY WELLS

Two new wells, 9N/1W-14B3 (Nebo 6) and 9N/1E-3P2 (Yermo 5), were drilled in the summer of 1969. Both wells were drilled with a 28-inch drill bit using the rotary reverse-circulation method and were developed with a surge block and air lift. The wells were further developed by intermittent pumping with a turbine pump. Both wells were cased with 16-inch casing having 1/8-inch louver-type perforations with 48 square inches open area per lineal foot. The lithologic logs of these wells are shown in table 4.

Well 9N/1W-14B3 (Nebo 6) was drilled to a depth of 410 feet. The drill cuttings and the electric log indicated a relatively impermeable zone of low yield below the depth of about 300 feet. The electric log also indicated a possible deterioration in water quality with depth. For these reasons the well was cased only to a depth of 336 feet and was perforated from 109 feet to 312 feet. In addition, 2-inch pipes were set in the gravel pack at depths of 399 feet and 126 feet, both perforated in the bottom 25 feet. These pipes were assigned well numbers in accordance with the well-numbering system used by the U.S. Geological Survey in California. The 399-foot well was assigned the number 9N/1W-14B4, and the 126-foot well, the number 9N/1W-14B5. Those pipes will be used to study the water quality in the zones in which they are perforated.

After development, well 9N/1W-14B3 (Nebo 6) was test-pumped at rates of 575 gpm (gallons per minute), 1,450 gpm, and 2,570 gpm. The specific capacities (gallons per minute per foot of drawdown) at these pumping rates were respectively 108, 83, and 73. The test indicated that the well could be pumped efficiently at a sustained yield of about 1,500 gpm.

After test pumping, considering the projected future change in water levels and potential future yield of the well, the U.S. Geological Survey recommended that the pump bowls of the supply pump be set at a depth of about 95 feet.

TABLE 4.--*Lithologic logs of new supply wells*

	Thickness (feet)	Depth (feet)
9N/1W-14B3 (Nebo 6). Drilled by Beylik Drilling Co. 16-inch casing 0 to 336 feet, perforated 109 to 312 feet, louver type, 1/8-inch by 2-3/8-inch, 48 square inches of open area per lineal foot. Drilled by rotary reverse-circulation method, June 1969. Log by U.S. Geological Survey.		
Boulders, up to 1 ft. diameter; gravel and sand	50	50
Boulders; cobbles, 2 to 4 inch; gravel and sand	20	70
Boulders	4	74
Cobbles, coarse gravel; sand; some clay; occasional boulders	11	85
Sand; streaks of clay, light brown to tan; few pebbles; soft	3	88
Sand; gravel; few cobbles; some small boulders	6	94
Gravel, angular; sand; streaks of clay	1	95
Sand; gravel and boulders	9	104
Sand, fine to very fine; silt and clay, light brown	8	112
Gravel, sandy	2	114
Sand; gravel; few small boulders	11	125
Gravel, up to 2-inch, rounded; sand and clay stringers	5	130
Boulders	1	131
Boulders; some gravel and clay stringers	4	135
Sand; gravel; some silt and clay stringers	30	165
Sand, coarse; pebbles to 1-inch	3	168
Gravel	1	169
Gravel; thin beds of clay	2	171
Gravel; sand; clay stringers	1	172
Sand and gravel	2	174
Boulders; sand; gravel and clay	2	176
Sand and gravel with streaks of clay	16	192
Boulders and gravel	1	193
Gravel; very coarse sand; very little clay	6	199
Sand; silt and clay	7	206
Boulders	1	207
Sand and gravel some cobbles and pebbles with streaks of clay	14	221
Sand and gravel; some cobbles; little or no silt or clay	5	226
Sand; clay and silt	2	228
Gravel and sand	6	234
Gravel and sand; some stringers of clay	4	238
Gravel and sand; no clay	4	242
Sand; silt and clay	5	247
Gravel; cobbles and sand; some clay	25	272
Cobbles and gravel	2	274
Gravel and sand	2	276
Sand and gravel, some cobbles	6	282

	Thickness (feet)	Depth (feet)
9N/1W-14B3 (Nebo 6)--Continued		
Silt and sand	1	283
Cobbles and gravel	1	284
Silt; clay; and sand; small gravel	2	286
Sand, clean; and fine gravel	1	287
Clay; silt and sand; some gravel	8	295
Sand and gravel	1	296
Silt	3	299
Gravel, coarse; and sand	3	302
Cobbles	2	304
Sand, coarse; and gravel	3	307
Silt and clay; some sand and gravel	20	327
Sand; gravel; silt; and reddish clay	10	337
Gravel; sand; some clay	27	364
Sand; some gravel and clay	46	410

9N/1E-3P2 (Yermo 5). Drilled by Beylik Drilling Co. 16-inch casing 0 to 400 feet, perforated 160 to 400 feet, louver type, 1/8-inch by 2-3/8-inch, 48 square inches of open area per lineal foot. Drilled by rotary reverse-circulation method, July 1969. Log by U.S. Geological Survey.

Sand, coarse to very coarse; some cobbles	50	50
Clay lens	1	51
Cobbles, 2 to 3-inch; and sand, coarse to very coarse	6	57
Gravel, subangular, medium to large	30	87
Gravel and cobbles, subangular	4	91
Sand, fine	1	92
Gravel; some cobbles	2	94
Gravel, fine to medium; some coarse sand	11	105
Sand, coarse; and fine gravel	7	112
Gravel, fine to medium; some sand	39	151
Gravel, fine; small streaks of clay	4	155
Sand, coarse; streaks of clay	9	164
Sand, coarse; gravel ¼ to ½ inch; some clay	5	169
Sand, coarse; some gravel, ¼ inch	3	172

	Thickness (feet)	Depth (feet)
9N/1E-3P2 (Yermo 5)--Continued		
Sand, coarse; some clay	1	173
Sand, coarse; some gravel to ½ inch	2	175
Gravel, coarse to medium; coarse sand	4	179
Clay, brownish; gravel and coarse sand	1	180
Gravel lens	1	181
Clay, brownish; some coarse sand and gravel	12	193
Sand; some gravel	4	197
Hit galvanized pipe (test well 68-2)		200
Gravel, fine to medium; some very coarse sand; pipe	23	220
Gravel, fine to very coarse; clay; pipe	8	228
Gravel 1/4 to 3/4-inch; sand coarse to very coarse; some streaks of brown clay	9	237
Gravel, fine to medium; sand coarse to very coarse; some cobbles	2	239
Gravel, fine to medium; round to subround	5	244
Sand, coarse to very coarse with streaks of clay	26	270
Sand, medium to very fine; silt; some seams of clay	7	277
Sand, very fine, some coarse; some gravel	9	286
Same as above but no gravel	3	289
Gravel 1/8 to 1/4-inch; fine to coarse sand	3	292
Sand and silt	1	293
Gravel 1/8 to 1/4-inch; sand medium to coarse	3	296
Sand; silt; some gravel lenses (hard drilling)	20	316
Clay, brownish; some sand, fine to medium	8	324
Sand, medium to coarse; some clay	10	334
Sand, medium to coarse: gravel	9	343
Gravel 1/4 to 1/2-inch; coarse sand	15	358
Sand, medium; clay, brownish; some gravel	7	365
Clay, brownish; medium sand	15	380
Sand, very coarse; some silt and gravel	3	383
Sand and gravel, poorly sorted	4	387
Sand and gravel, with seams of clay	6	393
Sand, very coarse; some clay	2	295
Sand and gravel; few seams of clay	13	408
Sand, coarse to very coarse; some silt and gravel	2	410

During the pumping test, a deep well flowmeter was used to measure the flow at various depths when the well was being pumped at 2,575 gpm. Figure 5 shows the quantity of water entering the selected perforated portions of the casing. Each point was plotted at the center of the interval tested. The flow graph was superimposed on a copy of the electric log of the well. The maximum unit inflow was at a depth of about 135 feet. At that point the aquifer yielded about 75 gpm per foot of thickness, and the water velocity through the perforations was calculated to be about 0.5 fps (foot per second). At this velocity the flow is probably turbulent, which slightly decreases the potential yield. When the velocities become great enough to cause turbulent flow, the specific capacity of the well decreases, and the potential for bringing sand into the well increases. The specific capacity determined during the pumping test decreased from 108 at 575 gpm to 73 at 2,570 gpm. This further suggests the occurrence of turbulent flow at the higher pumping rates. However, the well could be pumped at a sustained yield of about 1,500 gpm and still maintain an acceptable efficiency.

As indicated in figure 5 most of the water enters the well above the depth of 200 feet. If additional supply wells are planned for the Nebo area, a test hole should be drilled and logged at the tentative site or sites. If the same or similar lithologic conditions are found, the depth of the supply well should probably be limited to about 200 feet. To help slow the entrance velocity and prevent turbulent flow, the perforated part of the casing should consist of wire-wound screen, which has a much greater open area per lineal foot.

This analysis of the data obtained from the drilling of well 9N/1W-14B3 (Nebo 6) points out the value of a test well prior to the designing of the specifications for any supply well.

Well 9N/1E-3P2 (Yermo 5) was drilled to a depth of 410 feet and cased to 400 feet; the casing was perforated from 160 feet to 400 feet. The drill cuttings and the electric log on a nearby test hole indicated a fairly uniform aquifer in the perforated zone.

This well is about 6 feet south of well 9N/1E-3P1 (test hole 68-2, Koehler, 1969, p. 15). While drilling at a depth of about 200 feet, the drill bit struck the 2-inch casing of well 3P1. The driller was able to fish out 200 feet of the 2-inch casing and continue drilling at the same site.

The pumping test on 9N/1E-3P2 (Yermo 5) was done at rates of 450 gpm, 1,420 gpm, and 2,720 gpm. The specific capacities at these pumping rates were 214, 197, and 172, respectively. To allow for future decline in water levels, the supply pump bowls should be set at a depth of about 140 feet.

Pumping test data indicate that the well has a specific capacity of almost two times as great as any other well at Yermo (table 3). The well could be pumped at a sustained rate of as much as 2,500 gpm without a significant decrease in well efficiency.

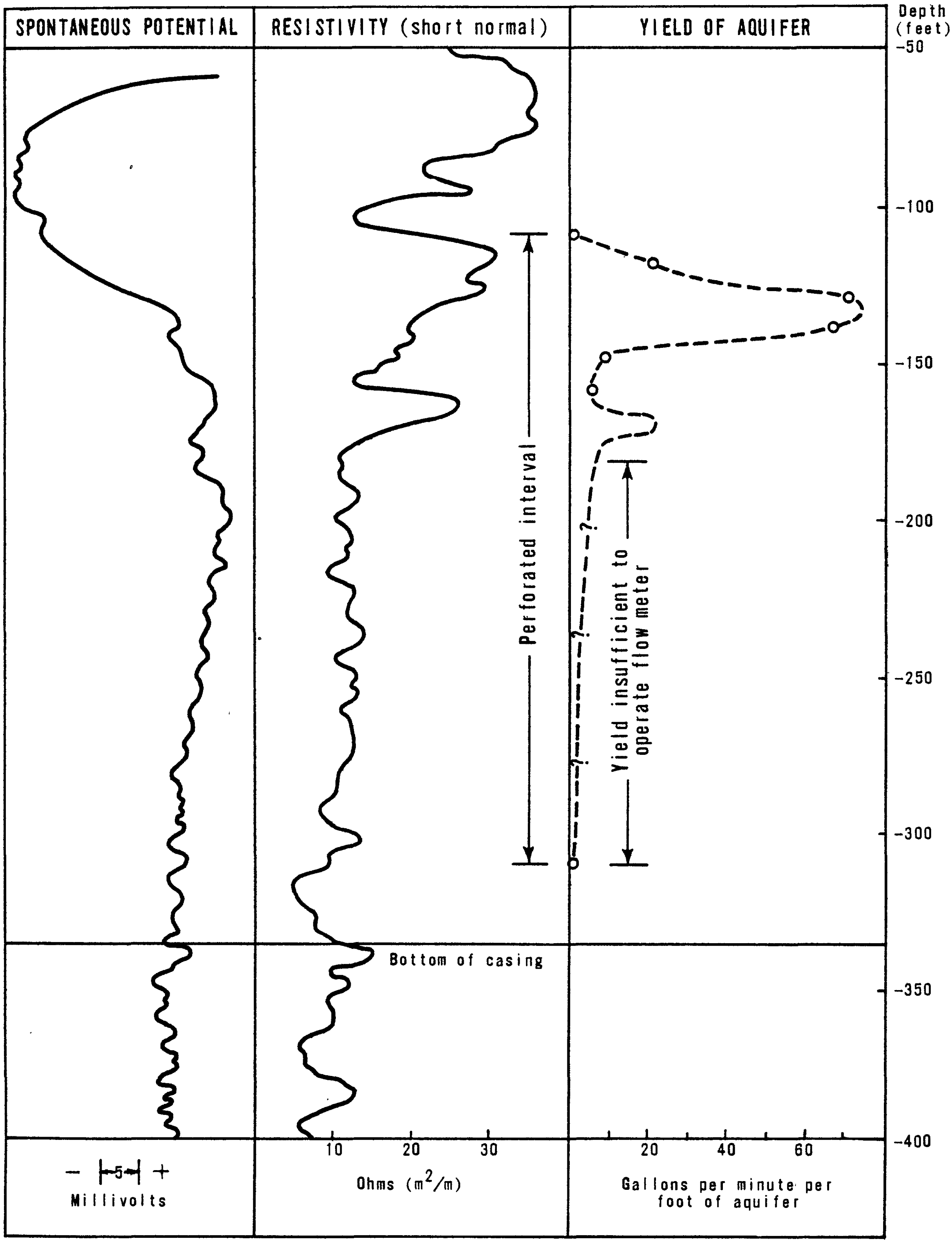

FIGURE 5.--Electric log and aquifer yield for well 9N/1W-14B3 (Nebo 6).

SELECTED REFERENCES

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