EVALUATION OF INCREASES IN DISSOLVED SOLIDS IN GROUND WATER, STOVEPIPE WELLS HOTEL, DEATH VALLEY NATIONAL MONUMENT, CALIFORNIA

By Anthony Buono and Elaine M. Packard

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CONVERSION FACTORS

For those readers who may prefer metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acres	0.4047	ha (hectares)
ft (feet)	0.3048	m (meters)
ft^2/d (feet squared per day)	0.0929	m^2/d (meters squared per day)
ft^3 (cubic feet)	0.0283	m^3 (cubic meters)
gal (gallons)	3.785	L (liters)
gal/d (gallons per day)	.003785	m^3/d (cubic meters per day)
gal/min (gallons per minute)	.003785	m^3/min (cubic meters per minute)
(gal/min)/ft (gallons per minute per foot)	0.01242	$(m^3/min)/m$ (cubic meters per minute per meter)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
µmho (micromhos)	1	µS (microsiemens)

Degrees Fahrenheit are converted to degrees Celsius by using the formula:
Temp °C = (temp °F - 32)/1.8

Additional abbreviations used:
- lsd, land surface datum
- mg/L, milligrams per liter
- µg/L, micrograms per liter
- µmho/cm, micromhos per centimeter at 25°C

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.

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ABSTRACT

Increases in dissolved solids have been monitored since 1976 and 1977 in two observation wells in the vicinity of Stovepipe Wells Hotel, a facility of the Death Valley National Monument in California. The hotel's present supply wells produce water of about 3,000 milligrams per liter dissolved solids, which is the best quality water found locally. One of the wells supplies water to a reverse-osmosis treatment facility that produces the area's potable water supply. The costs of potable water production by the facility will increase should water with increased dissolved solids reach the well.

The well that supplies the area's reverse-osmosis treatment plant is located about 0.4 mile south of one of the wells where increases have been monitored, and 0.8 mile southwest of the well where the most significant increases have been monitored. The direction of ground-water movement in the area is eastward, which reduces the probability of the increases adversely affecting the supply well.

Honey mesquite are located about 1.5 miles to the east, downgradient from the well where the most significant increases in dissolved solids have been monitored. These phreatophytes might be adversely affected should the area of increased dissolved solids in ground water extend that far.

Available data and data collected during this investigation do not indicate the source of the dissolved-solids increases. Continued ground-water-quality monitoring of existing wells and the installation of additional wells for water-quality monitoring would be necessary before the area affected by the increases, and the source and direction of movement of the water with increased dissolved solids, can be determined.

INTRODUCTION

Increases in dissolved solids have been monitored since 1976 and 1977 in two observation wells in the vicinity of Stovepipe Wells Hotel, Death Valley National Monument, Calif. The hotel's supply wells are located southwest of the observation well showing the most significant dissolved-solids increases, and south of the well showing the lesser increase.

A map of the configuration of the water table in August 1977 (Lamb and Downing, 1979, p.7) indicates that a local pumping depression surrounds the supply wells. On the basis of information from the map and the dissolved-solids increases, the National Park Service expressed concern that local pumping might be drawing water from a more saline source into the area and toward the supply wells. The supply wells currently produce water of about 3,000 mg/L dissolved solids, which is the best quality water found locally. Water from one of the hotel's supply wells is treated by reverse osmosis to reduce levels of dissolved solids to 500 mg/L or less for the area's potable supply. This well is located about 0.8 mile southwest of the observation well where the most significant increases have been monitored, and about 0.4 mile south of the observation well where the lesser increases have been monitored. An increase in dissolved-solids concentration at the supply well would increase the cost of potable water production.

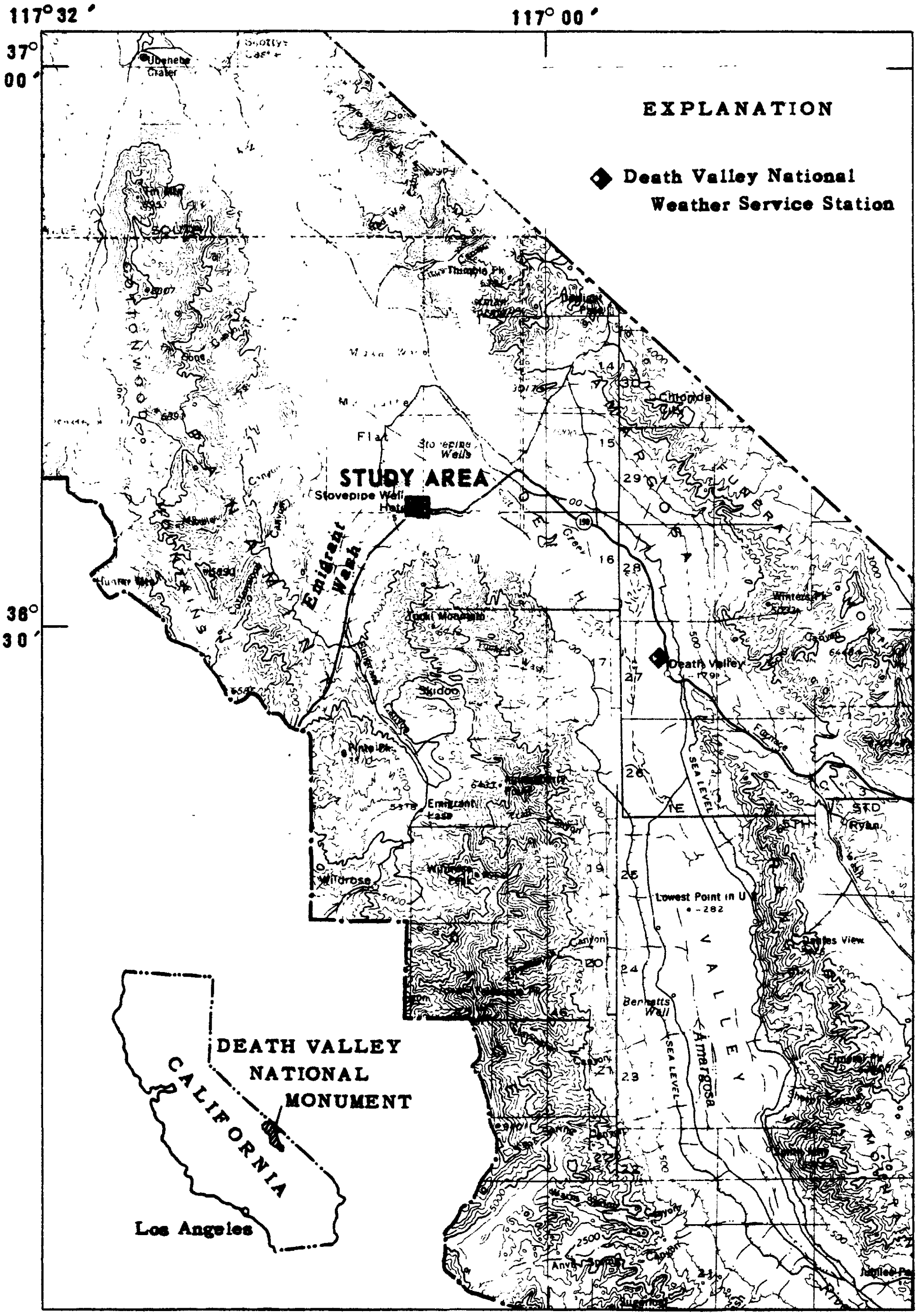
Geography and Climate

Stovepipe Wells Hotel is located on State Highway 190 in the western part of Death Valley about 200 miles northeast of Los Angeles, Calif. Death Valley is a 140-mile long northwestward-trending desert basin in the southwestern part of the Great Basin. The valley, bounded on the east by the Amargosa Range and on the west by the Panamint Range, is famous as the site of the lowest point in the United States at 282 feet below sea level (fig. 1).

The climate in Death Valley is arid, with an average annual rainfall of less than 2 inches and an average monthly temperature ranging from 52°F in January to 102°F in July. Measurements have been recorded since 1913 at the National Weather Service Station at Death Valley, Calif., altitude, 194 feet below sea level, about 18 miles southeast of the study area. The highest temperature recorded at this station was 134°F on July 10, 1913.

Purpose and Scope

The purposes of the investigation were to determine if the water with increased dissolved solids monitored in wells 15S/44E-36K2 and 15S/45E-31M1 (fig. 2) will have an adverse effect on the local ground-water supply, and to attempt to identify the cause of the increases. The area of investigation was less than 1 square mile surrounding the Stovepipe Wells Hotel.

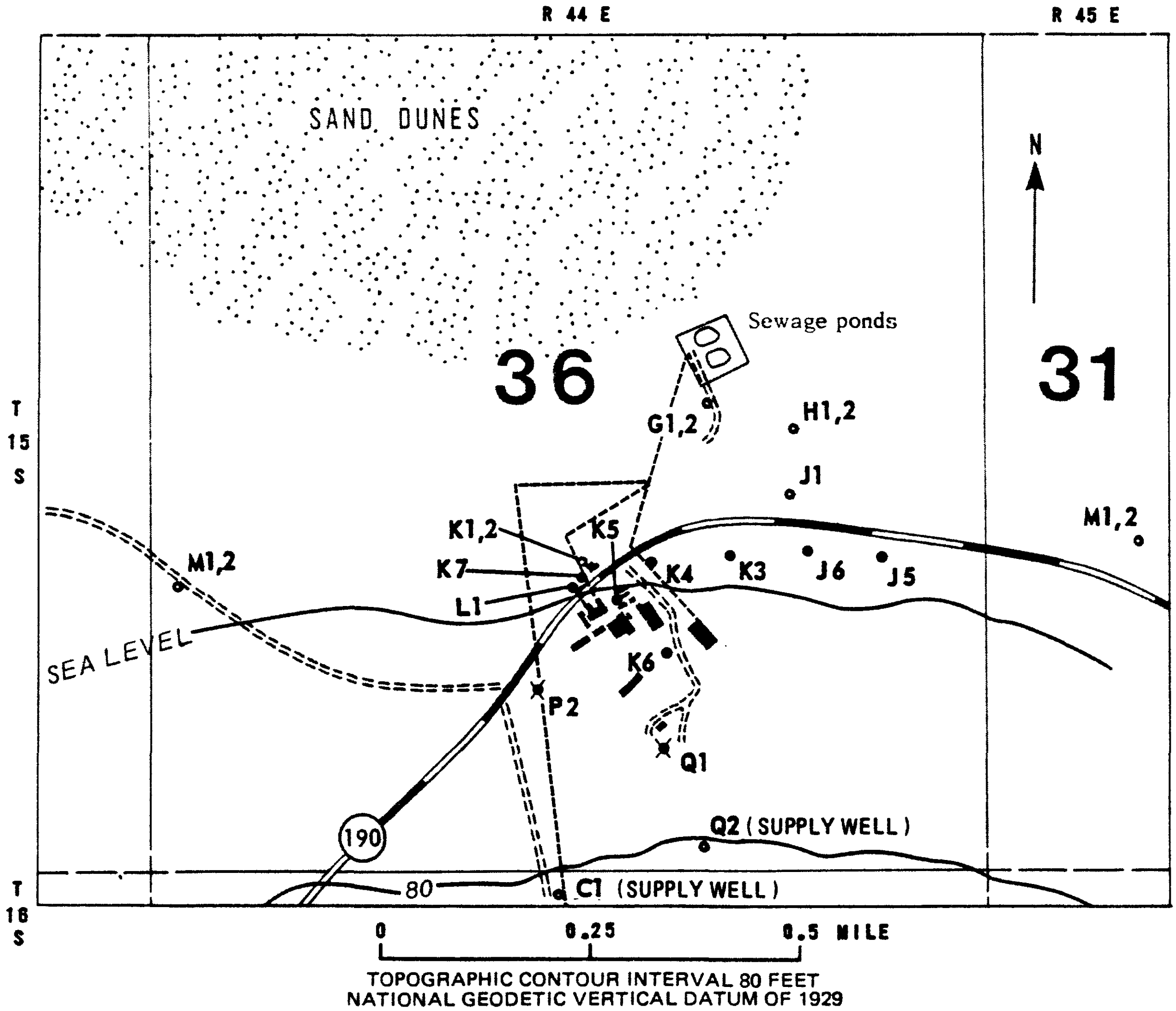


Base from U.S.Geological Survey, California (South half) 1:500,000, 1970

0 10 20 30 MILES

CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

FIGURE 1.--Location of study area in Death Valley National Monument, California.



EXPLANATION

WELL—

- o M1,2 Drilled prior to May 1980
- • J5 Drilled May 1980
- ✕ Q1 Destroyed

------- SEWAGE PIPELINE—Approximate location

FIGURE 2.--Location of wells.

Approach

The objectives of the investigation were accomplished through: the determination of the effects that pumpage has had on local ground-water levels through the evaluation of well hydrographs and water-table maps comparing past and present directions and patterns of ground-water movement in the area; the determination of the horizontal and vertical distribution of dissolved solids in the aquifer through the evaluation of water quality and well-construction information.

Previous Investigations

Information from previous studies in Death Valley used during this investigation included: General background information concerning the climatic, hydrologic, and geologic setting from Hunt, Robinson, Bowles, and Washburn (1966); the salt tolerance of local vegetation from Hunt (1966); ground-water quality data from Miller (1977); and ground-water level and quality data from Lamb and Downing (1979).

Well-Numbering System

Wells are numbered according to their location in the rectangular system for the subdivision of public lands. For example, in the number 15S/44E-36K1, the part of the number preceding the slash indicates the township (T. 15 S.), the part between the slash and the hyphen indicates the range (R. 44 E.), the number between the hyphen and the letter indicates the section (sec. 36), and the letter indicates the 40-acre subdivision of the section, as shown in the diagram below. Within the 40-acre tract, wells are numbered serially as indicated by the final digit.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Acknowledgments

The authors express their appreciation for cooperation extended to them during the investigation by National Park Service personnel, in particular, Gerard S. Witucki of the Western Regional office and George Von der Lippe, Bob Quesenberry, and Richard S. Rayner of Death Valley National Monument.

HYDROLOGIC SETTING

Ground water is the only local source of water available to the Stovepipe Wells Hotel facilities. The local aquifer is composed of unconsolidated gravelly sandy silt having a transmissivity of about 3,400 ft^2/d. Transmissivity was estimated by using the Jacob and Lohman straight-line solution for well-recovery data (Lohman, 1972, p. 26-27) from a specific-capacity test of supply well 16S/44E-1C1. The specific capacity of the well was about 7 (gal/min)/ft of drawdown. The depth to the water table in the hotel area ranges from about 22 feet below land surface (table 1) at monitor well 15S/44E-36G2, near the hotel's sewage ponds (fig. 2), to about 145 feet at supply well 16S/44E-1C1 farther up an alluvial fan toward Tucki Mountain (fig. 1).

TABLE 1.--Water-quality and well data

[Specific conductance: F, field; L, laboratory. Constituents in milligrams
Analyses by the U.S. Geological Survey Central

Site and date	Depth to water (ft below lsd)	Perforated interval (ft below lsd)	Depth of well (ft below lsd)	Specific conduct-ance [(μmho/cm) at 25°C]	pH (units)	Water tem-pera-ture (°C)	Hard-ness as $CaCO_3$	Non-car-bon-ate hard-ness	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)
14S/44E-32Q1											
5-07-72	25.34	57.5-59.0	59	4,100F	7.8	30.0	500	97	75	75	660
14S/44E-32Q2											
5-07-72	20.09	38.5-40.0	40	8,000F	7.8	30.0	--	--	--	--	--
15S/44E-34D1											
3-26-68[1]	38.17	51.0-53.0	53	5,530	8.2	26.4	566	267	114	68	956
15S/44E-36G1											
6-17-80	22.78	44.9-46.9	46.9	--	--	--	--	--	--	--	--
15S/44E-36G2											
6-17-80	22.46	24.7-27.7	27.7	13,700L	7.0	26.0	1,300	850	180	210	2,400
15S/44E-36H1											
11-03-73	22.25	49.2-51.2	51.2	8,570F	8.0	24.0	690	310	78	120	1,700
6-17-80	23.53	--	--	8,250F	7.4	28.5	660	290	68	120	1,700
15S/44E-36H2											
6-17-80	23.80	25.2-28.2	28.2	--	--	--	--	--	--	--	--
15S/44E-36J1											
6-17-80	27.22	48.2-50.2	50.2	9,600F	7.4	30.0	690	330	60	130	2,000
15S/44E-36J5											
6-17-80	36.26	32.6-44.3	44.3	12,900F	7.3	28.5	950	640	100	170	2,500
15S/44E-36J6											
6-17-80	37.42	36.0-46.0	46.0	8,740F	7.3	28.5	810	570	110	130	1,600
15S/44E-36K1											
3-21-67	--	37(?)-65(?)	65	14,400L	7.4	29.0	1,450	1,150	171	248	2,660
2-14-74	37.57	--	--	--	--	--	--	--	--	--	--
2-27-75	37.67	--	--	--	--	--	--	--	--	--	--
6-23-76	37.66	--	--	--	--	--	--	--	--	--	--
4-05-77	37.61	--	--	--	--	--	--	--	--	--	--
5-10-78	37.57	--	--	14,500F	7.4	28.5	1,300	1,000	130	240	3,200
5-09-79[1]	37.55	--	--	15,000F	7.4	31.5	1,340	--	137	242	2,940
6-18-80	37.86	--	--	14,200F	7.6	30.5	1,200	930	82	230	2,700
15S/44E-36K2											
2-14-74	37.37	Unknown	50	--	--	--	--	--	--	--	--
2-27-75	37.53	--	--	--	--	--	--	--	--	--	--
6-23-76	37.49	--	--	--	--	--	--	--	--	--	--
4-06-77[1]	37.51	--	--	5,812F	8.0	27.0	--	--	39	59	1,050
5-10-78	37.53	--	--	6,430F	8.2	30.5	330	86	29	63	1,200
5-09-79	37.60	--	--	7,150F	7.8	34.0	315	--	19	65	1,400
15S/44E-36K3											
6-17-80	39.42	37.4-45.4	45.4	8,430F	7.3	--	1,200	1,000	260	130	1,300
15S/44E-36K4											
6-17-80	40.53	38.0-47.0	47.0	7,520F	7.0	29.0	1,300	1,100	230	170	1,400
15S/44E-36K5											
6-18-80	49.06	49.8-59.8	59.8	10,500F	7.1	30.0	1,100	820	140	190	1,800
15S/44E-36K6											
6-18-80	63.62	62.0-71.7	71.7	9,500F	6.8	28.0	1,700	1,400	200	300	1,700
15S/44E-36K7											
6-17-80	42.53	37.0-54.0	54.0	12,000F	7.3	29.0	1,000	680	110	180	2,300

See footnotes at end of table.

in the Stovepipe Wells Hotel area

per liter, except arsenic, boron, and iron, in micrograms per liter.
Laboratory, Arvada, Colo., unless otherwise noted]

Potassium (K)	Alkalinity, (total as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, calculated sum	Nitrate plus nitrite as nitrogen (N)	Arsenic (As)	Boron (B)	Iron (Fe)
76	399	520	790	4.7	69	2,520	--	9	4,700	40
--	--	--	--	--	--	--	--	--	--	--
72	299	440	1,360	3.3	58	3,290	--	--	7,300	30
--	--	--	--	--	--	--	--	--	--	--
160	460	1,500	3,300	0	--	8,080	--	--	26,000	330
110	384	920	2,200	1.3	45	5,430	2.5	8	18,000	120
110	370	980	2,300	1.3	45	5,580	2.3	--	19,000	50
--	--	--	--	--	--	--	--	--	--	--
140	360	1,000	2,800	1.2	34	6,410	1.5	--	24,000	70
200	310	1,200	3,800	1.3	70	8,260	1.3	--	23,000	70
150	240	1,000	2,200	1.3	39	5,390	.02	--	16,000	70
172	298	1,660	3,940	1.0	82	9,170	--	--	24,000	10
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
190	300	1,200	6,000	.8	24	11,200	.08	--	23,000	4,700
190	280	1,480	4,580	.7	37	10,000	--	--	24,000	3,000
200	220	1,200	4,200	.6	22	8,790	.06	--	22,000	150
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
85	--	4.9	1,800	.3	3.7	3,270	--	--	6,300	--
110	250	15	2,000	.2	2.8	3,570	.04	--	6,700	20
112	516	5	2,110	.2	3.1	3,770	.1	--	6,600	10
130	150	1,400	1,900	1.1	30	5,250	.04	--	13,000	70
130	160	1,500	2,000	1.2	28	5,570	.10	--	12,000	70
130	310	1,100	2,800	1.4	35	6,400	.03	--	18,000	40
140	300	1,600	2,600	0.8	50	6,790	--	--	16,000	70
180	340	1,100	3,500	1.2	50	7,650	.05	--	23,000	60

TABLE 1.--Water-quality and well data

Site and date	Depth to water (ft below lsd)	Perforated interval (ft below lsd)	Depth of well (ft below lsd)	Specific conductance [(μmho/cm) at 25°C]	pH (units)	Water temperature (°C)	Hardness as $CaCO_3$	Noncarbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
15S/44E-36L1											
6-17-80	45.07	44.3-54.4	54.4	9,500F	7.2	29.0	840	540	90	150	1,900
15S/44E-36M1											
11-03-73	28.1	43.7-45.7	45.7	10,480F	8.2	25.0	750	440	84	130	2,100
2-26-76	--	--	--	10,920F	7.7	28.0	720	400	90	120	2,000
4-06-77[1]	27.88	--	--	10,630F	7.9	26.5	--	--	81	124	2,040
5-10-78	27.84	--	--	10,310F	7.6	30.0	730	420	77	130	2,000
9-21-78	28.04	--	--	11,800F	7.2	29.0	690	--	76	120	2,000
5-09-79[1]	28.01	--	--	10,400F	7.5	31.0	736	--	89	125	2,040
6-18-80	28.20	--	--	9,720F	7.3	28.0	730	450	76	130	1,900
15S/44E-36M2											
11-03-73	--	30.4-33.4	33.4	11,120F	8.0	26.5	780	530	97	130	2,200
15S/44E-36P2 (Destroyed)											
11-03-73	74.1	85.6-87.6	87.6	10,000F	7.9	25.0	850	560	110	140	1,900
15S/44E-36Q1 (Destroyed)											
12-10-59[1]	--	Unknown	105	7,030L	7.35	24.0	774	484	91	133	1,240
4-20-61[1]	--	--	--	7,320L	7.6	--	800	503	108	129	1,265
1-23-64	--	--	--	7,300L	8.0	--	820	508	96	141	1,220
1-10-67[1]	70	--	--	7,418L	7.6	--	824	532	113	132	1,306
9-08-73	--	--	--	14,500F	--	27.2	--	--	--	--	--
15S/44E-36Q2											
5-08-67[1]	--	Unknown	>300	4,740F	7.6	--	666	--	110	95	745
9-09-73[2]	130.25	--	--	4,500F	--	27.8	--	--	--	--	--
6-19-75	--	--	--	4,490F	--	29.0	700	380	140	84	730
2-26-76	--	--	--	6,020F	7.7	27.0	700	400	130	91	710
4-06-77[1]	129.98	--	--	4,616F	6.9	29.0	--	--	138	88	728
5-10-78	130.02	--	--	4,630F	7.1	28.5	720	420	140	91	680
5-10-79[1]	130.23	--	--	4,500F	7.3	27.0	689	--	134	86	763
6-17-80	130.25	--	--	4,400F	7.4	--	740	420	150	88	670
15S/45E-31M1[3]											
2-26-76	27.57	35.7-37.7	37.7	5,100F	7.8	25.0	570	320	94	82	830
4-06-77[1]	27.25	--	--	9,965F	7.7	27.5	630	390	87	103	1,650
5-10-78	27.29	--	--	12,880F	7.5	34.0	710	390	71	130	3,100
9-21-78	27.45	--	--	15,100F	7.1	41.0	610	380	64	110	2,800
5-10-79[1]	27.42	--	--	13,400F	7.5	29.5	712	--	80	124	2,820
6-18-80	27.67	--	--	13,200F	7.8	26.5	710	480	85	120	2,600
15S/45E-31M2[4]											
6-17-80	27.59	28.3-30.3	30.3	--	--	--	--	--	--	--	--
16S/44E-1C1											
9-09-73	145.4	264-294	294	4,400F	--	27.8	--	--	--	--	--
4-06-77[1]	144.84	--	--	4,540F	6.8	25.0	--	--	152	88	675
5-10-78[5]	144.67	--	--	4,870F	7.3	24.5	21	0	4.7	2.2	1,100
5-10-79[1]	144.90	--	--	4,500F	7.2	29.5	734	--	145	90	703

[1]Analysis by California Department of Water Resources.
[2]Analysis by National Park Service.
[3]Formerly 15S/44E-36J3.
[4]Formerly 15S/44E-36J4.
[5]May have been sampled after water softening.

in the Stovepipe Wells area--Continued

Potassium (K)	Alkalinity, (total as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, calculated sum	Nitrate plus nitrite as nitrogen (N)	Arsenic (As)	Boron (B)	Iron (Fe)
160	300	920	2,900	1.3	45	6,370	0.04	--	20,000	70
190	305	960	2,900	.9	43	6,610	.72	--	16,000	410
180	322	950	2,900	1.1	37	6,490	.26	--	17,000	220
160	--	963	2,910	1.0	41	6,620	--	--	17,000	--
180	300	930	3,000	1.1	55	6,570	.14	--	17,000	50
180	290	920	2,700	1.1	55	6,230	.16	--	17,000	100
160	297	948	3,000	1.0	57	6,580	--	--	15,000	30
170	280	910	2,800	1.1	47	6,220	.15	--	18,000	70
220	248	1,100	3,300	.6	40	7,260	1.1	3	17,000	140
140	295	880	2,800	2.4	34	6,200	.77	1	14,000	10
77	--	621	1,903	1.2	65	4,670	--	--	11,900	--
78	--	635	1,897	2.3	60	4,421	--	--	10,000	--
86	312	605	1,840	2.1	64	4,530	--	--	13,000	--
80	356	691	2,000	2.4	--	4,584	--	--	6,500	--
--	--	--	--	--	--	--	--	--	--	--
54	287	433	1,167	1.6	--	2,984	--	--	4,500	--
--	--	--	--	--	--	--	--	--	--	--
59	312	410	1,100	1.7	56	2,780	.42	--	6,100	20
62	301	400	1,200	1.7	53	2,840	.13	--	6,100	1,600
60	--	425	1,130	--	60	2,910	--	--	5,500	--
66	300	400	1,100	1.7	54	2,720	.03	--	6,000	0
59	307	413	1,180	2.2	55	2,920	--	--	5,800	0
65	320	400	1,100	1.8	52	2,730	.09	--	7,200	260
59	248	420	1,300	1.4	25	2,990	5.0	--	6,800	300
110	243	930	2,240	1.3	16	5,540	--	--	14,000	--
200	320	1,800	3,700	1.1	40	9,260	.88	--	25,000	280
190	230	1,300	3,700	1.2	34	8,337	.78	--	24,000	70
185	313	1,540	3,880	1.0	40	8,830	--	--	24,000	10
190	230	1,200	3,800	1.0	17	8,180	.46	--	29,000	1,200
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
55	--	413	1,090	2.0	58	2,870	--	--	5,800	--
9.1	300	400	1,200	1.6	50	2,960	.03	--	5,700	50
60	309	413	1,140	2.2	54	2,890	--	--	5,400	60

Ground-water quality in the area is poor. Dissolved-solids concentrations in 1980 ranged from 2,730 mg/L in supply well 15S/44E-36Q2, the deepest well penetrating the aquifer locally, to 8,790 mg/L in abandoned supply well 15S/44E-36K1, open at the water table (table 1). The concentrations of dissolved solids are far above the recommended limit for drinking water of 500 mg/L (U.S. Environmental Protection Agency, 1976, p. 205-206). The dissolved solids consist of more than 50 percent dissolved sodium and chloride. The high concentrations of dissolved solids are presumed to be a result of the high rate of evaporation locally in the geologic past when salts were deposited in valley sediments from the evaporation of lakes of Holocene pluvial time and near-surface ground water (Hunt and others, 1966, B46-48).

EVALUATION OF INCREASES IN DISSOLVED SOLIDS

Ground-Water Withdrawals and Use

The water supply at Stovepipe Wells Hotel is obtained from two wells, 15S/44E-36Q2 and 16S/44E-1C1 (fig. 2). These wells penetrate and are open to deeper sections of the aquifer than other local wells and yield the best water in the area (table 1). The concentration of dissolved solids in these wells is nearly 3,000 mg/L, about six times the recommended limit for drinking water. Since 1975 when well 16S/44E-1C1 was put into production, water has been treated by reverse osmosis to reduce concentrations of dissolved solids to an acceptable level for the area's potable water supply. The pumping rate of well 1C1 is about 23 gal/min and about 25,000 gal/d of water is pumped during peak seasonal use. Treated water from well 1C1 supplies all potable needs of the area and the nonpotable needs of the area's campground, the domestic facilities for the Park Service personnel, and some sections of the hotel. Table 2 shows a breakdown of the volumes of water withdrawn from well 1C1 and the volume of reverse-osmosis treated water produced between 1975 and 1979. Water from well 15S/44E-36Q2 is not treated and supplies most of the area's nonpotable needs. The rate of well 36Q2 is about 65 gal/min and about 25,000 gal/d of water is pumped during peak seasonal use. No other pumpage records are maintained for well 36Q2.

TABLE 2. - Pumpage and reverse-osmosis product-water data, supply well 16S/44E-1C1, 1975-79

Year	Water withdrawn (gallons)	Product water[1] (gallons)
1975	1,159,200	223,000
1976	2,639,300	660,600
1977	4,026,400	1,147,170
1978	5,327,100	1,569,700
1979	3,406,200	1,333,200
1975-79 (Total)	16,558,200	4,933,670

[1]Product water is the potable water obtained from the reverse-osmosis processing. The remainder of the withdrawn volume is wastewater from the process.

Direction of Ground-Water Movement and Ground-Water Levels

Since 1977 dissolved-solids concentrations have increased from 3,270 to 3,770 mg/L in well 15S/44E-36K2 and from 2,990 to 8,180 mg/L since 1976 in well 15S/45E-31M1 (fig. 3, table 1). The increases, together with a map of the water-table configuration in August 1977 from a previous report (Lamb and Downing, 1979, p. 7), suggested that a local pumping depression surrounding the supply wells may be drawing water into the area from a more saline source, probably from the north. During the present investigation, however, altitudes of well-measuring points in the area were more accurately determined using a surveyor's leveling instrument. These data provide a better understanding of the direction of ground-water movement indicating a general easterly movement of ground water with no indication of a pumping depression in the study area.

A comparison of the altitude of the water table for April 1977 and June 1980 (fig. 4) shows a general decline (about 0.25 foot) in water levels, indicated by the westerly shift of the contours, and no change in the direction or patterns of ground-water movement. Hydrographs of several wells (fig. 5) show a declining trend along with normal seasonal fluctuations in water levels. The hydrograph of well 15S/44E-34D1, located 2.5 miles northwest of the supply wells (off fig. 2 to west), also shows a declining trend in water levels. The hydrographs indicate that part of the decline observed in figure 5 resulted from seasonal fluctuations and part from regional decline. Together, these data indicate that the present rate of withdrawal from the supply wells has had no noticeable effect on water levels or patterns of ground-water movement in the area.

The only noticeable variation in the direction of ground-water movement in the study area was indicated by the eastward bending of ground-water contours in the vicinity of the hotel's sewage ponds (fig. 4). The bending of contours prompted the inspection of ground-water-level data from nearby wells. Well 15S/44E-36G2, located about 200 feet south of the ponds and perforated from about 2 to 5 feet below the water table (table 1), shows a more pronounced fluctuation in water level than occurs in other wells in the study area (fig. 5). These facts indicate that the ponds may be a local source of ground-water recharge.

Distribution of Dissolved Solids in Ground Water

Water-quality samples collected from 14 wells in June 1980 were used to determine the horizontal distribution of dissolved solids in local ground water (fig. 6, table 1). The distribution did not offer evidence of the sources of the increases, however. It shows that wells 15S/44E-36G2, 15S/44E-36J5, and 15S/45E-31M1, downgradient from the sewage ponds, and well 15S/44E-36K1, downgradient from a sewage pipeline, have concentrations of dissolved solids considerably higher than other wells in the study area. The data also show that wells 15S/44E-36H1 and 15S/44E-36J1, located between the ponds and wells 36G2, 36J5, or 31M1, have lower concentrations similar to those of most of the wells in the area. It was realized, however, that problems in trying to correlate the horizontal distribution exist because of the differences in well perforated intervals below the water table. The perforations are set deeper into the aquifer in wells 36H1 and 36J1, and it has been observed that decreases in dissolved solids with depth exist in the aquifer.

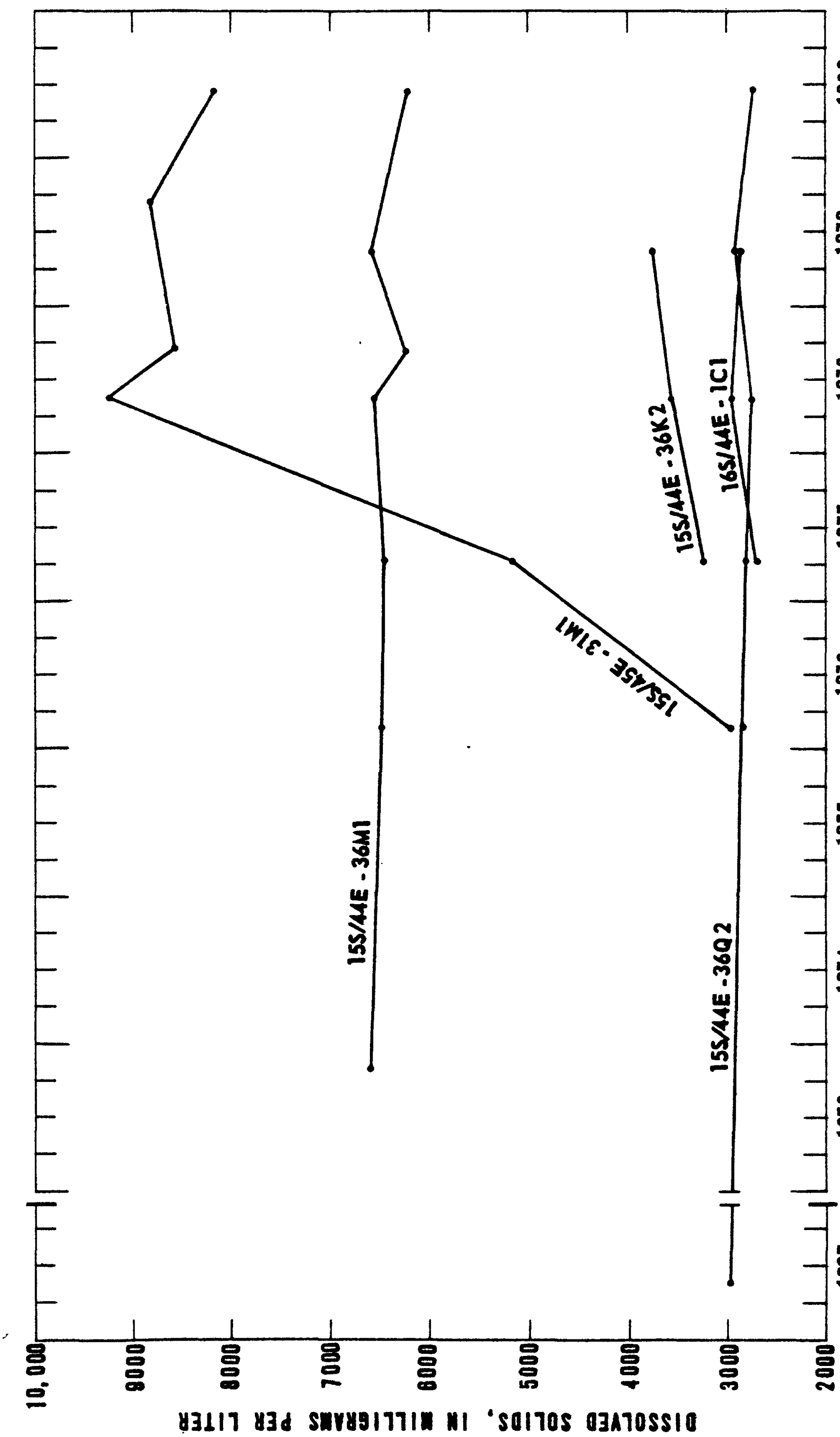
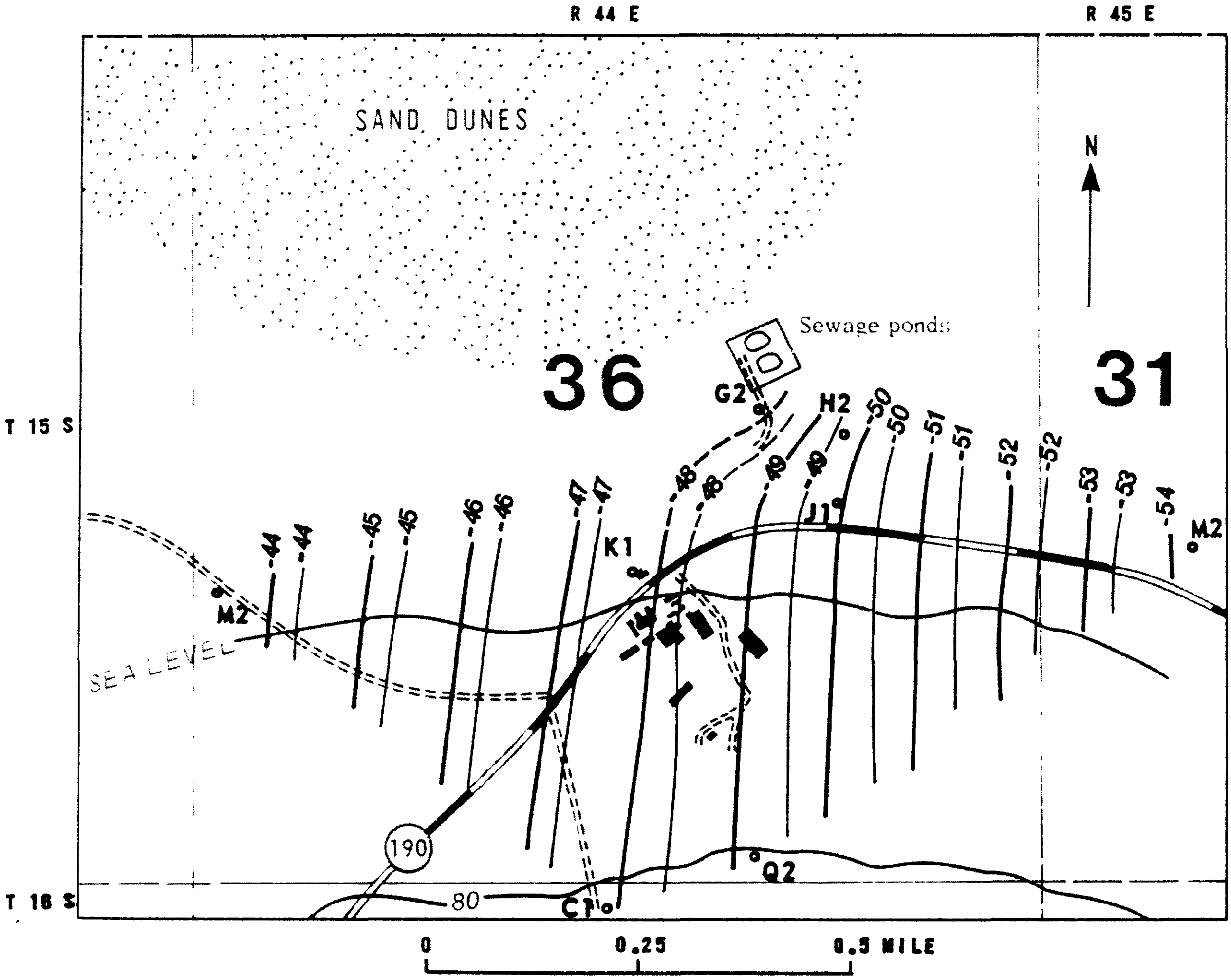


FIGURE 3.--Changes in dissolved solids in selected wells, 1967-80.



EXPLANATION

M2 **WELL AND NUMBER**

WATER-TABLE CONTOUR—Shows altitude of water table. Dashed where approximately located. Contour interval 1 foot. National Geodetic Vertical Datum of 1929

-53 **April 1977**

-54 **June 1980**

FIGURE 4.—Water-table configurations, April 1977 and June 1980.

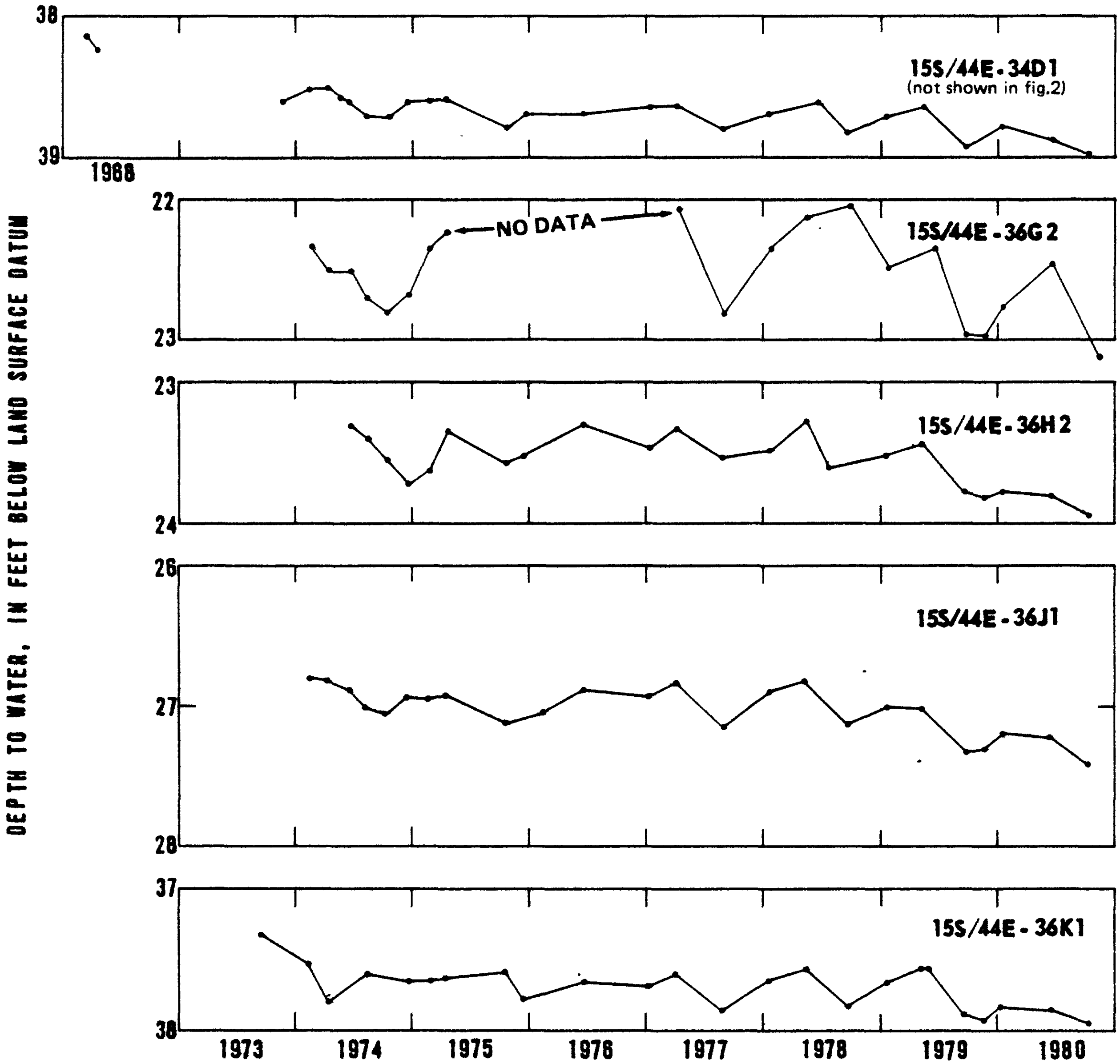


FIGURE 5. — Hydrographs of selected wells in the Stovepipe Wells Hotel area, 1968, 1973–80.

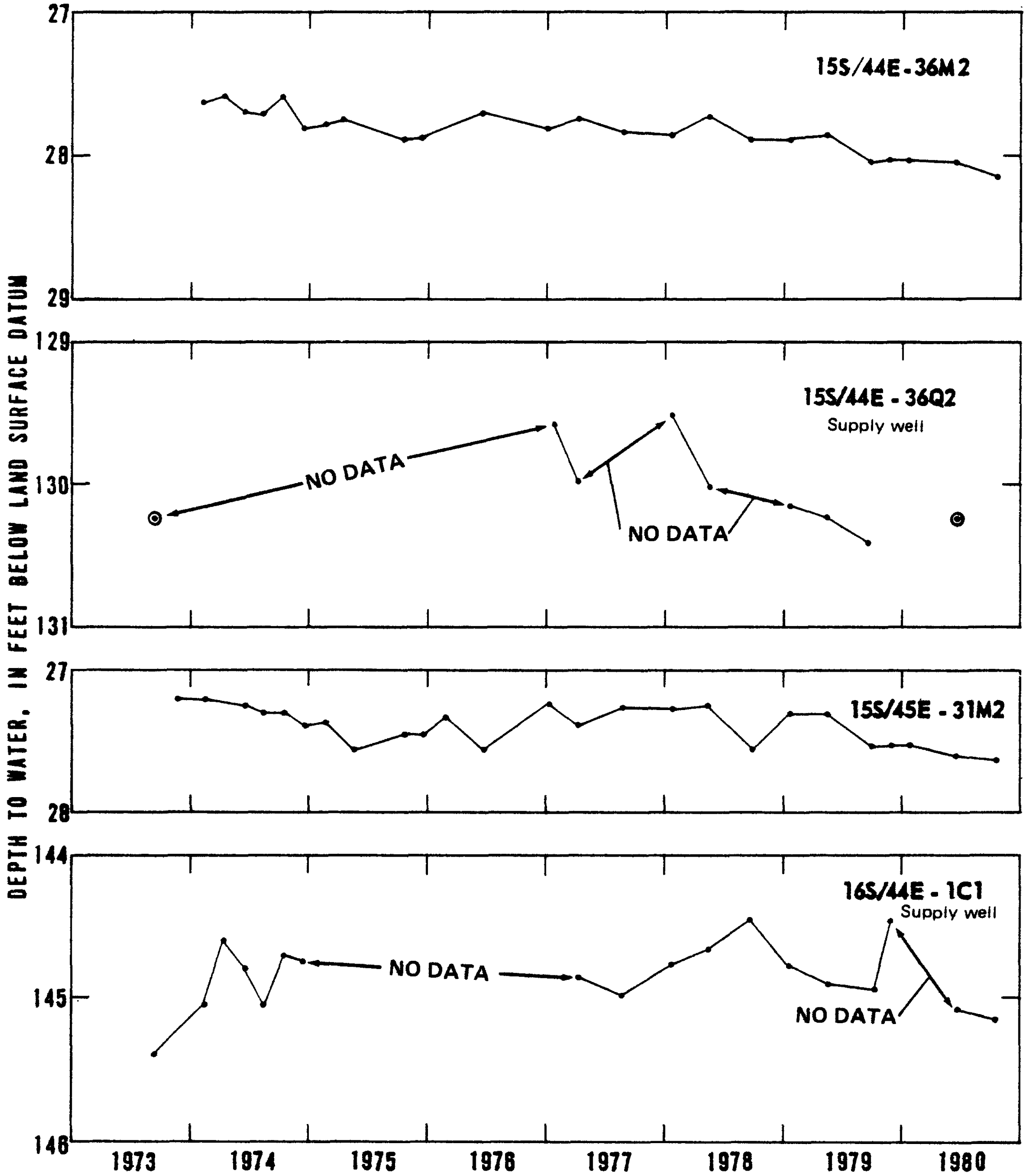
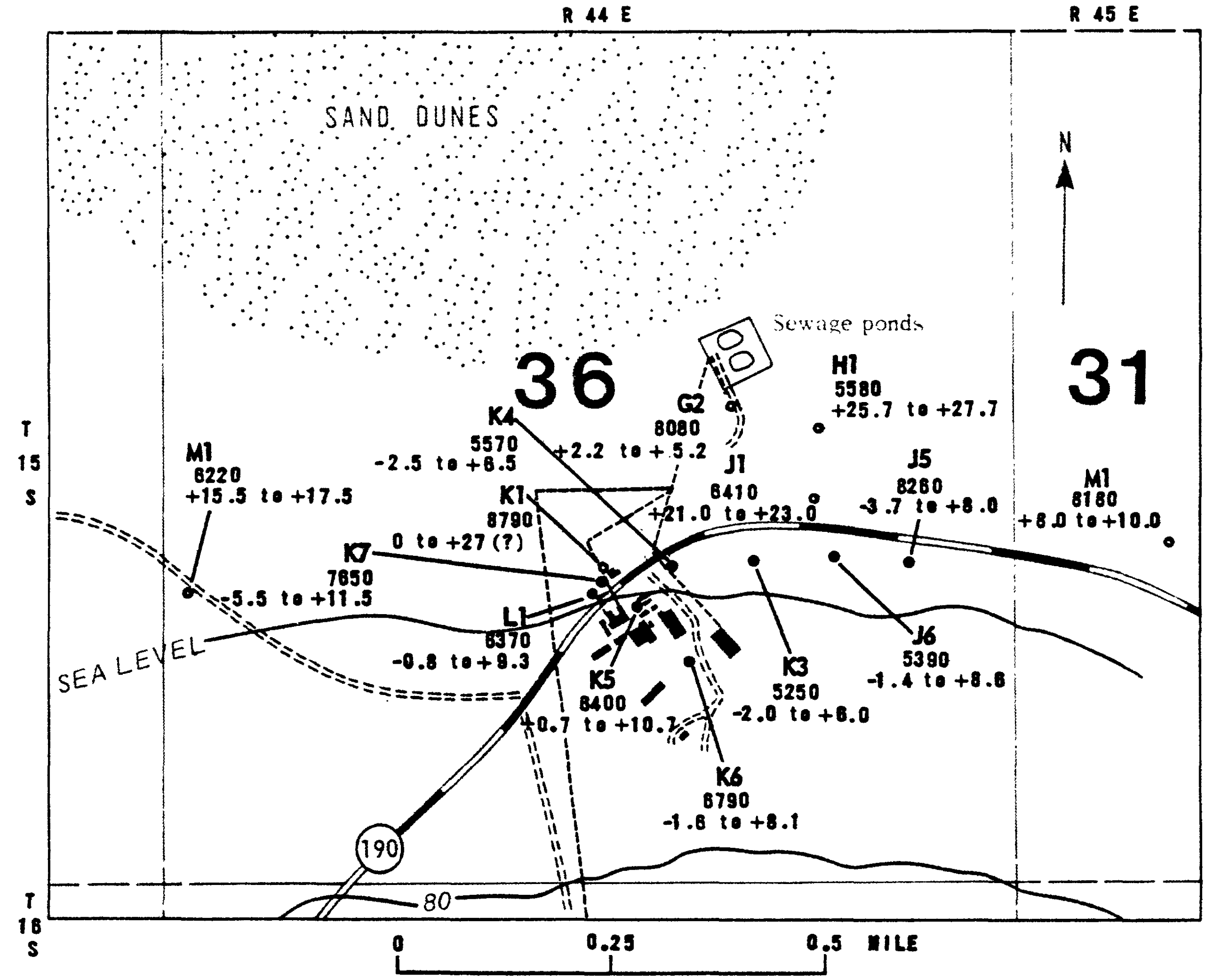


FIGURE 5.--Continued.



TOPOGRAPHIC CONTOUR INTERVAL 80 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

WELL--

• M1 8180 +8.0 to +10.0 — **Drilled prior to May 1980**

• J5 8260 -3.7 to +8.0 — **Drilled May 1980**

Top number is well number. Middle number is dissolved solids, in milligrams per liter. Bottom positive numbers indicate perforated interval, in feet below the water table. Negative numbers indicate perforated interval, in feet above the water table

———— **SEWAGE PIPELINE--Approximate location**

FIGURE 6.--Dissolved-solids concentrations in selected wells, indicating perforated intervals, June 1980.

Data from two nested well sites, each having two closely spaced wells (within several feet) open to different depths in the aquifer, show a decrease in dissolved solids with depth. Furthermore, supply wells 15S/44E-36Q2 and 16S/44E-1C1, which yield the best water in the area, are open much deeper in the aquifer than other local wells (table 1). In the closely spaced wells 15S/44E-36K1 (shallower perforations) and 36K2 (deeper perforations), a decrease from 10,000 to 3,770 mg/L from the shallower to the deeper well was reported in 1979. Although the drilled and perforated depths of these wells are not known, other available well data support this assumed relative positioning of the perforations. The presence of a gasoline layer in well 36K1 and not in 36K2 (Buono and Packard, 1982) indicates that 36K1 is open at the water table and 36K2 is open somewhere below it. The shallower depth to water in well 36K1, which is generally associated with the shallower of the nested wells in the area (fig. 2, table 1), is additional evidence supporting this assumption. In wells 14S/44E-32Q1 (deeper perforations) and 32Q2 (shallower perforations), about 6 miles northwest of the study area (not shown in fig. 2), specific conductance, an indicator of dissolved-solids concentration, decreased with depth, based on measurements made in 1972 (table 1). The specific conductance in well 32Q2 was 8,000 μmho/cm, and in well 32Q1 it was 4,100 μmho/cm. Specific conductance values can be converted to approximate dissolved-solids concentration by multiplying the value by 0.63, a number derived from an average of all water samples analyzed in the study area.

Cause of the Dissolved-Solids Increases

Available data and data collected during this investigation were insufficient to isolate the cause of the dissolved-solids increases in two local observation wells. Further sampling of the aquifer for the distribution and changes in dissolved solids will be needed before a meaningful determination of the cause, the area affected by the increases, and the direction of spreading of the poorer quality water can be made. Additional work should also be aimed at determining the effect sewage-pond leachate may be having on groundwater quality. The additional study may require the installation of several observation wells, especially in the direction of the supply wells from and surrounding well 15S/45E-31M1, where the most significant increases in dissolved solids have been monitored.

Hydrologic Effects of Increases in Dissolved Solids

Under present conditions, the increase in dissolved solids in wells 15S/44E-36K2 and 15S/45E-31M1 is not expected to affect the local supply wells. The supply wells are more than 0.4 mile from the observation wells where dissolved solids have increased; are approximately perpendicular to the direction of ground-water movement from well 36K2, and upgradient from well 31M1 where the most significant increases have been monitored; and are open to a deeper zone within the aquifer where the best quality water in the area is found. Should water with increased dissolved solids reach the supply wells because of a change in the direction of ground-water movement or some factors unknown at the time of this investigation, current reverse-osmosis processing of supply water can reduce levels of dissolved solids to within acceptable limits for drinking water at an increased operational cost.

An increase in dissolved solids comparable to that monitored in well 15S/45E-31M1 may adversely affect the honey mesquite (Prosopis juliflora) in the phreatophyte zone (off fig. 2) 1.5 miles east of well 15S/45E-31M1, should the increases extend that far. Dissolved solids in water beneath these plants normally is less than 5,000 mg/L (Hunt, 1966, p. 40). It is not known whether these plants could tolerate a transition to water with higher levels of dissolved solids. Arrowweed (Pluchea sericea) and Four-wing saltbush (Atriplex canescens), other phreatophytes in the same zone, grow in areas having dissolved solids of as much as 18,000 mg/L (Hunt, 1966, p. 37-39) and should not be affected. Xerophytic plants throughout the area obtain water from soil moisture above the water table and should not be affected by any increases in dissolved solids in the aquifer. Continued water-quality monitoring in existing wells, and installation of additional wells east of well 31M1, would be necessary to determine the spread of poorer quality water toward the phreatophytes.

SUMMARY AND CONCLUSIONS

The cause of the increases in dissolved solids in two local observation wells could not be determined from available data or from data collected during this investigation. However, information at the time of this study (1979-80) indicates that the increases will probably not have an effect on the present water supply. The reverse-osmosis treatment-plant supply well (16S/44E-1C1) is located about 0.8 mile southwest and upgradient from well 15S/44E-31M1, where the most significant increases in dissolved solids have been monitored, and 0.4 mile south and nearly perpendicular to the direction of ground-water movement from well 15S/44E-36K2, where less significant increases have been monitored. Furthermore, supply well 1C1 is open to a deeper part of the aquifer, where the best quality water in the area is found. Should increases in dissolved solids be observed in supply well 1C1, for reasons unknown at the time of this study or due to a change in the directon of ground-water movement, the reverse-osmosis treatment presently in use can reduce the levels of dissolved solids to an acceptable level for the area's potable supply at an increased operational cost. Honey mesquite, a phreatophyte located about 1.5 miles downgradient from well 15S/45E-31M1, where the most significant increases have been monitored, may be affected by an increase in dissolved solids of the magnitude monitored in that well.

Continued monitoring of existing wells, and the installation of additional wells toward the supply wells from well 15S/45E-31M1, and surrounding this well, would be necessary to determine the cause and area affected by increased dissolved solids and the directions of spreading of the poorer quality water. Additional study should also attempt to discover what effects sewage-pond leachate may be having on ground-water quality.

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