Hydrologic and Geologic Reconnaissance of Pinto Basin Joshua Tree National Monument Riverside County, California

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1475-O

Prepared in cooperation with the National Park Service

Hydrologic and Geologic Reconnaissance of Pinto Basin Joshua Tree National Monument Riverside County, California

By FRED KUNKEL

HYDROLOGY OF THE PUBLIC DOMAIN

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1475-O

Prepared in cooperation with the National Park Service

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

TABLES

HYDROLOGIC AND GEOLOGIC RECONNAISSANCE OF PINTO BASIN, JOSHUA TREE NATIONAL MONUMENT, RIVERSIDE COUNTY, CALIFORNIA

By Fred Kunkel

ABSTRACT

Pinto basin, in the north-central part of Riverside County, Calif., is a typical desert valley formed by downfaulting along several major fault zones. The valley is filled with alluvium, and ground water in the alluvium discharges as subsurface outflow through an alluvium-filled gap at the east end of the valley. Occasionally surface water from cloudburst floods also discharges in a wash through the gap at the east end of the valley.

A northeastward extension of the major fault along the south side of the valley acts as a barrier to the discharge of ground water from the valley. The average ground-water gradient is less than 1 foot per mile across the main part of the valley above this barrier, but the water level drops abruptly across the fault. The ground-water storage capacity of the uppermost 100 feet of saturated alluvium beneath the central valley area is estimated to be about 230,000 acre-feet. All this water in storage occurs at depths greater than 95 feet below the land surface and cannot be reached by plants or animals. During 1959 virtually all the water pumped in the area was withdrawn from storage. However, the quantity of water pumped is small in relation to the total quantity in storage. Except for a small decline in head, no evidence indicates that the pumping will greatly impair the yield for many years or cause the water to deteriorate in quality.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report presents the findings of a brief geologic and ground-water reconnaissance made by the U.S. Geological Survey in Pinto basin, Riverside County, Calif. The investigation was made at the request of the National Park Service to determine if the existing pattern of ground-water pumping from Pinto basin will reduce the yield of wells or impair the quality of the ground water in Pinto basin, which lies almost wholly within the Joshua Tree National Monument.

Specifically, this report presents: (1) a brief geologic reconnaissance of Pinto basin, with particular emphasis on the unconsolidated deposits and the geologic structure in the area of subsurface outflow at the southeast end of the basin; (2) information on the occurrence and movement of ground water; (3) an approximation of the ground-water storage capacity of the water-bearing deposits in the east-central part of Pinto basin and the relation of the storage capacity to pumpage; and (4) data on wells, water-level records, drillers' logs of wells, pumpage from wells, and chemical analyses of ground water.

Fieldwork was done intermittently between June 1955 and December 1959. This work has been carried on by the Long Beach, Calif., subdistrict office of the U.S. Geological Survey under the general supervision of J. F. Poland, G. F. Worts, Jr., and H. D. Wilson, Jr., successive district supervisors, Sarcamento, Calif.

LOCATION OF THE AREA

Pinto basin is in the Mojave Desert in the north-central part of Riverside County, Calif. (fig. 64). As usually applied, the term "Pinto basin" refers to the alluviated or valley-floor part of a drainage system that discharges to the south along a dry wash between the Eagle and Coxcomb Mountains. However, this investigation is concerned chiefly with the downstream part of the drainage area. Therefore, where the term "Pinto basin" is used in this report, it refers to the main valley area between 115°20′ and 115°42′30″ west longitude.

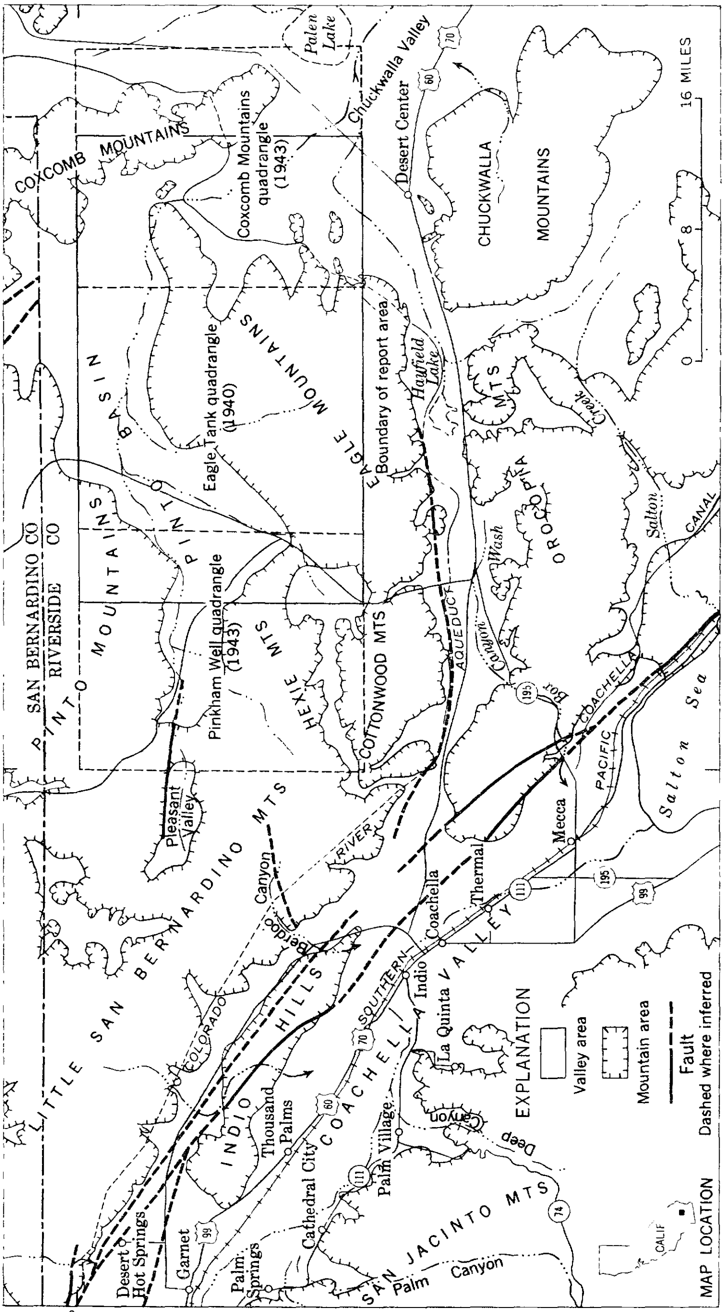
The area studied (pl. 28) is shown on the Pinkham Well, Eagle Tank, and Coxcomb Mountains quadrangles (scale 1:62,500) of the U.S. Army, Corps of Engineers. The area north of lat 34° N. is shown on the Amboy quadrangle (scale 1:250,000). However, this area is not critical to the present study and has not been included as part of plate 28.

PREVIOUS INVESTIGATIONS AND ACKNOWLEDGMENTS

The mountainous region south of Pinto basin was examined by E. C. Harder (1912) during the summer of 1909 in connection with a study of the iron-ore deposits of the Eagle Mountains. The report of that study contains a reconnaissance geologic map of the Eagle Mountains showing the types and extent of the consolidated rocks, but it does not show Pinto basin.

As part of an anthropologic study, the major geologic units of the lower part of Pinto basin are briefly described in a report by Scharf (1935). That report contains several excellent panoramic photographs but no geologic map.

As part of a general hydrologic study by the National Park Service, J. V. Lewis prepared a map, showing the extent of alluvial deposits and the locations of wells and springs (written communication, 1941), and a report discussing the water resources of Joshua Tree National Monument and vicinity (written communication, 1942).



Base map and fault pattern largely after geologic map of California (Jenkins, 1938)

FIGURE 64.—Map of part of southern California, showing area covered by this report.

Pertinent information from these maps and reports was used in the preparation of this report.

Special thanks are due M. J. Hughes, general manager of the Eagle Mountain mine, and his staff in furnishing well logs, water-level records, chemical analyses of water, and pumpage and other data from wells in Pinto basin. These data were vital in the preparation of this report.

PHYSIOGRAPHY AND GEOLOGY

GENERAL FEATURES

Pinto basin is a large alluvium-filled desert valley, about 15 miles long and 8 miles wide, bordered by the Pinto Mountains on the west and north, by the Coxcomb Mountains on the east, and by the Eagle Mountains on the south. In the central and major part of the valley floor is a large almost flat area, which is traversed by an eastward-draining sandy wash. The wash discharges through a gap between the Eagle and Coxcomb Mountains into Chuckwalla Valley to the south. This flat area is bordered on the south by the steep north face of the Eagle Mountains. To the west, north, and east, the flat area grades into the extensive alluvial fans and pediment cover that border the Pinto and Coxcomb Mountains.

The altitude of the central part of the flat valley area ranges from about 1,000 feet at the downstream (east) end to about 1,250 feet at the west end. Locally the alluvial fans and pediment cover extend to altitudes of about 1,800 feet. The altitudes of crests of the surrounding mountains are generally about 3,000 feet, and a few peaks in the Coxcomb Mountains (outside the area shown on pl. 28) are more than 4,000 feet in altitude.

Pinto basin is a structural depression formed by downfaulting along the north side of the Eagle Mountains and along the west side of the Coxcomb Mountains. The faulting along the north side of the Eagle Mountains is pronounced and is indicated by a steep eastward-trending scarp. The brecciated fault zone may be observed in the vicinity of the Mystery mine where basalt has been extruded to the surface along the fault zone. The eastern extension of this major fault is concealed beneath the alluvial deposits of the Pinto formation of Scharf (1935), that are deformed into an anticlinal fold where they overlie the extension of the fault. Movement of the fault during the Pleistocene probably caused this folding. The extension of the fault probably lies between wells 1 and 2, as indicated by the discontinuity of water levels between the wells.

Other hydrologic evidence, discussed in the section on ground water, also indicates that these wells are not in direct hydraulic continuity. Water levels for wells are shown in tables 3 and 4.

The major fault along the west side of the Coxcomb Mountains is concealed beneath the alluvial fans that extend into the valley, and the exact position of the fault trace is not known. Faulting along the northeast side of hill 1430 at the outlet of Pinto basin does not constitute a major structure, but its presence adds complexity to the area through which ground water discharges from Pinto basin by subsurface outflow to Chuckwalla Valley.

GEOLOGIC UNITS

In this report the geologic units of Pinto basin are divided into unconsolidated deposits and consolidated rocks. The reconnaissance geologic map (pl. 28) shows the areal distribution of these two groups. The map was prepared primarily to aid the estimating of the ground-water storage capacity of the basin.

The unconsolidated deposits of Pinto basin are Quaternary in age and consist of alluvial and lacustrine accumulations of tufa, clay, silt, sand, and gravel that are locally deformed and interbedded with flows of basalt at their base (Pinto formation of Scharf, 1935). In the central and lower parts of the basin the unconsolidated deposits yield nearly all the usable ground water that is pumped.

Tables 1 and 2 include drillers' logs of four wells in the alluvium and the rates at which the alluvium yields water to them as shown by pumping tests. Drillers' tests, in general, indicate maximum specific capacities because they usually are not of long enough duration for the drawdown of water level to become effectively stabilized. The tests (table 2) conducted by the Geological Survey on wells

TABLE 1.—*Drillers' logs of wells*

Material	Thickness (ft)	Depth (ft)
Well 1. Kaiser Steel Corp.		
[Drilled for Metropolitan Water District by R. E. McSwain and J. F. Barkwill. Cased with 16-in. 8-gage stovepipe casing. Perforated from 390 to 532 ft; 6 holes to the round, ⅜ by 1¼ in., 8 in. apart. Altitude 1,048.1 ft. Data from records of the Metropolitan Water District]		
Sand and gravel	132	132
Cemented rock	8	140
Fine sand and silt	44	184
Gravel	42	226
Cemented rock	8	234
Sand and gravel	40	274
Clay and gravel	18	292
Brown clay	54	346
"Shot" clay	16	362
Clay and gravel	30	392
Gravel	34	426
Hard clay	4	430
Gravel	114	544
Clay	3	547

TABLE 1.—*Drillers' logs of wells*—Continued

Material	Thickness (ft)	Depth (ft)
Well 2. National Park Service		
[Well drilled for Kaiser Steel Corp. by the Freelove Drilling Co., Phoenix, Ariz. Cased with 532 ft of 16-in. stovepipe casing and 53 ft of 14-in. liner. Perforated from 250 to 520 ft, 8 holes to the round, 1 in. apart. Altitude 1,080.6 ft. Data from files of Kaiser Steel Corp.]		
Boulders and sand	18	18
Sand and gravel	36	54
Conglomerate	46	100
Sand	30	130
Sandy clay	20	150
Sand and gravel	35	185
Sand with streaks of clay	155	340
"Decomposed granite"	140	480
Sand, gravelly clay with hard ribs of granite	95	575
Well 9. Kaiser Steel Corp.		
[Cable-tool well drilled by Ray Roberts Drilling Co. in April–May 1957; 20-in. casing, perforated with Mills perforator from 449 to 658 ft. Log by James Cahill, driller]		
Coarse sand and pea gravel	47	47
Gravel	8	55
Clay, brown	60	115
Sand, fine	28	143
Sand and some gravel	48	191
Sand, fine	53	244
"Pack" sand	6	250
"Caliche"	22	272
"Sand clay"	78	350
"Caliche"	41	391
Clay, hard brown	58	449
Clay, gravelly	72	521
Sand and gravel	6	527
Clay	4	531
Sand and pea gravel	15	546
Clay, gravelly	45	591
Sand and gravel	19	610
Clay, sandy	6	616
Sand, gravel, and layers of clay	42	658
Clay	15	673
Sand, cemented	2	675
Well 10. National Park Service, Cottonwood Pass well		
[Cable-tool well drilled by Clifford Suffdy in 1958; 12¾-in. casing from 0 to 232 ft, perforated with Mills perforator from 212 to 228 ft; 10¾-in. casing preperforated from 208.75 to 402.75 ft. Data by driller, except as indicated]		
Sand, gravel	60	60
Boulders, clay content	55	115
Sand, clay content	20	135
Clay, boulders	43	178
Clay, pure	5	183
Boulders, clay, very rough, water showed	32	215
Boulders, clay	16	231
Gravel, boulders, clay	54	285
Soft, probably more water	20	305
Clay, some gravel	98	403

1 and 9 indicate specific capacities of 18 and 19 gpm (gallons per minute) per ft of drawdown, respectively. These tests probably are more reliable than those recorded for wells 2 and 10. The Geological Survey did not test wells 2 or 10.

TABLE 2.—*Summary of pumping-test data*[1]

Date	Time	Pumping rate (gpm)	Depth to water (ft)	Drawdown (ft)	Specific capacity (gpm per ft of drawdown)
Well 1					
May 26, 1933		0	97		
		410	114		24
Feb. 11, 1956	12:30 p.m.	[2] 330	[3] 118.64		18
13	6:55 a.m.	0	100.28		
Well 2 [4]					
Dec. 4, 1954	6:50 p.m.	0	150		
	11:50	870	170		43
5	8:50 a.m.	1,075	174		46
	1:50 p.m.	1,480	183		45
Well 9 [4]					
June 20, 1957	6:00 a.m.		126		
	6:05	1,209	156	30	40
	6:20	1,209	176	50	24
	7:00	1,209	179	53	23
	8:00	1,209	182	56	22
	9:00	1,209	184	58	21
	10:00	1,209	184	58	21
	11:00	1,209	184	58	21
	12:00	1,200	184	58	21
	1:00 p.m.	1,200	190	64	19
	2:00	1,200	190	64	19
Well 10					
Nov. 21, 1958	8:00 a.m.		171		
	2:30 p.m.	40			
Dec. 1			171		
		45	256	85	0.5

NOTE.—Specific capacity is the yield of the well in gallons per minute per foot of drawdown of the water level below the static or nonpumping level.

[1] Sources of data: well 1, Metropolitan Water District; well 2, Kaiser Steel Corp.; well 9, U.S. Geol. Survey; well 10, Clifford Suffdy, driller.
[2] Rate determined from metered discharge.
[3] Well being pumped at least 6 hour .
[4] Depth-to-water measurements are by air line from an unspecified measuring point. These measurements are comparable with each other but not with measurements made by a steel tape or electric sounder from a specified measuring point.

The consolidated rocks of Pinto basin are pre-Tertiary and may range in age from Paleozoic to Mesozoic. The rocks that form the Coxcomb Mountains are predominantly granitic and are chiefly Jurassic in age or older (Jenkins, 1938). The rocks of the Pinto and Eagle Mountains are igneous, metaigneous, and metasedimentary rocks that are pre-Cretaceous in age (Jenkins, 1938). Locally the older consolidated rocks are intruded by younger volcanic rocks, but they are undifferentiated on plate 28.

None of the consolidated rocks bear significant quantities of ground water, although small amounts of water may percolate through joint system and other fractures. These rocks underlie the alluvium at depth and crop out to form the hills and mountains around the main valley. They receive most of the precipitation within the drainage area. Runoff from this marginal and mountain area flows onto the alluvial fans and contributes most of the recharge to the ground-water body. The structural basin, which is filled with the alluvium that contains the main ground-water body of the valley, is formed by consolidated rocks of the basement complex.

WATER RESOURCES

SURFACE WATER

Pinto basin has no perennial streams. However; the main dry wash and its dry tributaries form a well-integrated drainage system that discharges from the valley into Palen Lake in Chuckwalla Valley to the southeast. According to Campbell and Campbell (1935), occasional heavy thundershowers in the higher mountains may flood the wash to a depth ranging from a few inches to more than 1 foot for 8 or 9 hours. It is reported that during the summer of 1934 the wash flowed for 48 hours.

Placer Canyon is not identified on the Eagle Tank quadrangle map, and the map of Harder (1912) does not contain enough detail to correlate it with the Eagle Tank quadrangle map. However, the site shown as Eagle Tank (pl. 28) was visited on February 8, 1956, and no evidence of a tank was found.

According to Harder (1912):

> Eagle Tank is a natural rock basin about 20 feet in diameter 10 to 15 feet deep in the bed of a gorge tributary to Placer Canyon. The gorge is the third one entering Placer Canyon from the south below the reservoir, at a distance from it of about one-half mile. The tank is several hundred yards from the mouth of the gorge and stands in its bottom at the base of a vertical cliff about 20 feet high. It is said to contain water all the year round, but during the height of the dry season the water is stale and dirty, and even during the torrential rains it is filled with green algae and animal life, such as various crustaceans, larvae, and tadpoles.

GROUND WATER

OCCURRENCE

In Pinto basin, as in any ground-water basin, the pore spaces in deposits beneath the water table are saturated with water. However, not all deposits yield water to wells with the same facility. For example, beds of loose rounded well-sorted gravel or sand yield water to wells more freely than beds of clay, silt, cemented sand, or gravel, or compacted poorly sorted angular material. The consolidated rocks around the margins of and at depth beneath the valley are generally of low permeability and do not yield water to wells, except for small amounts from joints and other fractures.

Ten wells in Pinto basin have been described (table 3); of these wells, eight were examined by the Geological Survey. The reported ocation of wells 5 and 8 were visited but no wells were found.

SOURCE AND MOVEMENT

The only source of ground water in Pinto basin is precipitation within the tributary drainage area. The water that infiltrates the ground and reaches the water table does not move as a stream but percolates through the pore spaces in the water-bearing formations from points of replenishment toward points of discharge.

Under natural conditions, the only ground-water discharge from Pinto basin is underflow to Chuckwalla Valley through the unconsolidated deposits between the exposures of consolidated rock of the Eagle and Coxcomb Mountains. The water table in the basin lies at great enough depths to prevent ground-water discharge resulting from the transpiration of plants.

In February 1956, the altitude of the water surface was 949 feet above sea level at well 1, 926 feet at well 2, and 961 feet at well 3. These data show a difference in the altitude of the water table between wells 1 and 3, which are at opposite ends of the basin, of only 12 feet, or a hydraulic gradient of less than 1 foot per mile. On the other hand, the difference in the altitude of the water table between wells 1 and 2, which are only 1,485 feet apart, is 23 feet, which represents an apparent hydraulic gradient between the wells of about 80 feet per mile.

Most of the time water is pumped either from well 1 or from well 9; well 2 was pumped only during a development test. In February 1956 the altitude of the water table at well 1 was 23 feet higher than at well 2. Also, a small quantity of water in well 2 cascaded from a permeable zone above the main water level. Cascading water in a well is not conclusive evidence of a nearby fault. The combination of cascading water and the abrupt change in water-level gradient, however, strongly suggests that a concealed fault (pl. 28) or other

TABLE 3.—*Data on wells*

Altitude and depth of well are with reference to land-surface datum (lsd). Measuring point indicated as follows: Hpb, hole in pump base; Bnc, bottom of notch in casing; Bpb, bottom of pump base; Tc, top of casing; Tap, top of access pipe. The suffix letters N, S, E, and W indicate the side, north, south, east, or west, respectively, from which the water level was measured. The height of the measuring point in feet and tenths of feet above land-surface datum is given. This distance has been subtracted from the water level as measured. Therefore, the water level as shown is with respect to land-surface datum.
Pump type and power indicated as follows: T turbine, N none, G gasoline engine; where an electric motor is used the horsepower of the motor is given.
Use indicated as follows: Mn mining, Un unused, Ds well destroyed.

Well	Date of observation	Owner or user	Well data					Measuring point		Altitude of lsd (ft)	Water level (depth below lsd, in ft)
			Year completed	Depth (ft)	Diameter of well (in.)	Pump type and power	Use	Location	Ft above lsd		
1	June 22, 1955	Kaiser Steel Corp.	1933	[1] 547	16	T 15	Mn	HpbN	2.5	[2] 1,048.1	[3] 102.62
2	do	National Park Service	1954	[4] 575	16	N N	Un	BncN	0	[5] 1,080.6	154.94
3	Feb. 8, 1956	C. F. McGuire, Mission well				T G	Mn	BpbW	2.7	[6] 1,408.6	447.90
4	do	C. F. McGuire		421	12	N N	Un	TcE	2.8	[7] 1,410	Dry
5	do	do					Ds(?)				([8])
6	do	Sunrise Well			16	N N	Un	TcN	.5	[7] 1,410	448.65
7	do	Gold Rose Mining Co.	1949	500	16	T 15	Mn			[7] 1,400	([9])
8	do	Eagle Tank					Ds(?)				([8])
9	Nov. 30, 1957	Kaiser Steel Corp.	1957	675	20	T 75	Mn	TapS	1.13	[5] 1,059	114.22
10	Mar. 12, 1959	National Park Service	1958	403	12¾	N N	Un	Tc	1.0	[7] 2,975	170.29

[1] Data from records of the Metropolitan Water District. Depth measured on July 18, 1956, by Geol. Survey was 482 ft.
[2] Altitude of measuring point 1,050.57 ft, determined by National Park Service. Altitude of land surface calculated by difference.
[3] Pump off about 15 min.
[4] From driller's records; Geol. Survey measured 445 ft.
[5] Determined by difference from that of well 1 by Geol. Survey.
[6] Determined by National Park Service.
[7] Interpolated from topographic map.
[8] No evidence of well at site shown on map.
[9] Inaccessible.

barrier lies between the two wells and that some water is leaking through or flowing over the barrier.

CHEMICAL QUALITY AND TEMPERATURE

Chemical analyses of water from wells 1 and 2 (table 4) shows them to be of the sodium sulfate type containing dissolved solids of less than 1,000 ppm (parts per million). For most desert areas, this is considered to be water of good quality. However, the fluoride content of well 1 is 2.0 ppm, which is 0.5 ppm higher than that recommended by the U.S. Public Health Service (1946, p. 12) for domestic use on interstate carriers.

Water from the Cottonwood Pass well, as shown by the chemical analysis, is a sodium calcium bicarbonate type. It is low in dissolved solids and contains no constituent detrimental to its use for irrigation. The fluoride content of 2.7 ppm, however, makes it undesirable for drinking water.

The U.S. Public Health Service (1946) set a mandatory upper limit of 1.5 ppm of fluoride for drinking and culinary water supplied by interstate carriers and others subject to Federal quarantine regulations. The U.S. Navy, Bureau of Medicine (1957) set the upper limits for optimum fluoride concentrations at 0.7 to 1.2 ppm, the range being dependent upon the temperature of the region.

As it was not possible to collect water directly from well 9, the chemical analysis (table 4) represents water from well 9 mixed with a small percentage of water from well 1. This sample, collected on November 30, 1957, from a storage tank, was reported by personnel of the Kaiser Steel Corp. to be principally from well 9. Chemical analyses given in table 4 show that water from wells 1, 2, and 9 is of the sodium sulfate type and, compared with water in many other desert basins, is relatively low in dissolved-solids content. The fluoride concentration of 2.0 ppm in water from well 1 and 2.5 ppm in water from well 9 is above the desired limit for human consumption.

The percent sodium values of 93, 87, and 92 in water from wells 1, 2, and 9, respectively, are above the 65-percent limit for irrigation water recommended by Wilcox (1948). The sodium ions in water tend to disperse the colloidal clay particles in a soil, resulting in a sticky soil of poor texture for the cultivation of plants.

Water from wells 3, 6, and 7 is reported by the local residents to be of satisfactory quality. However, nothing is known regarding the fluoride content of water from these wells.

The temperature of ground water normally fluctuates within narrow limits during the course of a year, and the fluctuation commonly is greater in shallow wells and less in deep wells. The temperature of water in wells 100 to 150 feet deep is usually constant and about

TABLE 4.—*Chemical analyses of water*

[Analyses in parts per million except as noted]

Constituents	Well 1			Well 2				Wells 1 and 9	Well 10
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 4		
Silica (SiO_2)				20	20	20	20	12	24
Iron (Fe)				.1	0	0	0		
Calcium (Ca)			10	16	14	17	14	11	36
Magnesium (Mg)			.7	1.6	.7	.8	.7	2	8
Sodium (Na)			208	197	198	241	199	200	41
Potassium (K)			3.2	(1)	(1)	(1)	(1)	3.5	1.9
Bicarbonate (HCO_3)			118	81	77	96	77	102	142
Carbonate (CO_3)			0	8	8	8	8	0	0
Sulfate (SO_4)			[2] 216	241	224	292	245	216	23
Chloride (Cl)	46	64	102	98	96	115	97	104	44
Fluoride (F)			2.0					2.5	2.7
Nitrate (NO_3)			18					22	4
Boron (B)			.44					.38	.2
Sum [3]			[2] 618	[2] 622	[2] 599	[2] 741	[2] 622	[2] 623	[2] 255
Solids [4]	408	421		827	589	707	571	598	123
Hardness as $CaCO_3$	10	20	28				[2] 38	[2] 36	[2] 123
Percent sodium			93	80	87	87	87	92	42
Specific conductance (micromhos at 25° C)			1,010					1,020	473
pH			8.2	8.0	8.3	8.0	8.1	7.7	7.0
Date collected	May 13, 1933	May 20, 1933	Feb. 11, 1956	Dec. 5, 1954	Dec. 5, 1954	Dec. 5, 1954	Dec. 5, 1954	Nov. 30, 1957	Dec. 4, 1958
Time collected	(5)	(5)	(6)	[7] 3:50 a.m.	[7] 7:30 a.m.	[7] 11:50 a.m.	[7] 1:50 p.m.	(8)	(6)

[1] Analysis from records of the Metropolitan Water District. Analyst unknown.
[2] Analyses calculated.
[3] The sum of determined constituents is the arithmetic total in parts per million of all constituents determined except bicarbonate, for which the carbonate equivalent is used. When the sulfate is calculated by difference, the sum includes that quantity and is approximate.
[4] Residue on evaporation. This value, analytically determined, should approximate the sum of determined constituents.
[5] Analysis from records of Metropolitan Water District. Analyst unknown.
[6] Analysis by Geol. Survey.
[7] Analysis from records of Kaiser Steel Corp. Analyst unknown.
[8] Analysis by the California Dept. Water Resources.

equal to the mean annual air temperature. In deeper wells the temperature of the water normally increases at the rate of about 1° to 2° F per 100 feet of depth. A temperature gradient higher than this may indicate the proximity of comparatively young volcanic rocks or fault movement.

The temperature of the water in well 1 (547 ft deep) was 83°F on June 22, 1955, and 81° F on February 22, 1956. The mean annual air temperature at Eagle Mountain is about 72°F. Therefore, the water temperatures recorded for well 1 are slightly higher than might be expected but not high enough to be significant.

FLUCTUATIONS OF WATER LEVEL

The Geological Survey has made periodic measurements of the water level in wells 1 and 2 since 1955 and in well 9 since 1957. A measurement was made in well 1 by the Metropolitan Water District of Southern California in 1933, and periodic measurements have been made by the Kaiser Steel Corp. since 1949. These measurements are given in table 5 and are shown graphically on figure 65. In addition to periodic measurements of water level, a recording gage was installed on well 4 for irregular periods. Selected gage records are shown on figures 66 to 69.

In many desert areas, such as Pinto basin, having relatively long records of depth-to-water measurements, four types of water-level fluctuations commonly are observed: (1) long-term and (2) seasonal changes caused by the effect of pumping in nearby wells or in the observed well: (3) daily fluctuations caused by barometric changes and(or) the effect of pumping; and (4) almost instantaneous fluctuations caused by earthquakes.

The water-level records for wells 1, 2, and 9, shown graphically on figure 65, indicate a long-term net decline of the water level in well 1 of nearly 2 feet from 1949 to February 1956, about 2.5 feet from 1933 to February 1956, and a seasonal fluctuation of 1 to 3 feet for this period. From February 1956 to December 1959, the water level declined about 16 feet in wells 1 and 9. The altitude of the water surface in well 9 is virtually the same as that in well 1, and pumping in either well has a direct and almost immediate effect on the other. For discussion concerning the significance of the long-term water-level decline see the section "Relation of storage capacity to perennial yield."

The decline of water level in wells 1 and 9 was caused by withdrawal of ground water from these wells, which increased from about 130 acre-feet in 1952 to about 1,700 acre-feet in 1959. (See the section "Pumpage" and table 6.)

TABLE 5.—*Water levels in wells in Pinto basin, California*

[Water levels are in feet below land-surface datum; altitude is also with reference to land-surface datum]

Well 1. Kaiser Steel Corp.

[Altitude 1,048.1 ft; records through June 2, 1959, by Kaiser Steel Corp., except as indicated thereafter by the Geol. Survey]

Date	Water level	Pump off (hr)	Date	Water level	Pump off (hr)	Date	Water level	Pump off (hr)
1933			*1952*—Con.			*1955*—Con.		
May 26	[1] 97	-------	June 2	98.3	>1	June 22	102.61	<1
						Sept. 22	102.09	<1
1949			*1952*			22	101.57	>1
						Dec. 22	100.28	<1
Sept. 27	98.5	>1	July 1	99.3	<1	22	100.14	>1
Oct. 27	98.8	>1	Aug. 1	99.2	<1			
Nov. 28	98.1	>1	Sept. 2	98.7	<1	*1956*		
Dec. 28	97.5	>10	Oct. 1	99.7	<1			
			Nov. 1	98.7	>1	Feb. 11	[2] 117.64	-------
1950			Dec. 1	99.2	<1	11	101.19	<1
						11	100.17	>1
Jan. 31	97.5	>10	*1953*			13	99.28	>10
Feb. 28	97.6	>10				Mar. 23	[2] 118.35	-------
Mar. 31	97.8	>10	Jan. 3	98.3	>1	24	102.05	>1
Apr. 2	97.6	>1	Feb. 1	98.8	>1	May 27	100.93	>1
June 2	98.5	>10	Mar. 3	98.8	<1	28	100.19	>1
29	98.1	>10	Apr. 1	98.6	<1	Aug. 18	102.65	>1
Aug. 1	98.0	>10	May 3	99.4	>1			
31	98.3	>10	June 1	98.4	>1	*1957*		
Oct. 7	98.0	-------	July 1	98.9	>1			
Nov. 3	98.1	>1	Aug. 1	99.0	>1	May 18	[2] 232.3	-------
30	97.2	>10	Sept. 1	98.9	<1	19	115.5	<1
Dec. 31	98.2	>10	Oct. 4	98.5	>10	19	[2] 231.9	-------
			Nov. 1	98.4	>1	Nov. 30	102.8	>1
1951			Dec. 1	98.8	<1			
						1958		
Feb. 1	98.2	>10	*1954*					
Mar. 2	98.0	>10				Mar. 2	103.18	>10
31	98.1	-------	Feb. 1	98.4	<1	May 31	107.77	>1
May 2	98.1	-------	Mar. 1	98.8	-------	Sept. 15	108.08	>1
June 1	98.2	-------	Apr. 5	99.1	-------			
20	98.5	>10	May 5	100.7	-------	*1959*		
Aug. 3	98.3	>1	June 2	101.2	-------			
Sept. 4	98.3	>1	July 2	100.6	-------	Jan. 7	110.88	>1
Oct. 1	98.3	>1	Aug. 2	100.8	-------	Mar. 12	110.78	>1
Nov. 2	98.4	>1	Sept. 2	101.2	>1	June 11	116.85	>1
30	98.2	>1	Oct. 2	99.8	<1	Sept. 8	121.89	<1
						Dec. 10	117.67	<1
1952			*1955*					
						1960		
Jan. 2	98.0	>1	Mar. 2	100.0	>1			
Feb. 1	98.1	>1	Apr. 4	100.1	>1	Mar. 1	112.7	>1
Mar. 2	97.8	>1	May 4	100.0	>1	June 12	119.37	>1
Apr. 1	98.8	<1	June 2	100.4	<1	Oct. 13	116.67	>1
May 1	98.0	<1	June 22	[2] 110.33	-------			

Well 2. National Park Service

[Altitude 1,080.6 ft; records by Geol. Survey except as indicated]

Date	Water level	Pump off (hr)	Date	Water level	Pump off (hr)	Date	Water level	Pump off (hr)
1954			*1956*—Con.			*1958*—Con.		
Dec. 4	[3] 150	-------	July 27	[4] 155.3	-------	May 30	155.4	-------
4	[2,3] 183	-------	Aug. 18	155.3	-------	Sept. 15	155.6	-------
			Sept. 19	155.7	-------			
1955						*1959*		
			1957					
June 2	154.94	-------				Jan. 7	155.7	-------
Sept. 22	155.2	-------	May 18	155.21	-------	Mar. 12	155.6	-------
Dec. 22	155.6	-------	19	155.65	-------	June 11	155.8	-------
			June 26	[5] 155.48	-------	Sept. 8	155.71	-------
1956			Aug. 21	[4] 155.49	-------	Dec. 10	155.74	-------
			Sept. 18	[4] 155.37	-------			
Feb. 9	155.2	-------	Nov. 30	155.0	-------	*1960*		
11	155.1	-------						
12	155.0	-------	*1958*			Mar. 1	155.6	-------
Mar. 23	155.0	-------				June 12	155.90	-------
May 27	154.88	-------	Mar. 2	155.1	-------	Oct. 13	155.93	-------

See footnotes at end of table.

TABLE 5.—*Water levels in wells in Pinto basin, California*—Continued

Date	Water level	Pump off (hr)	Date	Water level	Pump off (hr)	Date	Water level	Pump off (hr)
Well 9. Kaiser Steel Corp. well 3 [Altitude, 1,059.4 ft; records by Geol. Survey]								
1957			*1959*			*1960*		
Nov. 30	114.22	>10	Jan. 7	121.89	>1	Mar. 1	123.63	>1
			Mar. 12	121.58	>1	June 12	127.00	>1
1958			June 11	127.42	>1	Oct. 13	126.99	>1
			Sept. 8	126.10	<1			
Mar. 2	114.27	>1	Dec. 10	127.87	<1			
May 31	118.64	>1						
Sept. 15	118.89	>1						
Well 10. National Park Service, Cottonwood Pass well								
1959			*1959*—Con.			*1960*		
Jan. 7	170.48	-------	June 11	170.30	-------	Mar. 1	170.3	-------
Mar. 12	170.29	-------	Dec. 10	170.32	-------	Oct. 13	170.36	-------

[1] From records of the Metropolitan Water District.
[2] Pumping.
[3] Measurement by Freelove Drilling Co., record from Kaiser Steel Corp.
[4] From Kaiser Steel Corp.
[5] From recorder chart.

For the period of record beginning in 1955 the water level in well 2 (fig. 65), on the other side of a fault from wells 1 and 9, has not declined appreciably. The fault, shown on plate 28, lies along the north side of the Eagle Mountains. Figure 66 is a copy of a chart from a recording gage installed in well 2 prior to drilling well 9. Similar studies in other desert areas indicate with reasonable certainty that the diurnal fluctuations observed in well 2 are caused by and are inversely proportional to changes in atmospheric pressure. The two sharp fluctuations shown on February 14 are typical of those caused by earthquakes and are believed to have been caused by earthquakes in Baja, California.

To determine the magnitude of mutual interference between wells 1 and 2 caused by the pumping of well 1 at a rate of about 350 gpm, a recording gage was geared to an expanded or rapid time scale from February 9–12, 1956 (fig. 67). A comparison of the recorder chart (fig. 5) and the pumping schedule of well 1 indicates that the drawdown in well 2 caused by pumping well 1 at a rate of about 350 gpm is less than the diurnal fluctuation caused by changes in atmospheric pressure.

In May 1957, the Kaiser Steel Corp. completed well 9 about 350 feet northwest of well 1 and about 1,500 feet west of well 2. After pumping had started at well 9, a recording gage was installed in well 2. Figures 68 and 69 are hydrographs of well 2 but do not show the highest

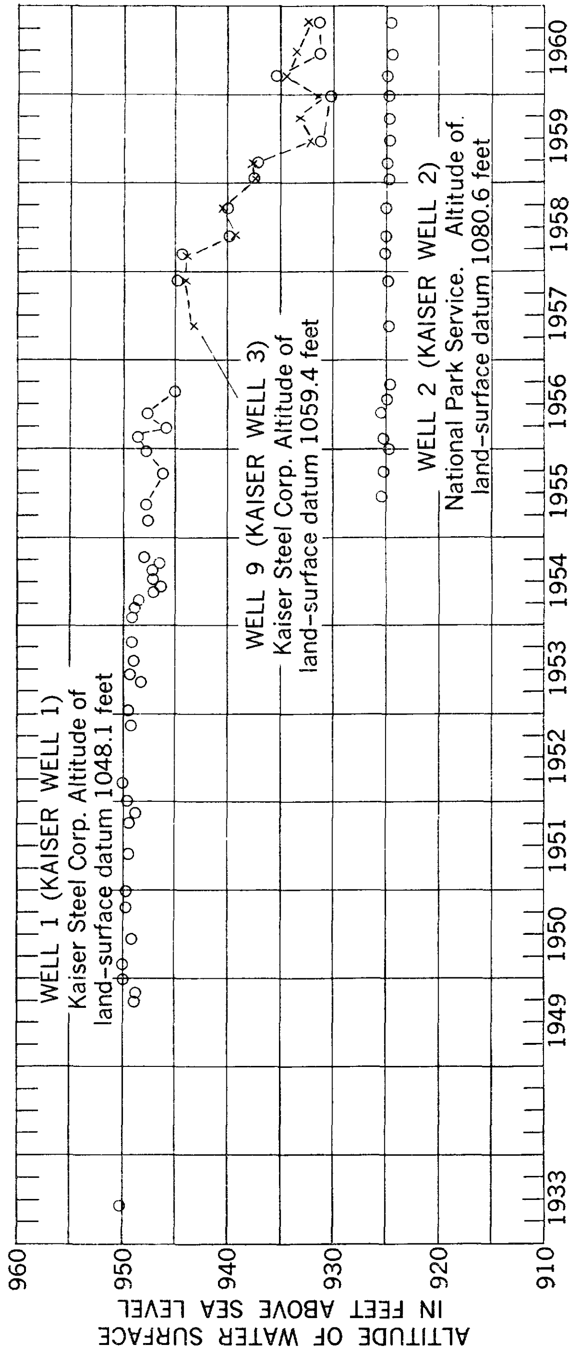


FIGURE 65.—Hydrographs of wells 1, 2, and 9 in Pinto basin, California.

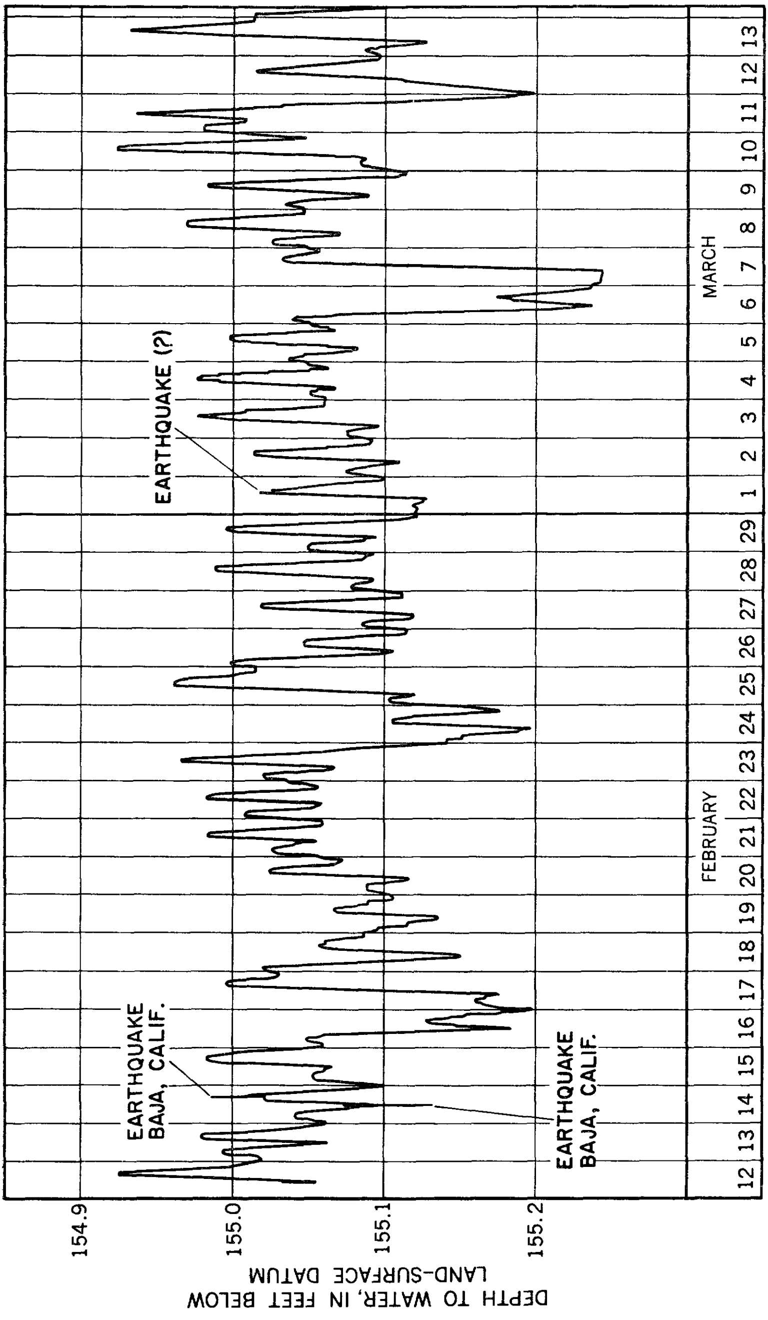


FIGURE 66.—Hydrograph of well 2 in Pinto basin for February 12–March 13, 1956.

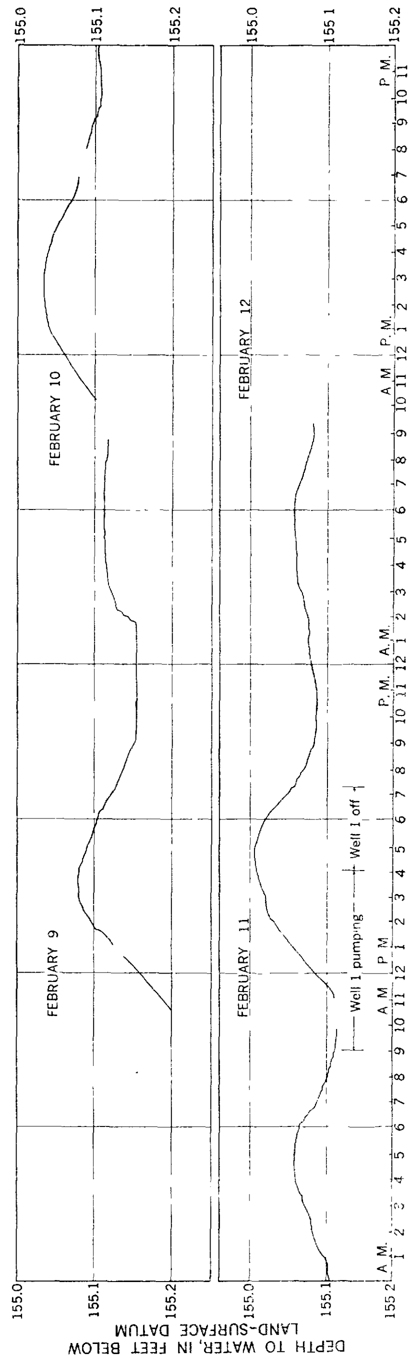


FIGURE 67.—Hydrograph of well 2 in Pinto basin for February 9-12, 1956.

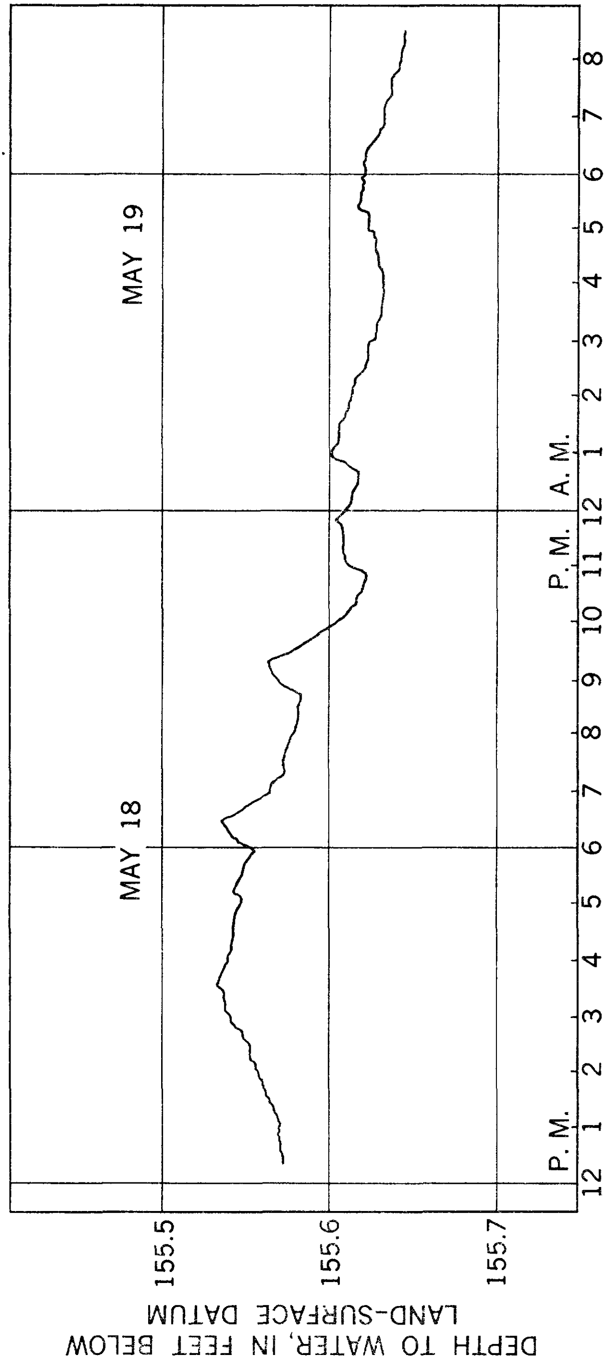


FIGURE 68.—Hydrograph of well 2 in Pinto basin for May 18-19, 1957.

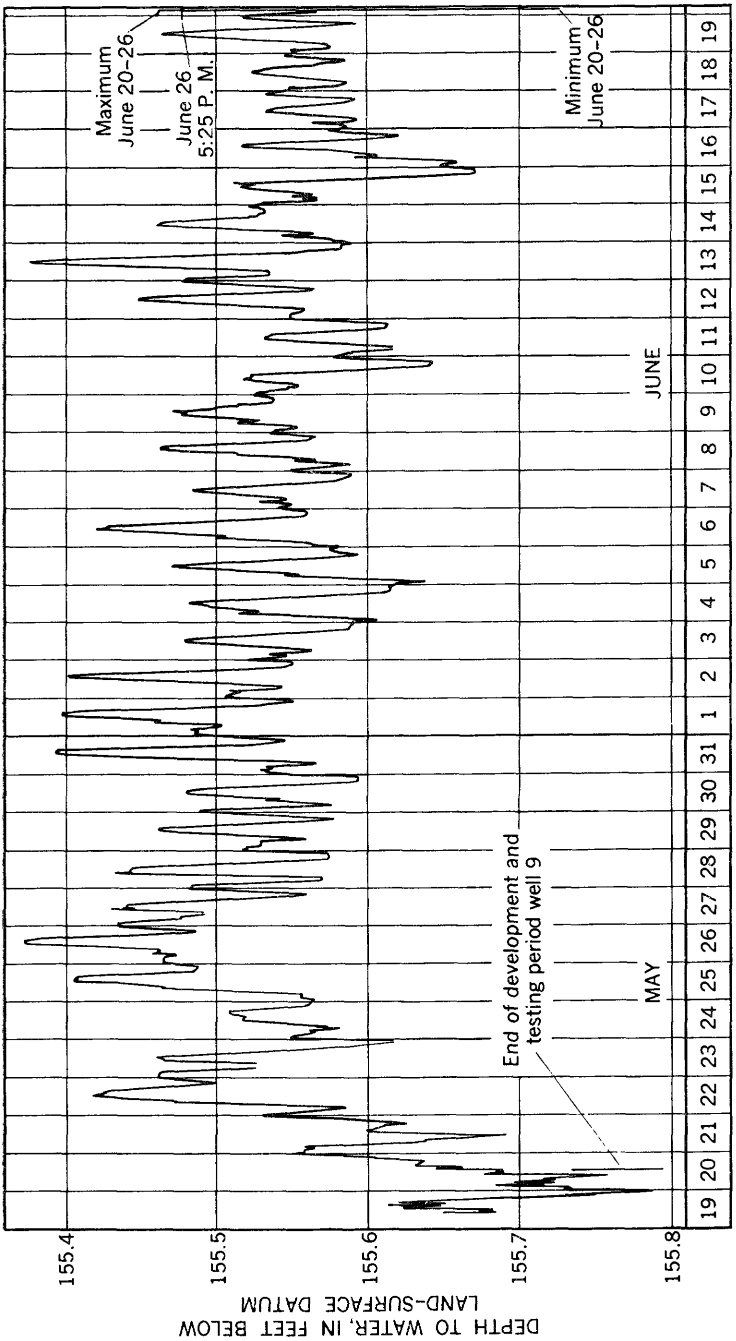


FIGURE 69.—Hydrograph of well 2 in Pinto basin for May 19–June 26, 1957.

water level in well 2 before pumping began. However, figure 68 shows a water-level decline of about 0.15 foot for the period of record. Figure 69 shows a recovery of water level of about 0.2 foot caused by the cessation of pumping of well 9, and a daily fluctuation of about 0.15 foot caused by changes in atmospheric pressure.

PUMPAGE

Records of ground-water pumpage from wells in Pinto basin are not complete, but in 1955–56 only wells 1, 3, and 7 (table 3) were equipped with pumps. During 1955 well 2 was pumped for a development test, but the pump was removed after the test. In May 1957 the Kaiser Steel Corp. completed well 9 and installed a 75-horsepower pump. Except for wells 1 and 9, the total pumpage from wells in Pinto basin has been very small, probably only a few acre-feet per year. Records of pumpage from well 1 for 1952–59 and from well 9 for 1956–59 were contributed for this study by the Kaiser Steel Corp. and are given in table 6.

PERENNIAL YIELD

The perennial yield of a ground-water basin may be defined as the rate at which ground water can be withdrawn year after year without depleting the ground-water storage to the extent that withdrawal at the given rate becomes physically impossible to maintain or is no longer feasible because of excessive pumping costs or deterioration of water quality.

Perennial yield theoretically can be determined by several methods if sufficient data are available. However, in an area such as Pinto basin, where virtually no quantitative hydrologic data are available, the perennial yield might be estimated by a series of aquifer tests in test wells drilled across the lower end of the basin. If a sufficient number of these tests can be made, it is theoretically possible to determine the long-term ground-water underflow moving through the basin. The value determined for the long-term ground-water underflow is equal to the long-term ground-water recharge. This quantity, less any unrecoverable subsurface outflow, is equal to the perennial yield of Pinto basin.

To estimate the ground-water underflow near the downstream (east) end of the basin, from six to eight deep test wells would be needed: (1) to determine the hydraulic gradient and shape of the water table; (2) to ascertain the character and thickness of the water-bearing materials; and (3) to determine the transmissibility of the deposits by means of aquifer tests. To avoid complications in the aquifer tests, it is essential that the tests be made at the sites of wells 1 mile or more upstream (generally northwest) from wells 1 and 9 and the nearby area of complex geology.

TABLE 6.—*Pumpage from wells in the Pinto basin by the Kaiser Steel Corp. for the calendar years 1952-59*

[Metered in gallons by Kaiser Steel Corp. except as indicated]

	1952	1953	1954	1955	1956	1957	1958	1959
January	1,915,700	2,745,624	4,693,830	[1] 8,000,000	7,336,750	10,690,040	36,455,100	40,000,000
February	2,179,436	3,141,180	[1] 5,000,000	[1] 7,000,000	9,523,000	9,655,520	29,039,550	39,739,588
March	2,381,092	4,490,723	[1] 5,500,000	6,764,280	9,867,800	9,700,000	38,358,253	47,293,000
April	2,373,336	2,668,064	6,034,197	6,607,440	10,012,700	10,345,200	37,120,890	43,345,000
May	3,049,108	[1] 3,800,000	7,666,723	7,242,000	16,775,500	10,780,000	41,490,107	46,310,800
June	[1] 3,800,000	4,827,738	10,030,310	9,300,100	9,916,700	10,455,000	40,500,400	50,528,400
July	4,630,332	4,847,620	7,939,670	10,326,500	11,897,000	11,134,300	46,029,916	54,312,500
August	4,793,208	5,685,418	8,907,000	12,925,900	13,968,000	26,950,000	45,545,080	48,903,400
September	4,622,576	5,578,526	8,724,830	11,405,818	13,724,000	28,350,000	46,029,916	47,180,000
October	4,300,000	6,341,786	8,183,370	9,367,682	12,141,000	27,875,200	64,135,001	47,153,100
November	4,297,000	4,513,400	[1] 8,000,000	9,310,000	11,085,000	26,064,860	59,997,259	48,068,000
December	3,017,000	3,927,808	[1] 8,000,000	8,428,000	9,664,000	30,879,200	63,100,566	[1] 45,000,000
Total (gal) [2]	41,400,000	52,600,000	88,600,000	107,000,000	136,000,000	213,000,000	548,000,000	558,000,000
Total (ac-ft) [3]	130	160	270	330	420	650	1,700	1,700

[1] Meter not in operation: quantity estimated by Kaiser Steel Corp.
[2] Rounded to three significant figures.
[3] Rounded to two significant figures.

The cost for the construction and development of deep test wells for the aquifer tests and for the report probably would be several tens of thousands of dollars and would result in considerable local damage to the natural state of the Joshua Tree National Monument. Furthermore, in nearly all desert ground-water basins where the recharge is very low in relation to the quantity of ground-water in storage and where it is virtually impossible to induce additional ground-water recharge or intercept more than a small part of the natural ground-water discharge, the concept of perennial yield is not meaningful. In most desert basins an attempt to limit ground-water development to a mythical perennial-yield determination does not allow full utilization of the important natural resource of ground-water in storage.

GROUND-WATER STORAGE CAPACITY

Ground-water storage capacity may be defined as the reservoir space contained in a given volume of deposits. The storage capacity is estimated by use of the following equation:

$$\text{Storage capacity} = \text{Area} \times \text{Thickness} \times \text{Specific yield}$$

in which storage capacity is in acre-feet, area is the selected surface area measured in acres, thickness is the selected depth zone of saturated deposits measured in feet, and specific yield of the deposits is a percentage. Specific yield of a rock or deposit was defined by Meinzer (1923) as:

> the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. This ratio is stated as a percentage and may be expressed by the formula $Y=100\left(\frac{y}{V}\right)$, in which Y is the specific yield, y is the volume of gravity ground water in the rock or soil, and V is the volume of the rock or soil.

In Pinto basin the ground-water storage capacity has been estimated for the ground-water storage unit shown on plate 28, which includes an area of about 36 square miles or 23,000 acres. The thickness of the depth zone is taken as the interval from the water table to a depth of 100 feet below the water table. It is unlikely that the depth to water anywhere in this unit exceeds 300 feet. Therefore, if the water in these deposits could be pumped for some beneficial use, the dewatering of the deposits probably is feasible.

Data in Pinto basin are insufficient to estimate the specific yield of the deposits, but, based on work by the Geological Survey in similar desert areas and in part on an analysis of the drillers' logs, a specific yield of 10 percent has been estimated. Therefore the quantity of water in storage in the Pinto basin storage unit (pl. 28) for a depth of 100 feet below the water table can be estimated as follows:

$$\text{Storage capacity} = 23{,}000 \text{ acres} \times 100 \text{ feet} \times 0.10$$
$$= \text{roughly } 230{,}000 \text{ acre-feet}$$

To demonstrate the magnitude of this storage capacity, assume that all natural recharge and discharge were halted and that it would be economically feasible to pump 2,000 acre-feet per year from storage in the Pinto basin, an amount slightly greater than the present use or maximum future pumpage estimated by the Kaiser Steel Corp. Under these circumstances, it would be possible to pump water at this rate for more than a century. This use of the water would not disturb the ecologic balance in the basin because the water in the storage unit is too deep for use by plants.

The estimate of the length of time necessary to deplete the storage unit probably is conservative because no allowance has been made for additions to the reservoir from recharge, salvaged discharge, or for the large quantity of ground water stored in the alluvium outside the storage unit. This presentation is not intended as a recommendation that Pinto basin be dewatered. It is intended to emphasize that the quantity of water pumped at the lower end of Pinto basin is exceedingly small compared to the total amount of ground water in storage.

RELATION OF STORAGE CAPACITY TO PERENNIAL YIELD

In a ground-water system under natural conditions prior to development, a dynamic balance is established between natural recharge and discharge. Over long periods, the change in ground-water storage is virtually zero, and recharge and discharge are equal. Pumping ground water upsets this balance, and some water must be taken from storage and some decline in water levels must occur. If the pumping rate exceeds the perennial yield (recharge less unrecoverable natural discharge) the water levels will decline and continue to decline as long as this rate is maintained. Eventually it would become impractical to pump water at this rate because of decreased well yields or increased pumping costs resulting from greater pumping lifts.

If ground-water pumpage in Pinto basin is equal to or less than perennial yield, the subsurface outflow plus pumpage at first will exceed perennial yield, and ground water will be withdrawn from storage. However, if pumpage is held approximately constant and does not exceed the perennial yield, a new dynamic balance eventually will be established, and pumpage plus a reduced rate of subsurface outflow across the barrier will equal recharge. Under some circumstances, although not in Pinto basin, an increase in recharge may balance a part of this pumpage so that not all of it need result in a reduction in natural discharge.

Thus it follows that a water-level decline of a few feet or few tens of feet in wells 1 and 9 is not a cause for concern. In order for water to flow toward a well, the water level in the well must be lower than it is in the surrounding material. By artificially lowering the water level at a well by pumping, ground water is induced to move toward the well. If the water level is not artificially lowered by pumping, ground water in the Pinto basin will continue to discharge by subsurface outflow to the next ground-water basin downstream, where the water occurs at greater depths, is of poorer quality, and is virtually undeveloped.

The critical point is whether or not, after the initial decline of water levels due to development of a well field, water levels stabilize or recover after a pumping season or after several pumping seasons during a series of dry years. Figure 65 shows that from 1933 through February 1956 the water level in well 1 declined about 2.5 feet. From February 1956 through October 1960, water levels in wells 1 and 9 declined about 14 feet. Pumping has not been continued for a long enough period to determine whether water levels will stabilize at or near these levels. However, compared to the amount of ground water in storage it does not seem probable that continued pumping at the present rate in Pinto basin is cause for concern. If measurements of water levels are continued in wells 1, 2, and 9, any critical overdraft can be readily anticipated and preventive measures taken.

REFERENCES

Campbell, E. W. C., and Campbell, W. H., 1935, The Pinto basin site: Southwest Museum Papers no. 9 Highland Park, Calif., p. 21–51.

Harder, E. C., 1912, Iron ore deposits of the Eagle Mountains: U.S. Geol. Survey Bull. 503, 81 p.

Jenkins, O. P., 1938, Geologic map of California: California Div. Mines.

Meinzer, O. E., 1923, Outline of ground-water hydrology with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Scharf, David, 1935, The Quarternary history of Pinto basin: Southwest Museum Papers no. 9. Higland Park, Calif., p. 11–20.

U.S. Navy, Bureau of Medicine, November 29, 1957, Instruction 11330.1A.

U.S. Public Health Service, 1946, Public Health Repts., v. 61, no. 11, 14 p.

Wiscox, L. V., 1948, The quality of water for irrigation use: U.S. Dept. Agriculture Tech. Bull. 962, 40 p.

U.S. GOVERNMENT PRINTING OFFICE: 1963