GROUND-WATER RESOURCES OF THE MARINE CORPS BASE, TWENTYNINE PALMS SAN BERNARDINO COUNTY, CALIFORNIA

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U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 77-37

PREPARED IN COOPERATION WITH THE U.S. MARINE CORPS
TWENTYNINE PALMS, CALIFORNIA

U.S. DEPARTMENT OF THE INTERIOR
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16. Abstracts The Marine Corps Base, Twentynine Palms, pumped 2,600 acre-feet of water in 1975 from five supply wells in Surprise Spring subbasin. Water levels in those wells declined an average of 35 feet in the past 10 years as a result of (1) the proximity of Surprise Spring fault, a ground-water barrier, (2) the close spacing of wells, and (3) the large volume of water extracted. At the present rate of water-level decline, the pumping water levels will be below the pump intakes by 1980. Projected water demand will increase to 3,000 acre-feet per year by 1980. As part of the evaluation of the geohydrology of Surprise Spring subbasin, three test holes were drilled in an area northwest of the present well field to appraise the area for three new supply wells. Adding these new wells to the water supply will take the stress off existing supply wells and reduce the rate of decline. With an estimated 600,000 acre-feet of ground water in storage and a projected water demand of 3,000 acre-feet per year, Surprise Spring subbasin could supply the base for many years to come.

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For readers who prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	*By*	*To obtain metric unit*
acres	4.047×10^3	square meters
acre-ft (acre-feet)	1.233×10^3	cubic meters
acre-ft/yr (acre-feet per year)	1.233×10^3	cubic meters per year
ft (feet)	3.048×10^{-1}	meters
gal/min (gallons per minute)	6.308×10^{-2}	liters per second
in (inches)	2.540	millimeters
mi (miles)	1.609	kilometers
mi^2 (square miles)	2.590	square kilometers

Degrees Fahrenheit are converted to degrees Celsius by using the formula:

$$°C = 5/9(°F-32)$$

GROUND-WATER RESOURCES OF THE MARINE CORPS BASE, TWENTYNINE PALMS, SAN BERNARDINO COUNTY, CALIFORNIA

By Donald H. Schaefer

ABSTRACT

The Marine Corps Base, Twentynine Palms, Calif., pumped 2,600 acre-feet of water in 1975 from five supply wells in the Surprise Spring subbasin. The water levels in those wells declined an average of 35 feet in the preceding 10 years. This decline is a result of (1) the proximity of Surprise Spring fault, a ground-water barrier; (2) the close spacing of wells; and (3) the large volume of water extracted.

At the present rate of water-level decline, the pumping water levels will be below the pump intakes by 1980. The projected water demand for the base will increase to 3,000 acre-feet per year by 1980.

To help evaluate the geohydrologic properties of Surprise Spring subbasin, three test holes were drilled northwest of the present well field. That area shows promise of being a good location for drilling three new supply wells. The addition of these new wells to the water supply will reduce the pumping stress from the existing supply wells and reduce the rate of decline.

With an estimated 600,000 acre-feet of ground water remaining in storage after 22 years of pumping and with a projected water demand of 3,000 acre-feet per year, Surprise Spring subbasin, if properly developed, could supply the base for many years to come.

INTRODUCTION

The Marine Corps Base, Twentynine Palms, Calif., covers about 1,000 mi^2 of a remote area of the Mojave Desert. The campsite, in the southern section of the base 5 mi north of the town of Twentynine Palms, relies solely on wells for potable water. The water is presently pumped from five supply wells in a small area of Surprise Spring subbasin. Water levels in these five wells declined an average of 35 ft in the 10-year period since 1965.

Purpose and Scope

The purposes of this study, made in cooperation with the U.S. Marine Corps, were to determine the need for new wells on the base and to evaluate the water-supply potential of Surprise Spring subbasin. The command is concerned with the prudent utilization of the ground-water supplies.

The scope of the investigation included:

1. Determining the configuration and geohydrologic properties of Surprise Spring subbasin, including the drilling of three test holes, one 350 ft deep and two 600 ft deep.

2. Collecting and assembling pertinent hydrologic data, including measurements of water levels in wells, pumpage from supply wells, drillers' logs, chemical analyses of water from wells, and results of aquifer tests.

3. Using natural gamma-logging techniques for all accessible wells that do not have a driller's log to delineate lithology of the subbasin.

4. Conducting three seismic refraction profiles across various sections of the subbasin to determine the thickness of unconsolidated sediments.

5. Augering three shallow test holes in the northern part of the subbasin to determine water-quality and water-level changes across the Emerson fault.

6. Evaluating the chemical quality of ground water in the subbasin and comparing it with the quality of ground water in Deadman Lake and Mesquite Lake subbasins.

7. Estimating the quantity of ground water in storage in Surprise Spring subbasin.

8. Evaluating the adequacy of the water supply for the base using current pumping rates and projected population trends.

9. Determining the best locations for three proposed supply wells in the subbasin.

10. Organizing the ground-water data collected on the base since 1952 and presenting it in a tabular form.

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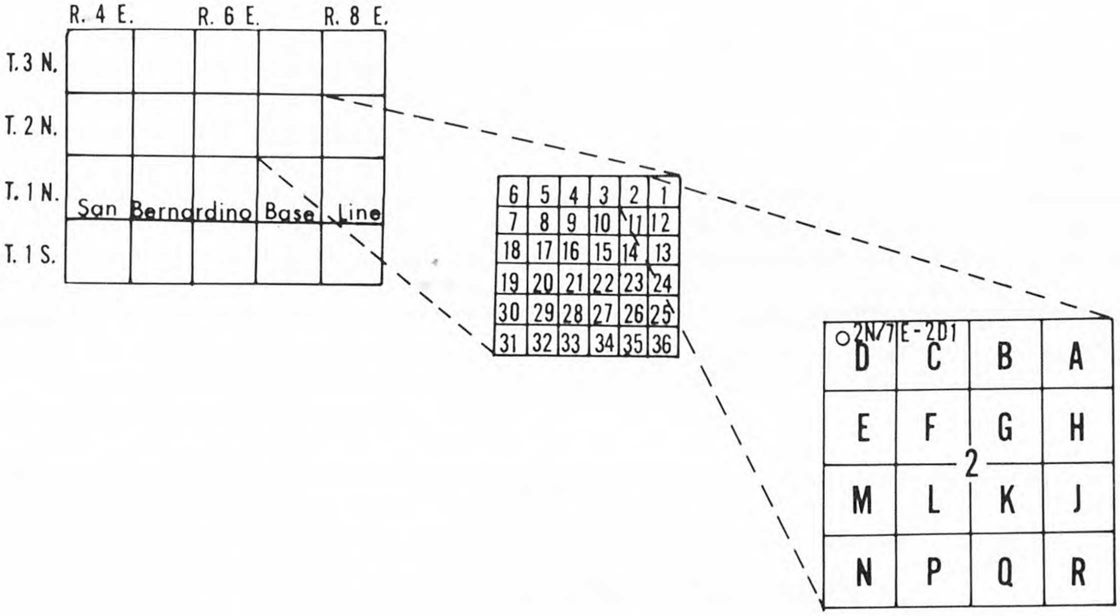
Acknowledgments

The Public Works Office at the Marine Corps Base, Twentynine Palms, provided invaluable aid by supplying data and assistance. Special appreciation is given to M. J. Boomer, Chief Engineer at the Public Works Office, and the personnel of the Explosive Ordnance Disposal Unit for their help in the study.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. For example, in the well number 2N/7E-2D1, that part of the number preceding the slash indicates the township (T. 2 N.); the number and letter following the slash indicates the range (R. 7 E.); the number following the hyphen indicates the section (sec. 2); the letter following the section number indicates the 40-acre subdivision of the section according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision.



In addition, the U.S. Navy has its own system for numbering supply wells and test wells. A cross index of Navy well numbers and those used by the Geological Survey is shown in table 1. For example, USN supply-well number 5A (SW 5A) is USGS number 2N/7E-2D1.

TABLE 1.--*Cross index of U.S. Navy and U.S. Geological Survey well numbers*

USN number[1]	USGS number	USGS number	USN number[1]
SW 1	1N/9E-4N3	1N/9E-4N3	SW 1
SW 2	1N/9E-5G1	1N/9E-5G1	SW 2
SW 3	3N/8E-34D1	2N/7E-2C1	TW 5
SW 1A	3N/8E-29L1	2N/7E-2D1	SW 5A
SW 2A	2N/7E-3B1	2N/7E-3A1	SW 3A
SW 3A	2N/7E-3A1	2N/7E-3B1	SW 2A
SW 4A	3N/7E-35P2	2N/7E-3E1	SW 6A
SW 5A	2N/7E-2D1	2N/7E-4H1	TW 12
SW 6A	2N/7E-3E1	2N/7E-14K1	TW 11
TW 2	3N/8E-33B1	3N/6E-4P2	TW TP-1
TW 3	3N/8E-17L1	3N/7E-13N1[2]	TW 10[2]
TW 5	2N/7E-2C1	3N/7E-18D1	TW 6
TW 6	3N/7E-18D1	3N/7E-19A1	TW 75-2
TW 8	3N/8E-29C1	3N/7E-31E1	TW 9
TW 9	3N/7E-31E1	3N/7E-30H1	TW 75-3
TW 10[2]	3N/7E-13N1[2]	3N/7E-34D1	TW 75-1
TW 11	2N/7E-14K1	3N/7E-35P2	SW 4A
TW 12	2N/7E-4H1	3N/7E-36G1	TW 67-2
TW 67-1	3N/7E-36K1	3N/7E-36K1	TW 67-1
TW 67-2	3N/7E-36G1	3N/8E-17L1	TW 3
TW 75-1	3N/7E-34D1	3N/8E-29C1	TW 8
TW 75-2	3N/7E-19A1	3N/8E-29L1	SW 1A
TW 75-3	3N/7E-30H1	3N/8E-33B1	TW 2
TW TP-1	3N/6E-4P2	3N/8E-34D1	SW 3
TW TP-2	4N/6E-32B1	4N/6E-18L1	TW TP-3
TW TP-3	4N/6E-18L1	4N/6E-32B1	TW TP-2

[1] SW, supply well; TW, test well.

[2] Destroyed.

HYDROLOGY

Description of the Ground-Water Basins

Two ground-water basins, Deadman Valley basin and Twentynine Palms Valley basin (fig. 1), are the area of investigation for this report. Deadman Valley basin is divided into Surprise Spring and Deadman Lake subbasins. Twentynine Palms Valley basin encompasses Mesquite Lake subbasin (fig. 1) and Dale Lake subbasin (not shown). Configuration of these basins is based on previous nomenclature and boundaries (California Department of Water Resources, 1975;

Lewis, 1972; Riley and Worts, U.S. Geological Survey, written commun., 1953) supplemented by hydrologic data collected during this study and earlier Geological Survey data-collection programs in the area. Surprise Spring subbasin supplies most ground water pumped at the base. Although most of the study was within the Surprise Spring subbasin, the other subbasins are referred to in brief for their possible future importance.

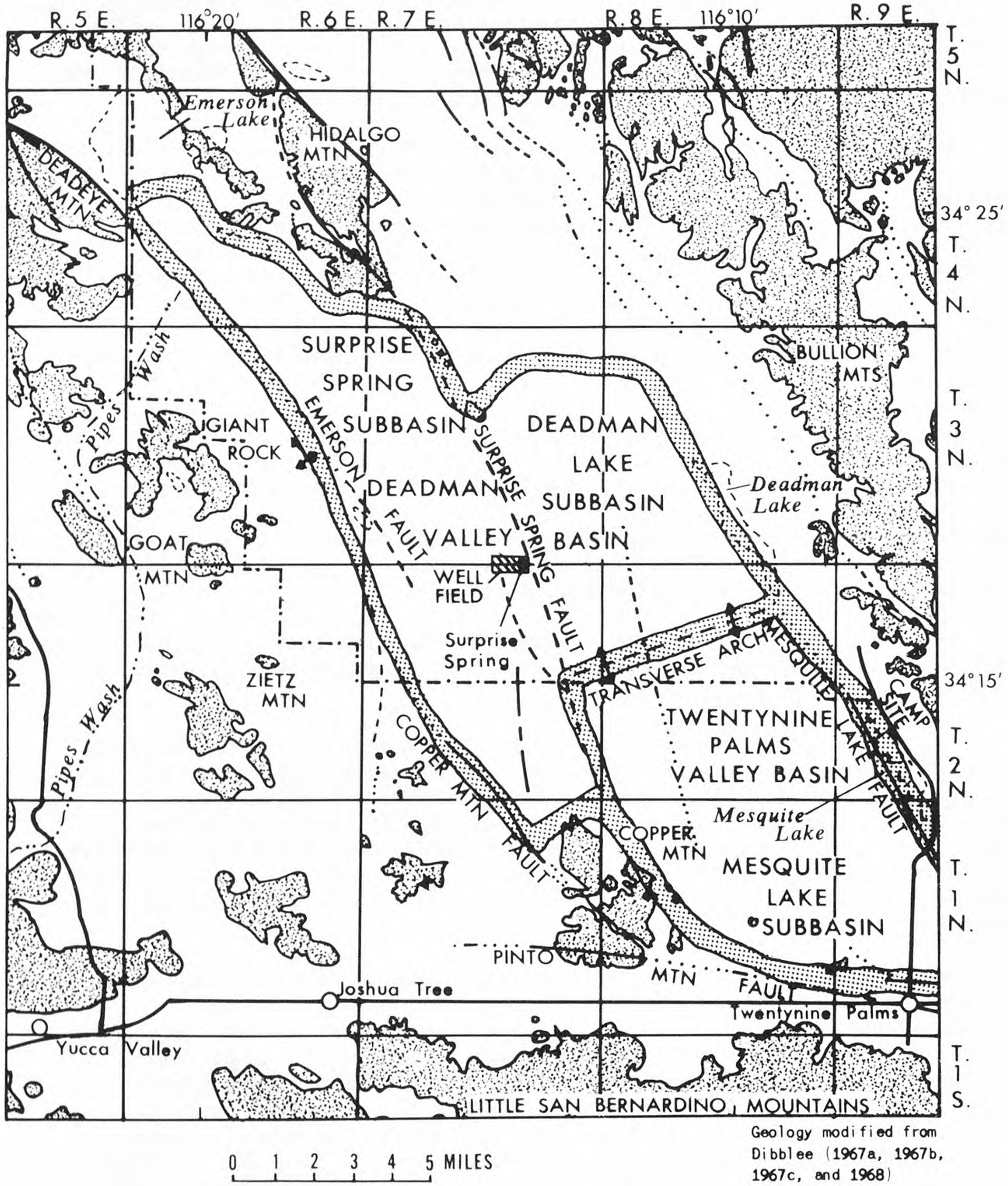
Geologic structure in the area is dominated by northwestward-trending faults (fig. 1). Many of these faults act as barriers to ground-water movement. Although the cause and nature of the barrier effects of faults are not completely understood, ground-water movement across the faults may be impeded because of one or more of the following conditions: (1) Offsetting of permeable beds against less permeable beds; (2) presence of clay fault gouge, which is less permeable than the aquifer; (3) local deformation of beds near the fault; and (4) cementation of the fault zone and material immediately adjacent to the fault by deposition of minerals from ground water.

The transverse arch (Riley and Worts, written commun., 1953), shown in figure 1, may also impede ground-water movement. This arch forms a broad, low, westward-trending topographic high that separates Deadman Valley basin from Twentynine Palms Valley basin. Exposures at its east end show it to be a structural arch or anticline composed of generally fine-grained deposits of Tertiary age. Toward the west end, the exposed core of the arch is formed by consolidated rocks.

For this report the geology as mapped by Dibblee (1967a, 1967b, 1967c, and 1968) was generalized to show consolidated rocks, alluvial deposits, and playa deposits (fig. 1).

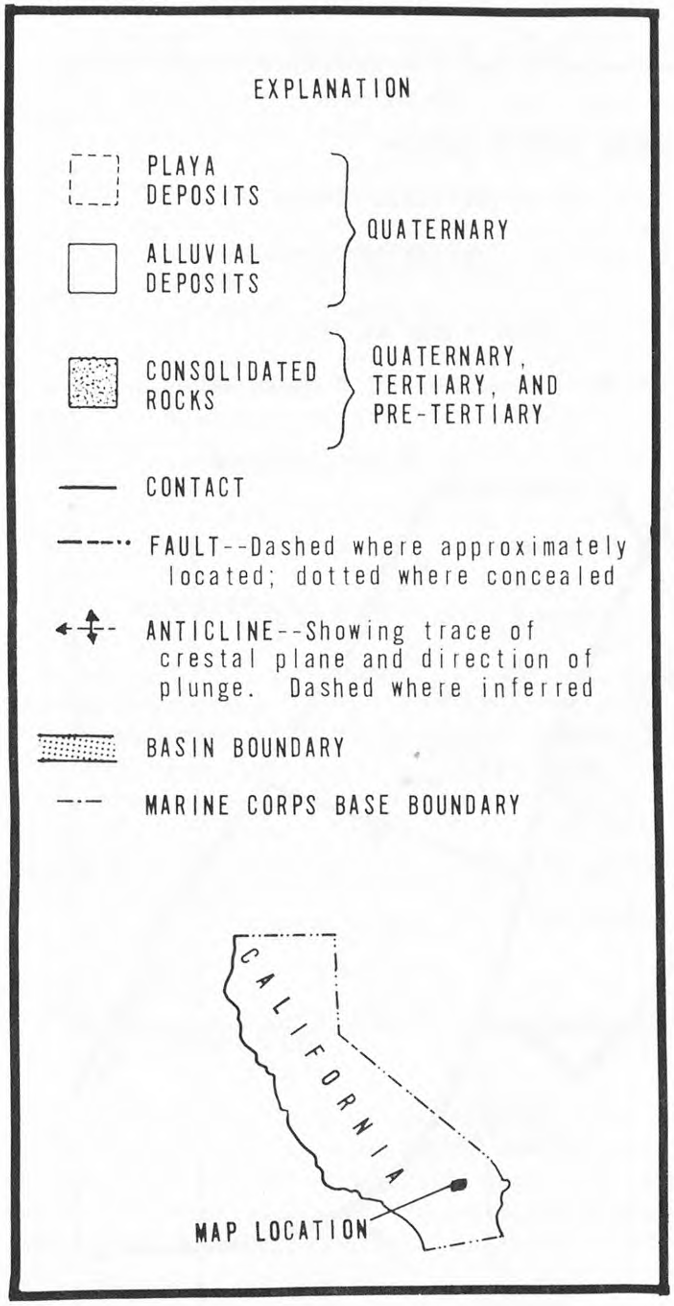
The consolidated rocks consist primarily of igneous and metamorphic rocks of pre-Tertiary and Tertiary ages, basalt flows of Tertiary and Quaternary ages, and continental sedimentary rocks of Tertiary age. These rocks underlie the alluvial and playa deposits and make up the surrounding hills and mountains. They are nearly impermeable except where fractured or weathered and are generally not an important source of ground water. For the purpose of this study, the consolidated rocks are not considered to be water bearing.

The alluvial deposits of Quaternary age consist of alluvium, fans, and sand dunes. These deposits comprise gravel, sand, silt, and occasional boulders and are unconsolidated to semiconsolidated. Where saturated, the alluvium yields water freely to wells. Three seismic-refraction profiles were made in the area of the Surprise Spring well field (fig. 1) and indicated alluvial deposits to a depth of at least 2,000 ft--the physical limitation of the equipment. No profiles were made northwest of the well field. Well logs indicate that the thickness of the alluvial deposits does not diminish in any direction in the area explored by wells. The alluvial deposits overlie the consolidated rocks and locally underlie the playa deposits.



Geology modified from Dibblee (1967a, 1967b, 1967c, and 1968)

FIGURE 1.--Location of area, geology, basins, and subbasins.



The playa deposits of Quaternary age occupy the many dry lakebeds in the area and are composed of clay with some sand and silt. Previous studies (Riley and Worts, written commun., 1953) indicated, from test borings, that the thickness of the playa deposits in Mesquite Lake (fig. 1) is about 50 ft. Other playa deposits in the area are smaller in areal dimension but have about the same thickness. Test drilling, done for this study on the perimeter of Emerson Lake, indicated playa deposits thicker than 100 ft. These deposits, where saturated, yield little water to wells.

Basin and subbasin boundaries are the faults and consolidated rocks (fig. 1). Surprise Spring subbasin is bounded on the west by Emerson and Copper Mountain faults and on the east by Surprise Spring fault and consolidated rocks. Deadman Lake subbasin, which adjoins Surprise Spring subbasin to the east, is bounded on the east by Mesquite Lake fault and Deadman Lake and on the south by the transverse arch. Mesquite Lake subbasin, south of the transverse arch, is bounded on the southwest by Copper Mountain and Pinto Mountain fault and on the east by Mesquite Lake fault.

Occurrence and Movement of Ground Water

Recharge to Surprise Spring subbasin is by subsurface flow across Emerson fault from the adjacent basin to the west (fig. 2). No data exist to calculate the recharge, but it is probably small. Some ground water probably moves through the alluvial deposits between Giant Rock and Zietz Mountain. This flow, based on old measurements of water levels in wells now destroyed, apparently crosses Emerson fault into Surprise Spring subbasin.

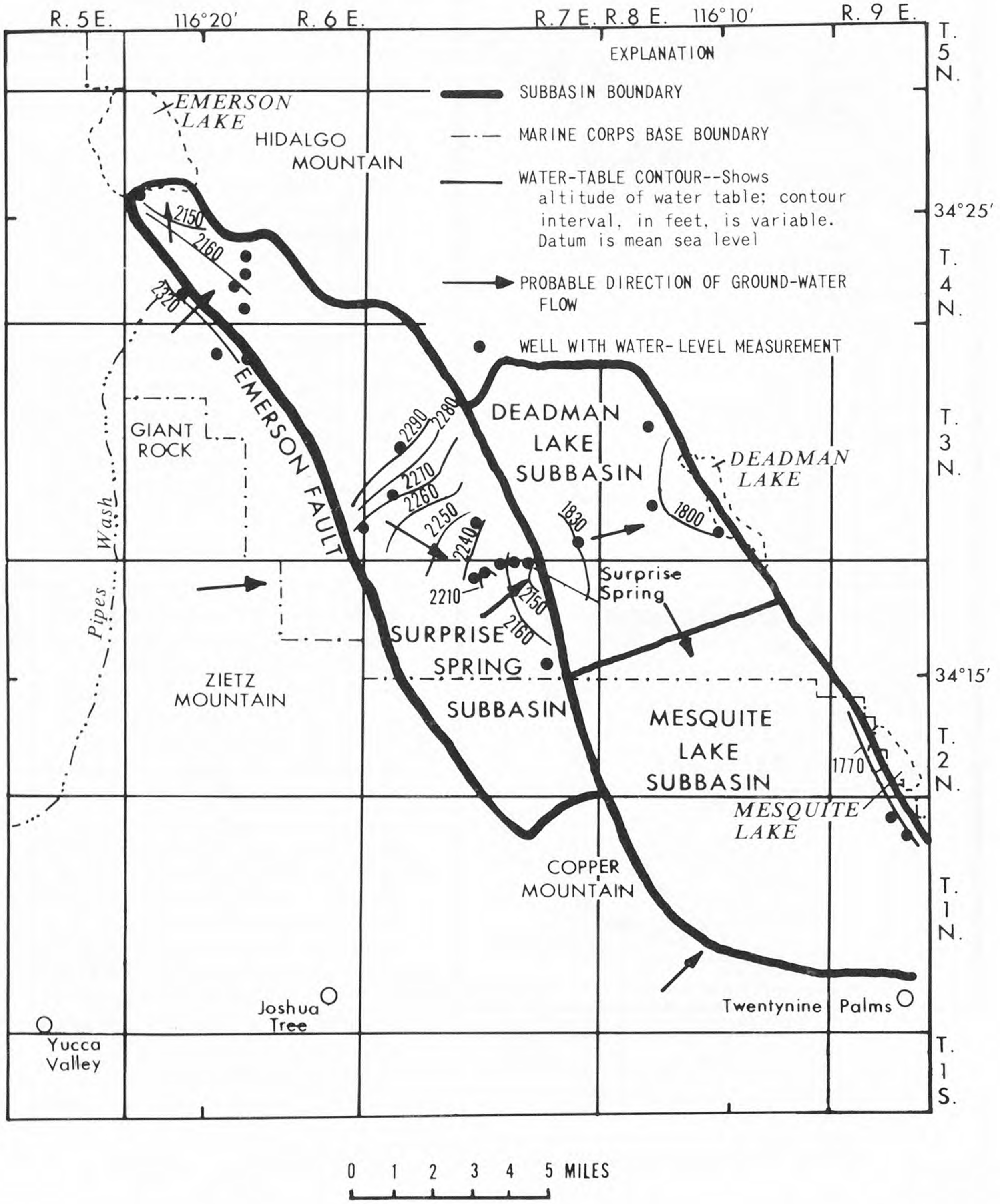


FIGURE 2.--Water-table contours, autumn 1975.

Figure 2 shows the general direction of flow of ground water as indicated by water-level measurements in the three subbasins. At the north end of the subbasin, where Pipes Wash enters, water levels in wells on the east side of Emerson fault are about 50 ft lower than water levels in wells on the west side. East of the fault, some ground water moves northward toward Emerson Lake. The depth to water in a test hole in the playa deposits at Emerson Lake is about 40 ft. Saline deposits on the lakebed and the very fine-grained material penetrated in the test augering suggest that historically some ground water discharged because of capillary rise and evaporation.

Most of the ground water moves southeastward toward Surprise Spring. Historically, ground water discharged from the oasis at Surprise Spring. In recent years pumping from the supply wells near the spring has lowered the water table almost 50 ft. Ground water is no longer discharged at the spring, and the mesquite that once grew in abundance is dying.

Data indicate a difference in water-surface altitude of about 200 ft between Surprise Spring subbasin and Deadman Lake subbasin.

In Deadman Lake subbasin the water moves generally eastward toward Deadman Lake. Previous (mid-1960's) measurements of water level in wells that are now destroyed indicated a southward component of flow from the Deadman Lake area across the transverse arch into Mesquite Lake subbasin. This situation probably has not changed. In addition to ground water moving into the Mesquite Lake area from the north, a small quantity of ground water moves northeastward into Mesquite Lake subbasin from the Joshua Tree and Yucca Valley areas (Lewis, 1972). Ultimately some ground water discharges at Mesquite Lake, and some continues to move eastward across Mesquite Lake fault toward Dale Lake to the east (not shown).

Water-Quality and Hydrologic Conditions

Table 2 contains chemical analyses of water from selected wells in Surprise Spring, Deadman Lake, and Mesquite Lake subbasins. Figure 3 shows the location of water-quality maps that show relative concentrations of ions for water samples. These water-quality diagrams (figs. 4-7) illustrate the ionic concentration expressed in terms of chemical equivalence (milliequivalents per liter). To convert the units in table 2 (milligrams per liter, except iron in micrograms per liter) to the units used in figures 4-7 (milliequivalents per liter), use the factors below (after Hem, 1970).

Constituent	Factor	Constituent	Factor
Bicarbonate	0.01639	Magnesium	0.08226
Calcium	.04990	Potassium	.02557
Carbonate	.03333	Sodium	.04350
Chloride	.02821	Sulfate	.02082
Iron	35.81		

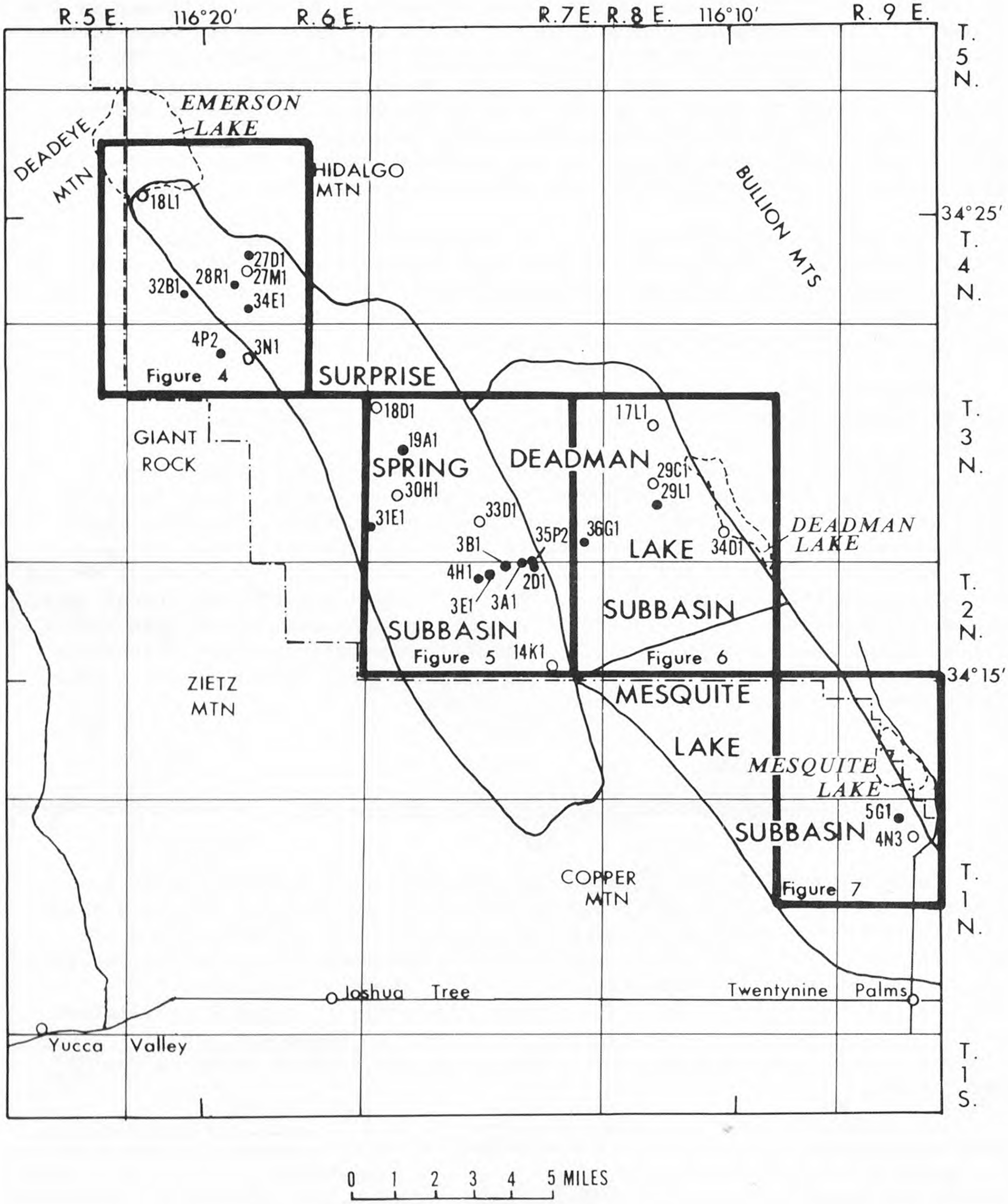
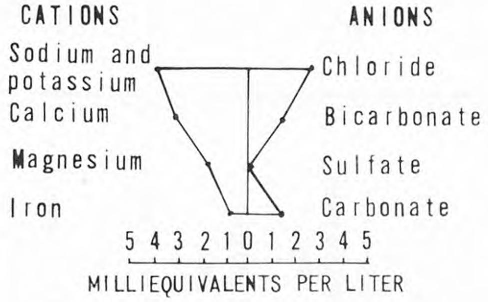


FIGURE 3.--Location and explanation of water-quality maps, figures 4 through 7.

EXPLANATION



WATER-QUALITY DIAGRAM--The area of the diagram is an indication of the relative dissolved-solids concentration--the larger the area of the diagram, the greater the dissolved solids. Differences in configuration reflect differences in chemical character

○ WELL AND NUMBER--See text for explanation of well number

● WELL AND NUMBER WITH CHEMICAL ANALYSIS

See text and table 2 for data

Surprise Spring Subbasin

The northern section of Surprise Spring subbasin is shown in figure 4 and the southern section is shown in figure 5. The ground water is primarily a sodium bicarbonate type with dissolved-solids concentrations ranging from 141 mg/L (milligrams per liter) in the southern section of the subbasin to 1,050 mg/L in the northern section and averaging 177 mg/L in the area of the base supply wells. Fluoride concentrations range from 0.4 mg/L in the southern section of the subbasin to 5.0 mg/L near Emerson Lake. The average fluoride concentration in the area of the base supply wells is about 0.7 mg/L.

Fluoride, which is frequently a problem in desert water supplies because of high concentration, is below the recommended limit (U.S. Environmental Protection Agency, 1972) in the southern section of Surprise Spring subbasin. The maximum concentration there is 0.9 mg/L. With an annual average maximum daily air temperature of 83°F (28.3°C) at Twentynine Palms, the recommended limit for fluoride is 1.4 mg/L.

The water quality does not change with depth. Wells in Surprise Spring subbasin range from 80 ft to 690 ft in depth (table 3). Two water samples were obtained from test hole 3N/7E-19A1, drilled for this study. The samples, obtained with a thief sampler, were collected opposite a screened interval from just below the water surface and at the bottom of the well. The analyses of these samples showed no significant differences (table 2) and are considered representative of the depth indicated.

TABLE 2.--*Chemical*

[Constituents in milligrams per liter except iron and boron
specific conductance in micromhos

Well number	Date of collection	Method of obtaining sample	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
U.S. Environmental Protection Agency Standards (1972)				300						
									SURPRISE SPRING	
2N/7E-2D1	Feb. 18, 1976	(1)	18	120	7.9	0.0	48	4.9	83	9
3A1	Feb. 18, 1976	(1)	17	80	11	.4	45	2.8	81	0
3B1	Feb. 18, 1976	(1)	16	0	11	.2	48	4.5	74	2
3E1	Feb. 18, 1976	(1)	16	10	3.4	.2	58	2.7	79	6
4H1	Feb. 18, 1976	(2)	12	130	5.5	.4	40	4.4	58	7
3N/7E-19A1	Feb. 19, 1976	(3)	5.4	150	4.5	1.3	79	3.9	140	0
19A1	Feb. 19, 1976	(4)	9.8	80	5.9	1.4	71	3.8	120	9
31E1	Mar. 2, 1976	(2)	6.2	30	11	1.0	40	2.2	120	0
35P2	Feb. 18, 1976	(1)	16	120	4.7	.4	48	2.6	77	5
4N/6E-27D1	Feb. 19, 1976	(2)	23	460	4.8	3.7	230	2.7	360	0
28R1	Feb. 19, 1976	(2)	5.2	10	150	41	140	4.2	40	0
34E1	Feb. 19, 1976	(2)	6.0	10	130	21	93	3.8	53	0
								ADJACENT TO SURPRISE		
3N/6E-4P2	Feb. 19, 1976	(2)	13	40	58	8.6	67	10	110	0
4N/6E-32B1	Mar. 2, 1976	(2)	16	10	35	5.3	59	3.6	150	0
									DEADMAN LAKE	
3N/7E-36G1	Jan. 16, 1968	(1)	21	50	5.8	.2	106	1.8	140	110
3N/8E-29L1	Feb. 18, 1976	(1)	16	10	44	3.6	280	6.0	80	0
									MESQUITE LAKE	
1N/9E-4N3	May 4, 1954	(1)	--	--	31	5.2	190	4.0	88	0
1N/9E-5G1	Mar. 15, 1967	(1)	3.1	40	31	3.5	190	3.1	70	0

---

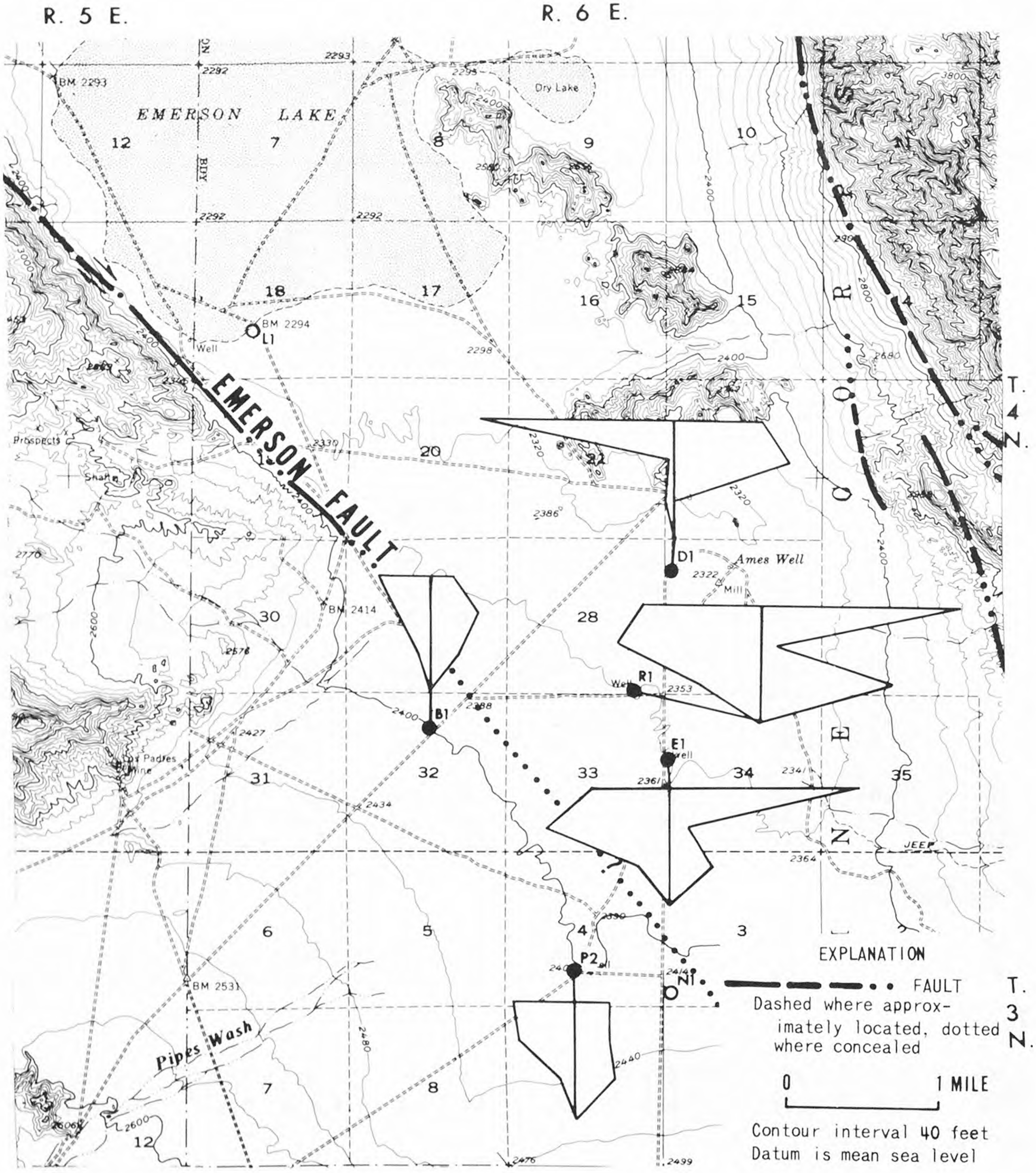
[1] Sample pumped from well.
[2] Sample obtained with thief sampler.
[3] Sample obtained with thief sampler 600 feet below land surface datum.

analyses of water

in micrograms per liter; water temperature in degrees Celsius; per centimeter at 25°C; and pH]

Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved nitrite plus nitrate as nitrogen (NO_2+NO_3)	Dissolved solids	Hardness as calcium carbonate ($CaCO_3$)	Hardness as noncarbonate	Percent sodium	Specific conductance	pH	Water temperature (°C)	Boron (B)
250	250	1.4	1						5.0- 9.0		
SUBBASIN											
24	16	0.7	1.3	175	20	0	80	275	8.4	31.0	70
33	21	.8	1.2	176	29	0	75	265	8.3	28.0	60
34	26	.6	1.2	184	28	0	75	290	8.4	28.0	40
34	21	.4	.88	185	9	0	91	300	9.1	29.0	50
25	17	.9	.02	141	15	0	81	225	8.8	23.5	60
48	27	.8	.16	239	17	0	89	415	9.5	24.0	90
42	22	.8	.98	228	21	0	86	380	9.4	24.0	90
3.9	15	.6	.0	141	32	0	72	250	8.1	23.0	100
27	15	.8	1.3	163	13	0	86	255	8.8	29.0	60
4.0	160	5.0	.08	614	27	0	94	1,050	8.8	22.0	1,700
330	360	.9	.04	1,050	540	510	36	1,700	7.0	21.5	90
100	350	.4	.08	731	410	370	33	1,380	7.6	20.0	50
SPRING SUBBASIN											
93	61	1.0	21	459	180	89	43	620	8.3	22.0	90
70	44	.9	.08	306	110	0	53	490	8.0	22.0	90
SUBBASIN											
64	33	9.6	1.1	311	16	0	93	517	7.9	23.5	50
380	210	4.8	.01	985	120	59	82	1,600	7.7	23.0	1,200
SUBBASIN											
[5]320	62	8.0	--	[5]702	99	27	80	1,070	7.9	25.0	--
340	57	11	1.1	688	92	35	81	1,050	7.8	18.5	30

[4] Sample obtained with thief sampler 230 feet below land surface datum.
[5] Calculated.



EXPLANATION

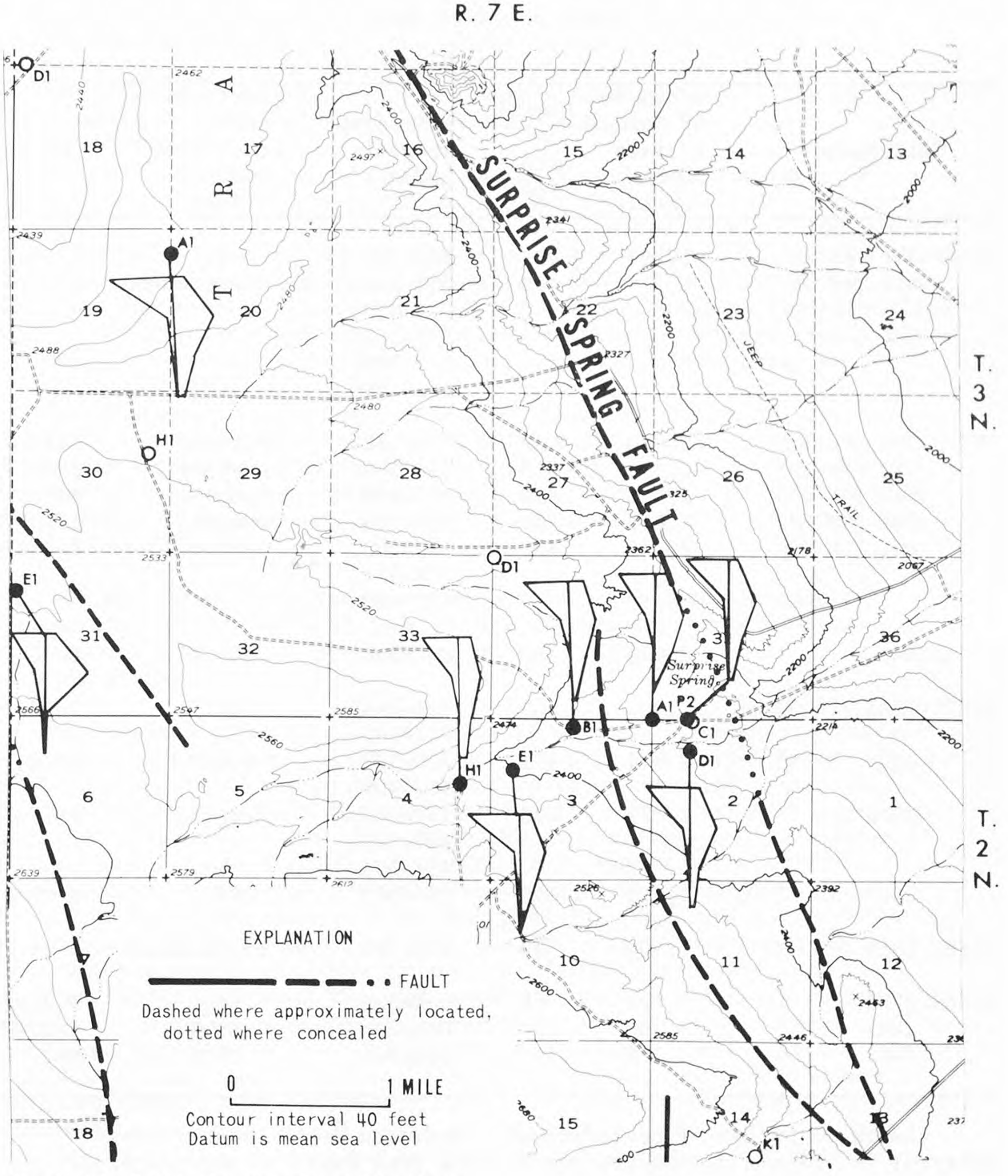
FAULT
Dashed where approximately located, dotted where concealed

0 1 MILE

Contour interval 40 feet
Datum is mean sea level

See figure 3 for location and explanation

FIGURE 4.--Ground-water quality in northern Surprise Spring subbasin.



See figure 3 for location and explanation

FIGURE 5.--Ground-water quality in southern Surprise Spring subbasin.

TABLE 3.--*Well data*

Well number	Altitude of land-surface datum (feet)	Depth[1] of well (feet)	Perforated intervals (feet)	Depth to water below land surface (feet)	Date
1N/9E-4N3 (SW 1)	1,787	495	390-495	16.1	3-18-76
5G1 (SW 2)	1,779	428	260-284, 324-330, 358-365, 390-396, 415-428	No measurement	3-18-76
2N/7E-2D1 (SW 5A)	2,290	532	250-532	Pumping	9-18-75
3A1 (SW 3A)	2,301	550	210-550	Pumping	9-18-75
3B1 (SW 2A)	2,355	690	260-690	Pumping	9-15-75
3E1 (SW 6A)	2,385	510	250-510	Pumping	2-19-76
4H1 (TW 12)	2,442	420	300-320, 338-370, 400-420	201.3	8-27-75
3N/6E-3N1	2,420	130	Unknown	91.1	8-22-75
3N/7E-19A1 (TW 75-2)	2,482	605	228-244, 601-605	189.7	2-19-76
31E1 (TW 9)	2,514	401	300-328, 340-401	250.2	10-22-75
35P2 (SW 4A)	2,271	593	137-257, 281-425, 457-593	Pumping	9-18-75
36G1 (TW 67-2)	2,111	399	384-399	280.1	8-28-75
3N/8E-29L1 (SW 1A)	1,906	590	270-590	No measurement	2-19-76
4N/6E-27D1	2,328	80	Unknown	68.5	8-21-75
28R1	2,360	134	Unknown	99.4	8-27-75
34E1	2,358	117	Unknown	98.4	8-27-75

[1] Depth to bottom of perforations. Measured depth if perforated interval is unknown may be greater or less than depth of perforations.

Water levels in Surprise Spring subbasin began declining as soon as the first two wells, 2N/7E-3A1 and 3B1, were put into service in 1953 at Surprise Spring (fig. 5). Water levels in most of the wells are declining a few feet each year. Well 2N/7E-3A1 declined 15 ft from mid-1964 through mid-1965. The water-level decline in the five supply wells can be attributed to several factors:

1. The proximity of the wells to the Surprise Spring fault, a ground-water barrier. Two of the wells, 2N/7E-2D1 and 3N/7E-35P2, are within 2,000 ft of the fault. The altitude of water levels in Surprise Spring subbasin is about 300 ft higher than the altitude in Deadman Lake subbasin to the east. These supply wells receive little water from the east once the pumping depressions reach the fault owing to its impervious nature. Consequently the cone of depression expands asymmetrically with the reduced supply of water from the east increasing the drawdown.

2. The close spacing of the wells. Three of the wells, 2N/7E-2D1, 3A1, and 3N/7E-35P2, are about 1,000 ft from each other. The cones of depression formed by pumping of the wells expand radially outward until they meet. Because less water is available in the area of intersection of the cones of depression, the pumping wells must draw more water from other directions.

3. The large volume of water extracted. The large pumpage concentrated in this area of less than 1 mi^2 greatly exceeds the natural recharge resulting in a depletion of storage and thereby in a progressive lowering of the water table.

An original estimate of the amount of water available from storage in the Surprise Spring subbasin (Riley and Worts, written commun., 1953) was 520,000 acre-ft. This estimate was based on an areal extent of 40,000 acres, a saturated thickness of 100 ft, and an estimated specific yield[1] of 13 percent. For this study the surface area of the entire subbasin was estimated at 38,400 acres. This figure was based on (1) relocating the subbasin boundaries to conform to actual hydrologic conditions developed from data collected during this study, (2) excluding the area overlying the water of poor quality (fig. 4 and table 2) in the north which probably will not be used for future extraction, and (3) arbitrarily excluding the area south of the base boundary to provide a more conservative estimate of usable water. These additional considerations reduced the surface area underlain by usable ground water to 25,000 acres. Test drilling, seismic-refraction work, and economic considerations of shallow pumping indicate the presently usable saturated thickness to be about 200 ft. The recent test drilling and logs from other wells drilled subsequent to the original work in 1953 in the area confirmed the estimated specific yield of 13 percent. A recalculation of storage capacity yields a figure of about 650,000 acre-ft for Surprise Spring subbasin.

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[1] Specific yield is the ratio of the volume of water the rock or soil will yield by gravity to the total saturated volume of the deposit, expressed as a percentage of the total volume.

Deadman Lake Subbasin

Water in Deadman Lake subbasin is of poorer quality than the water in the southern part of Surprise Spring subbasin. In water samples from wells 3N/7E-36G1 and 3N/8E-29L1, the dissolved-solids concentration ranged from 311 mg/L to 985 mg/L and fluoride concentration from 4.8 mg/L to 9.6 mg/L. This is in contrast to the water from well 3N/7E-35P2 in Surprise Spring subbasin, just to the west of the fault, where the dissolved-solids concentration was 163 mg/L and fluoride concentration was 0.8 mg/L.

Water from well 3N/7E-36G1 (table 2) resembles that in Surprise Spring subbasin, being a sodium bicarbonate type, but most of the ions have doubled in concentration. The analysis of water from well 3N/8E-29L1, near Deadman Lake, shows the water to be a sodium sulfate type (fig. 6).

Water levels in Deadman Lake subbasin have declined less than 1 ft in the past 23 years, probably because of limited pumping in the subbasin. Less than 100 acre-ft of ground water is pumped from the subbasin annually. Ground water in storage in Deadman Lake subbasin was estimated at 290,000 acre-ft (Riley and Worts, written commun., 1953). No attempt was made in this study to substantiate this estimate.

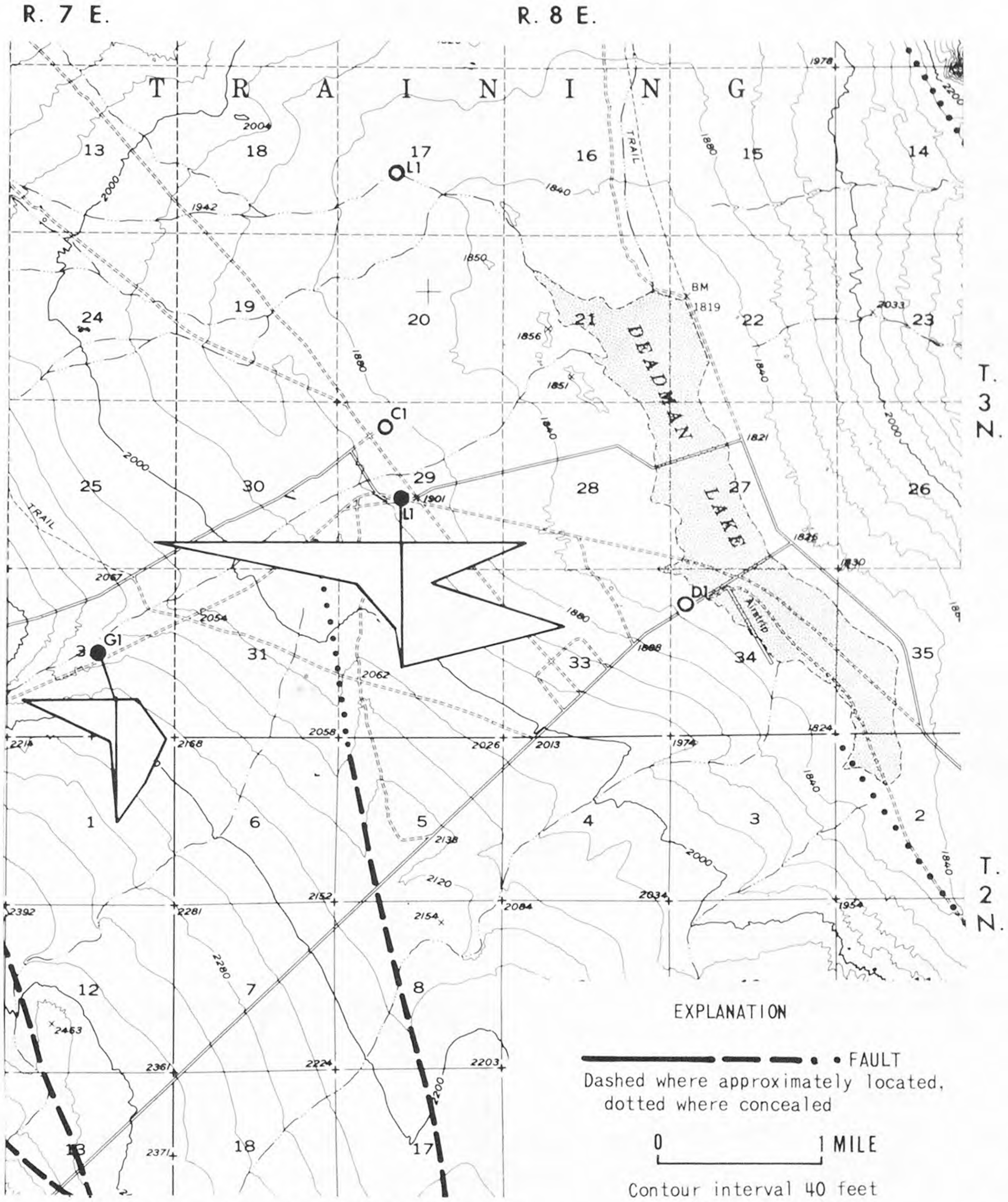
The potential for development of ground water in this subbasin depends on future hydrologic conditions in Surprise Spring subbasin. If the water demand increases, limited use could be made of standby supply well 3N/8E-29L1 in Deadman Lake subbasin. The water is high in fluoride, dissolved solids, sulfate, and boron (table 2); however, it can be used if mixed with water of better chemical quality from the Surprise Spring well field.

Mesquite Lake Subbasin

An analysis of water from well 1N/9E-5G1, an old supply well, shows concentrations of dissolved solids of 688 mg/L, sulfate of 340 mg/L, and fluoride of 11 mg/L (table 2 and fig. 7). The water in this area of Mesquite Lake subbasin is predominantly a sodium sulfate type.

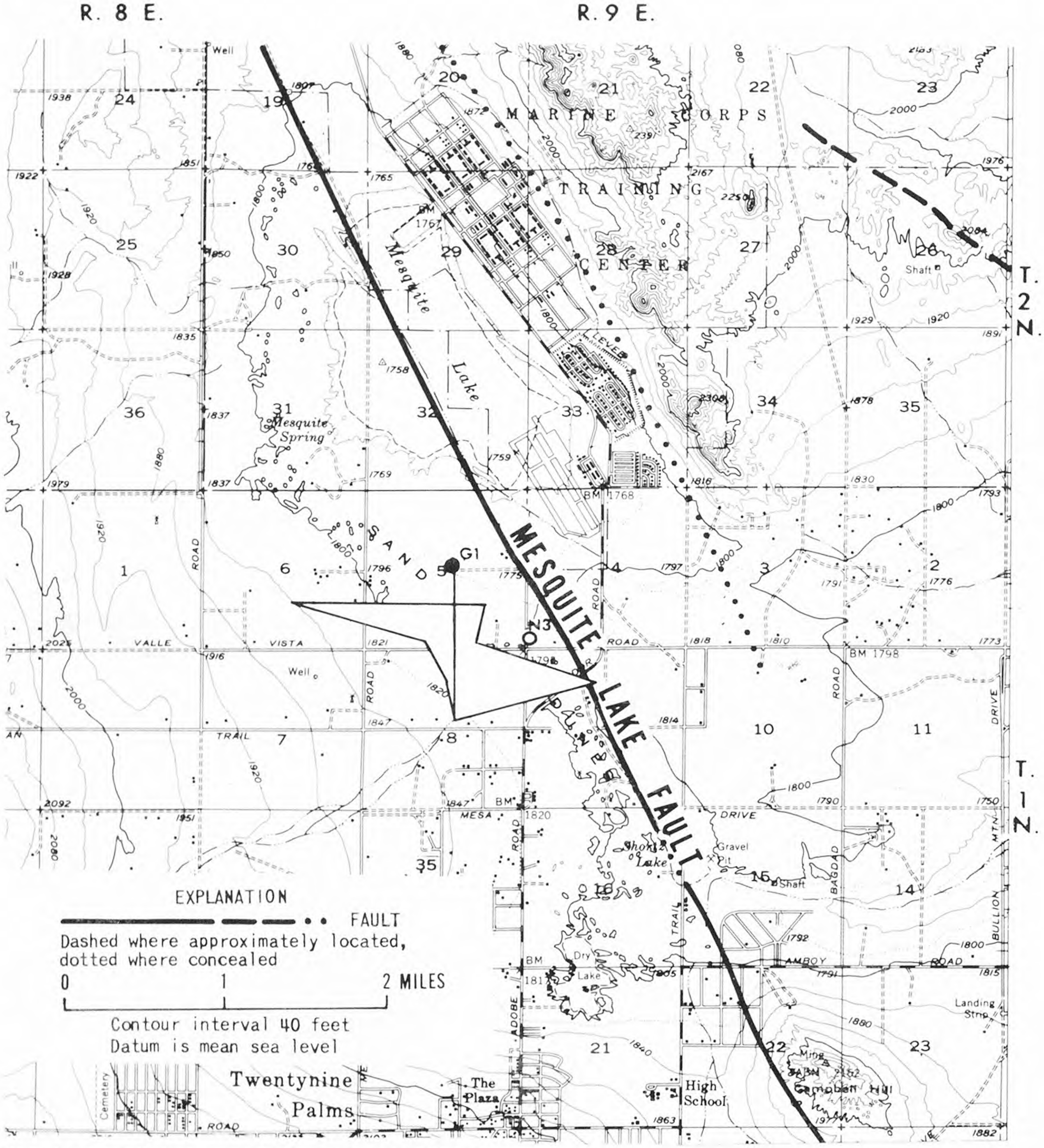
The water level has not declined appreciably in Mesquite Lake subbasin in the past 22 years. This again is because of very little pumping.

No estimate was made in previous studies (Riley and Worts, written commun., 1953) of the storage capacity, and no attempt was made in this study. The necessity for future use depends again on future requirements. As the water quality in this subbasin is inferior with respect to selected chemical constituents, to the other two subbasins, only a severe water shortage might warrant use of ground water from this subbasin.



See figure 3 for location and explanation

FIGURE 6.--Ground-water quality in Deadman Lake subbasin.



See figure 3 for location and explanation

FIGURE 7.--Ground-water quality in Mesquite Lake subbasin.

Test Drilling

To gain further geohydrologic information in Surprise Spring subbasin, six test holes were drilled.

Three shallow test holes (3N/6E-4P2, 4N/6E-18L1, and 4N/6E-32B1) were augered in the northwestern area of the subbasin (fig. 4) to determine direction of ground-water movement across Emerson fault. The lithology of the holes was logged (table 4) as they were augered, and the holes were cased with 2-in diameter PVC (polyvinyl-chloride) casing with a 2-ft well point at the bottom.

TABLE 4.--*Lithologic logs of test holes*

	Thickness (feet)	Depth (feet)
3N/6E-4P2 (TW TP-1). Augered by U.S. Geological Survey. Altitude 2,402 ft; 2-in casing 0-80 ft, well point 80-82 ft. Finished February 18, 1976. Depth to water 75.75 ft, February 19, 1976.		
Sand, medium to coarse, some silt and medium gravel-------	5	5
Sand, fine, and silt------------------------------------	3	8
Clay, silty, fairly tight--------------------------------	4	12
Sand, silty, reddish-brown-------------------------------	38	50
Clay, hard, gray---	25	75
Clay, sandy--	12	87
3N/7E-19A1 (TW 75-2). Drilled by R. Anderson Corp. Altitude 2,482 ft; 2-in casing 0-605 ft, screened 228-244 and 601-605 ft. Finished December 12, 1975. Depth to water 189.72 ft, February 19, 1976.		
Sand, very coarse--	20	20
Sand, very coarse, some rock-----------------------------	19	39
Sand, coarse to very coarse, some rock-------------------	22	61
Sand, very coarse, some rock-----------------------------	48	109
Sand, coarse, and some silt------------------------------	21	130
Sand, very coarse, some rock-----------------------------	19	149
Sand, coarse to very coarse, some silt-------------------	53	202
Sand, very coarse, and rock------------------------------	8	210
Sand, coarse to very coarse, rock and silt---------------	8	218

TABLE 4.--*Lithologic logs of test holes*--Continued

	Thickness (feet)	Depth (feet)
3N/7E-19A1--Continued		
Sand, coarse, and some silt, becoming semiconsolidated below 250 feet	42	260
Silt, coarse sand, and rocks	5	265
Clay, silty, and coarse sand	5	270
Silt and coarse sand	39	309
Sand, coarse, silt, and rock	11	320
Silt and coarse sand	22	342
Sand, coarse to very coarse, some silt, very consolidated	27	369
Sand, very coarse, silt, and rocks, consolidated	62	431
Silt and coarse sand, consolidated	21	452
Sand, very coarse, and silt	9	461
Silt, heavy, coarse sand, consolidated	41	502
Silt and coarse sand, very consolidated	37	539
Silt and coarse to medium sand, consolidated	19	558
Silt and coarse sand, consolidated	48	606

3N/7E-30H1 (TW 75-3). Drilled by R. Anderson Corp. Altitude 2,519 ft; 2-in casing 0-351 ft, screened 312-348 ft. Finished December 3, 1975. Depth to water 248 ft, March 2, 1976.

	Thickness (feet)	Depth (feet)
Sand, medium to coarse	25	25
Sand, medium to coarse, some gravel	25	50
Sand, medium to coarse, some gravel and clay	30	80
Sand, medium to coarse, some gravel	14	94
Gravel, coarse, and some sand	22	116
Sand, fine to medium, some fine gravel	8	124
Sand, medium to coarse, some fine gravel	50	174
Sand, coarse, and gravel	31	205
Sand, very coarse, and gravel	9	214
Sand, coarse and medium gravel	52	266
Sand, medium to coarse, and gravel, with occasional tight zones below 300 feet	88	354

TABLE 4.--*Lithologic logs of test holes*--Continued

3N/7E-34D1 (TW 75-1). Drilled by R. Anderson Corp. Altitude 2,503 ft; 2-in casing 0-605 ft, screened 270-286, 601-605 ft. Finished January 6, 1976. Depth to water 257 ft, March 2, 1976.

	Thickness (feet)	Depth (feet)
Sand, very coarse, rock	40	40
Sand, very coarse, some silt	29	69
Sand, coarse to very coarse, some rock and silt	22	91
Sand, coarse to very coarse, rock	63	154
Sand, coarse to very coarse, some silt	6	160
Sand, very coarse, some dark silty clay	21	181
Sand, very coarse	21	202
Sand, very coarse, some silt and rock	8	210
Silt, and coarse to very coarse sand	9	219
Sand, coarse to very coarse	11	230
Silt, and coarse to very coarse sand	31	261
Sand, very coarse, and silt	79	340
Sand, coarse to very coarse, silt	11	351
Sand, very coarse, some silt	29	380
Silt and coarse sand	10	390
Sand, very coarse, some silt	19	409
Silt, heavy, coarse sand	19	428
Silt, medium sand, some rock	13	441
Sand, medium to coarse, and silt	22	463
Silt, coarse to very coarse sand	7	470
Sand, coarse, silty clay	10	480
Sand, medium to coarse	13	493
Clay, sand, dark	17	510
Sand, coarse to very coarse	35	545
Sand, very coarse	18	563
Clay, sandy, dark, and sand	16	579
Sand, medium to coarse, some clay	26	605

4N/6E-18L1 (TW TP-3). Augered by the U.S. Geological Survey. Altitude 2,293 ft; 2-in casing 0-90 ft, well point 90-92 ft. Finished February 20, 1976. Depth to water 46.8 ft, March 2, 1976.

Sand, fine, and silt	20	20
Clay, sandy, brown	20	40
Clay, fine-grained, very tight, black and green interbedded; hydrogen sulfide smell	52	92

TABLE 4.--*Lithologic logs of test holes*--Continued

4N/6E-32B1 (TW TP-2). Augered by U.S. Geological Survey. Altitude 2,400 ft; 2-in casing 0-100 ft, well point 100-102 ft. Finished February 19, 1976. Depth to water 77 ft, March 2, 1976.

	Thickness (feet)	Depth (feet)
Sand, fine to medium, some silt----------------------------	102	102

The other three test holes were drilled in the area northwest of the present well field (fig. 8) to adequately appraise the suitability of that area for new supply wells. The holes were drilled using the hydraulic-rotary method to provide water-level, lithologic, and water-quality data. Test holes 3N/7E-19A1 and 34D1 were drilled to a depth of about 600 ft, and test hole 3N/7E-30H1 was drilled to a depth of about 350 ft.

Spontaneous-potential and resistivity logs were obtained from all three holes. Samples of the drill cuttings from each hole were examined, and specific yield was estimated. Lithologic logs of the holes are shown in table 4. The test drilling in this area indicated that subsurface deposits are fairly permeable with the exception of those at test hole 3N/7E-19A1. During the course of drilling this hole, a semiconsolidated zone was penetrated at about 250 ft that became more consolidated with depth.

The test holes were cased with 2-in diameter galvanized-steel casing, and well screens were placed in accordance with information from the lithologic and electric logs. The cased holes were then developed by airlifting for about 4 hours. The small-diameter casing prevented the evaluation of aquifer properties by the use of aquifer tests. Difficulties with well development, which hampered the removal of drilling mud from the test holes, prevented the collection of samples representative of water in the aquifer at holes 3N/7E-30H1 and 34D1. A clear sample, free of drilling mud, was obtained from test hole 3N/7E-19A1, and the analyses gave results considered reliable, indicating the occurrence of good water.

Even though representative chemical analyses were not obtained for holes 3N/7E-30H1 and 34D1, the data obtained indicate that the optimum area for the new supply wells is in the vicinity of these two holes.

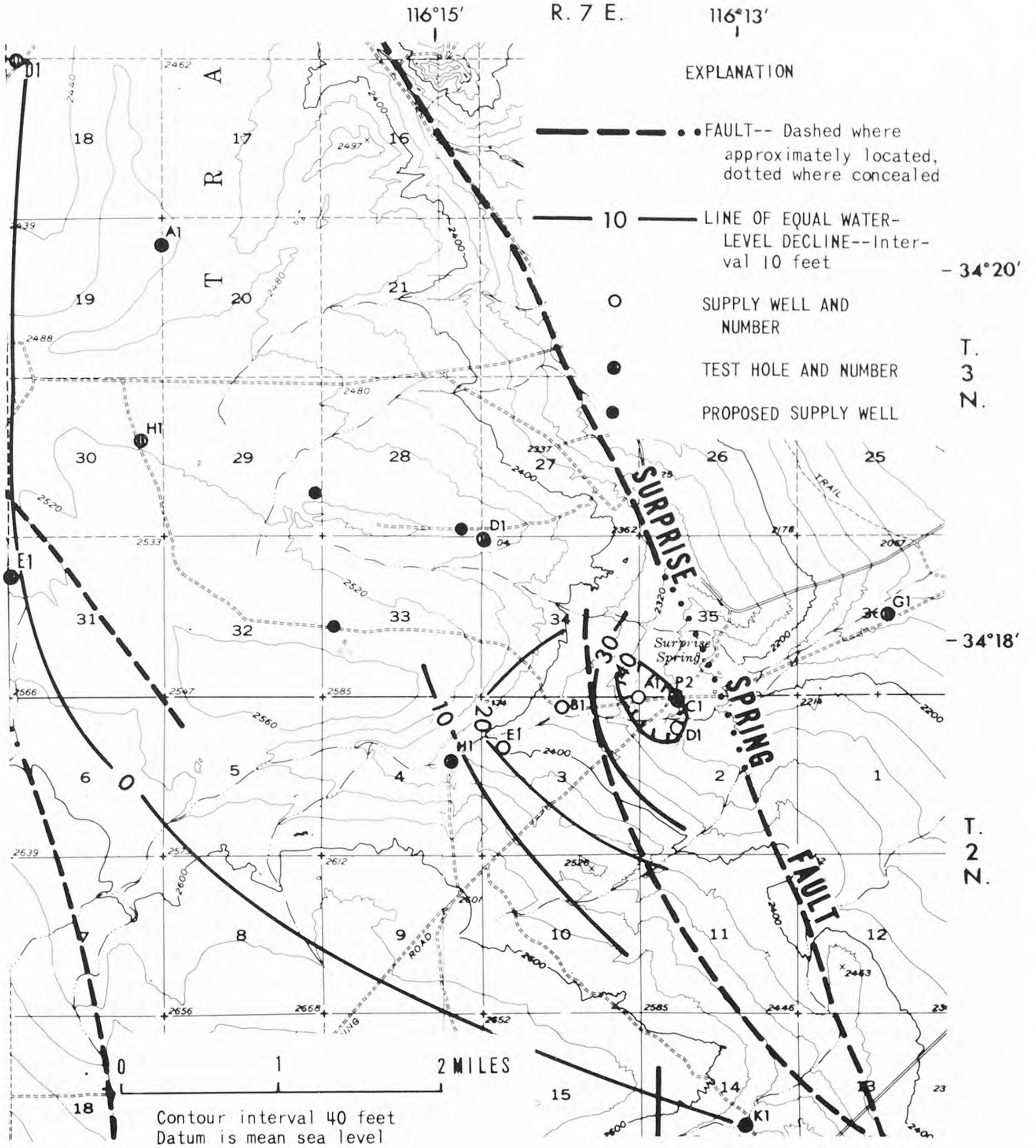


FIGURE 8.--Location of supply wells and test holes, and distribution of water-level decline, 1965-75.

ADEQUACY OF PRESENT GROUND-WATER SUPPLY IN SURPRISE SPRING SUBBASIN

The Marine Corps Base at Twentynine Palms was established in 1952. Prior to this, ground-water withdrawal from Surprise Spring subbasin was small and probably did not exceed the natural recharge. In 1953 the first two supply wells, 2N/7E-3A1 and 3B1 (fig. 8), were drilled, and the pumpage from Surprise Spring subbasin for that year was 84 acre-ft. In 1961 a third supply well, 3N/7E-35P2, was drilled, and the annual pumpage from the subbasin was 1,362 acre-ft. By 1961 water levels in the first two supply wells had declined almost 20 ft. Two additional supply wells, 2N/7E-2D1 and 3E1, were drilled in 1968, and the annual pumpage from the Surprise Spring well field increased to 2,340 acre-ft. In 1975, with all five wells in operation, the ground-water withdrawal from Surprise Spring subbasin was about 2,600 acre-ft. Water levels in the supply wells had declined an average of 35 ft in the 10-year period since 1965. Figure 9 shows the pumpage and the decline of water levels from the Surprise Spring well field from 1955 to 1975.

Projecting the current rate of decline, the pumping water levels will be below the present bowl settings by the year 1980. Production from this well field can be prolonged by lowering the pump bowls; this, however, may result in a decrease in the yield and an increase in the cost of pumping because of higher lifts. Increased population on the base and the resulting increased water demand would put even more stress on the well field.

A projected increase in pumpage to 3,000 acre-ft per year by 1980 (M. J. Boomer, Public Works Office, Marine Corps Base, Twentynine Palms, written commun., 1976) from the present rate of about 2,600 acre-ft will require an additional source of water supply. If three supply wells are constructed north of the Surprise Spring well field and if each of the three new wells is pumped continuously at about 1,000 gal/min (as per well specifications specified by the Marine Corps), about 4,800 acre-ft/yr would be available to supplement the water supply for the base.

With new supply wells, pumpage from existing wells in the Surprise Spring field can be reduced, and the rate of water-level decline would lessen or even reverse. Evaluation of the effect of increased pumpage since 1953 and of the decline in water levels in the supply wells indicates that, by reducing the pumpage in the present well field to about 1,000 acre-ft/yr, the rate of decline of water levels in the wells would be reduced. In this manner the present wells may continue to be utilized, and the new supply wells to the northwest would supply the rest of the required water without having to be pumped continuously.

Calculations using limited transmissivity data in the area (McClelland, 1964) indicate that the new wells should be drilled at least 1 mi apart. With this spacing the interference effects of the pumped well in the surrounding wells would be minimized. This spacing interval should also be observed with respect to any known faults in the area. Proposed locations for these wells are shown in figure 8.

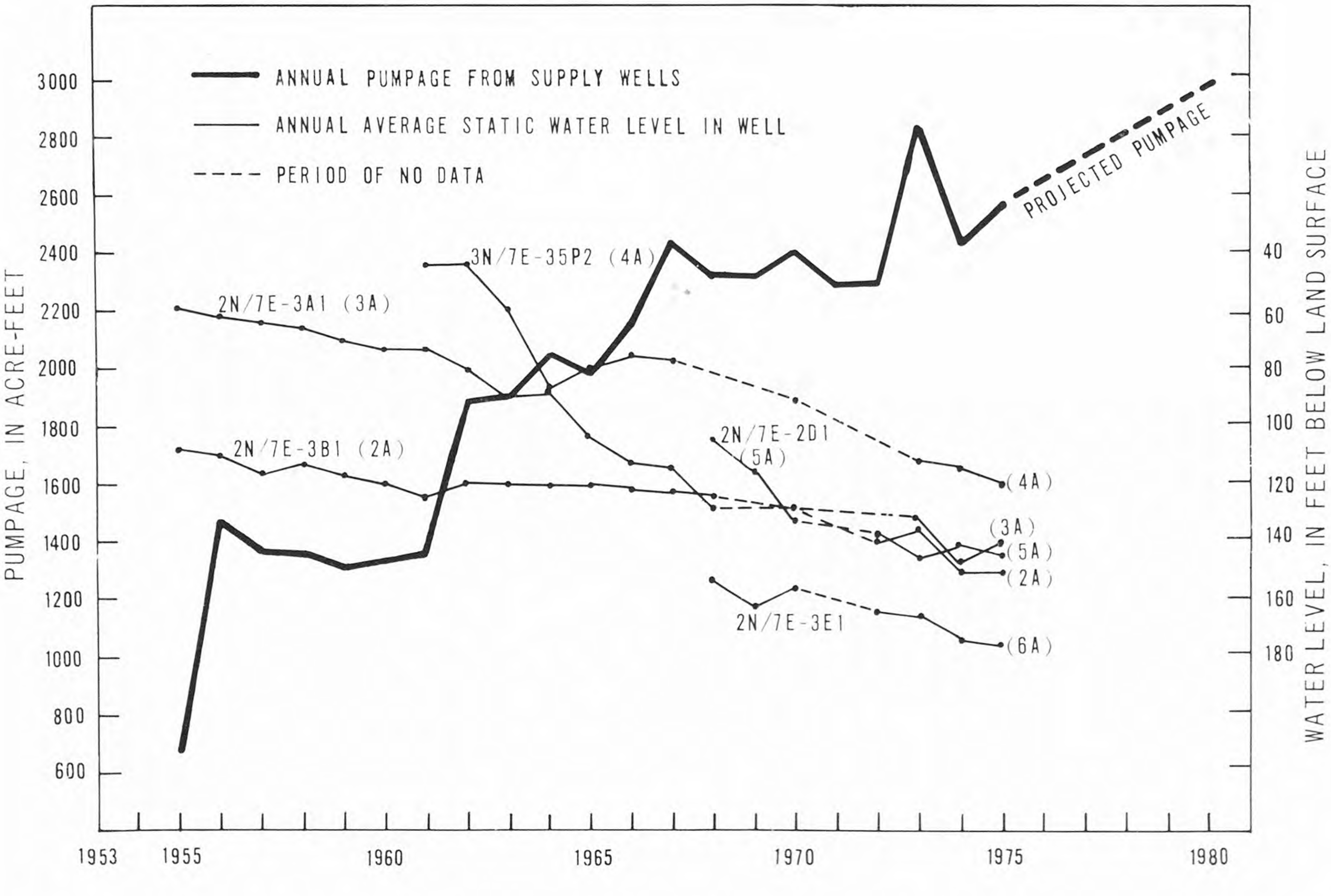


FIGURE 9.--Pumpage from supply wells and water-level trends.

The total cumulative pumpage to December 1975 from Surprise Spring subbasin was about 42,000 acre-ft. With an estimate of 650,000 acre-ft as the amount of water originally available from storage, about 600,000 acre-ft of ground water remains in the subbasin.

Because the population of the base beyond 1980 has not been estimated, projecting water needs is difficult. As the need arises, supply wells drilled farther north at a sufficient distance from other wells and faults would develop the ground water of Surprise Spring subbasin with the least general drawdown of water levels.

One of the major problems in evaluating alternative management plans is the lack of detailed information concerning the possible response of the ground-water system to changes in the location and quantity of pumping. This would be an especially difficult problem should the base population expand far beyond its present level.

A digital-computer model might help in assessing the long-term availability of a water supply and provide predictive capability for management of the supply. If a model is constructed, considerably more detailed aquifer-hydraulic information is needed, in order for the model to be a reasonably realistic representation of the aquifer system.

With an effective management plan for Surprise Spring subbasin, including proper long-term development of ground-water withdrawal, the water supply for the Marine Corps Base at Twentynine Palms would be insured for many years to come.

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