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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

A GEOHYDROLOGIC RECONNAISSANCE OF THE SARATOGA SPRING AREA, DEATH VALLEY NATIONAL MONUMENT, CALIFORNIA

Prepared in cooperation with the
National Park Service
U.S. Department of the Interior

OPEN-FILE REPORT

Menlo Park, California
1966

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Fred Kunkel

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A GEOHYDROLOGIC RECONNAISSANCE OF THE SARATOGA SPRING AREA,

DEATH VALLEY NATIONAL MONUMENT, CALIFORNIA

By Fred Kunkel

ABSTRACT

Saratoga Spring, at the south end of Death Valley National Monument, is one of the largest springs in the Mojave Desert region. The mountains in the area of the spring consist of highly fractured metasedimentary rocks intruded by sills of dense, highly fractured basic volcanic rocks. The orifice of the spring occurs in the fractured rocks and is associated with a contact zone at the base of one of the intruded volcanic sills.

The water from the spring has a temperature of 83°F and contains about 3,100 parts per million of dissolved solids, is high in sodium and chloride, and does not meet the drinking-water standards of the U.S. Public Health Service.

The principal occurrence of ground water is in the alluvium of the valley areas. Whether the water that emerges from the spring is derived from the alluvium or from some independent source is uncertain. However, a working hypothesis considers that some of the water in the alluvium moves through the fractured rocks to a contact metamorphic zone in those rocks. Because the contact metamorphic zone is relatively unfractured, the water is forced to a spill level or discharge point.

Because the water at Saratoga Spring is not potable and because extensive development probably would upset the natural ecologic balance of the area, no well drilling or testing in the immediate vicinity of the spring is proposed. However, to test for a possible alternate source of water, bail testing and sampling of the water for chemical analysis at an existing well in sec. 19, T. 19 N., R. 6 E., is proposed.

INTRODUCTION

Purpose and Scope

To assist in the development of water supplies for camping areas and public-service facilities, the U.S. Geological Survey, at the request of the Park Service, made a geologic reconnaissance in December 1964 of the Saratoga Spring area (figs. 1 and 2) in Death Valley National Monument.

The purpose of this report is to furnish information concerning the probable water supply of the area. The scope is (1) to provide a brief description of the geology of the area as it relates to ground water and (2) to make proposals for well drilling and testing.

Previous Work

Reports of previous hydrologic work in the Saratoga Spring area are limited to:(1) A quantitative description of the area by Thompson (1929, p. 586-588), (2) several administrative reports by the Park Service, (3) an estimate of the flow of the spring by Robinson (1957), and (4) chemical analyses of water by Scott and Barker (1962, p. 26-27) and by the California Department of Public Health (written commun., 1962).

Because the report by Thompson (1929) has been out of print several years and because his lucid description of the area is as applicable today as it was in 1917-18, pages 586-588 of his report are quoted directly in "Location and General Features" and in other sections of this report. Also, a chemical analysis of water from Saratoga Spring from Thompson (1929, p. 598) is given in table 1 of this report.

Because the report by Robinson (1957) was typewritten and does not duplicate the scope of this study, it is reproduced in its entirety as an appendix to this report.

The chemical analyses of water by Scott and Barker (1962, p. 27) and the California Department of Public Health (written commun., 1962) are given in table 1.

According to Thompson (1929, p. 586-587):

"Saratoga Springs are among the largest springs in the Mohave Desert region. They have long been a noted camping place for desert travelers. Picture writings on the south face of a rock hill a few hundred feet to the southeast show that the springs were important in the life of the desert Indian prior to the coming of the white man.

"The springs, four in number, are in the NW¼ sec. 2., T. 18 N., R. 5 E., on the northwest side of a low rock hill that forms the south end of a ridge that extends southward from the Ibex Mountains (also called Black Mountain). A road formerly led past the springs up the east side of Death Valley for a short distance and thence across the Ibex Mountains to Zabriskie. The road north of the springs is generally impassable for automobiles, and they are now reached only by a branch road that turns off from the Silver Lake-Owl Holes road about 2 miles south of the springs. The road to the springs skirts the south side of the rock hill. Near the west end of the hill tules, or 'Indian sugar cane,' and salt grass on the south side of the road suggest that water is near the surface, but the presence of the springs is not suspected until a northward turn in the road around the hill brings the main spring into sight. An old road leads directly west across the valley flat to the Silver Lake-Owl Holes road up the west side of Death Valley near the Saratoga niter hills. This road is likely to be treacherous in places, and although it saves several miles it should be avoided.

"The principal spring forms a large pool about 30 feet in diameter and 4 feet deep. The bottom is covered with sand, which is agitated by water bubbling up through it. An overflow of at least some tens of gallons a minute escapes through a channel to a pond several hundred feet to the north. Farther north are two or three other ponds that cover an aggregate area of several hundred square feet. The other three springs are much smaller than the one just described. One is a few feet east of the main spring. Another is 150 feet or more east of the main spring, close to the base of the rock hill. The fourth spring, which was not seen by the writer but is shown on a sketch map of the area around the springs which was made by Hoyt S. Gale, is near the base of the hills about 700 feet northeast of the main spring. The spring is said to be poisonous and when visited by Mr. Gale in May 1918 was walled up."

From Saratoga Spring north to the Superior Mine (fig. 2) the mountains consist of a series of highly fractured metasedimentary rocks intruded by sills of dense, but also highly fractured, basic volcanic rock. The Ibex Mountains, about 3 miles east of Saratoga Spring, also are composed of a similar sequence of rocks.

The dense basic volcanic rocks that compose the water-bearing unit at Saratoga Spring have been identified by Scott and Barker (1962, p. 25) as faulted quartz diorite of the Pahrump Series of Precambrian age. Also, locally in the mountain range north of Saratoga Spring and in the Ibex Mountains, some of the rocks are shown as Cambrian(?) in age by the California Division of Mines and Geology (1963).

North and east of Saratoga Spring the consolidated rocks strike from about N. 7° E. to N. 15° E. and dip about 45°E. Extending north and northeast from a point about a quarter of a mile north of Saratoga Spring to the Saratoga, Whitecap, and Superior Mines is a prominent zone of contact metamorphism. This zone, above an intrusive sill at the base of a metasedimentary sequence, has been altered to talc. The talc is a soft foliated rock which, compared to other consolidated rocks, is relatively unfractured. Because the talc is relatively unfractured, it will not transmit water as readily as the more fractured rocks. The same contact metamorphic zone occurs stratigraphically about 10 or 12 feet above the orifice of Saratoga Spring. However, detailed inspection of the area showed no alteration of the zone to talc.

The valley areas near Saratoga Spring, comprising the alluvial fans and flood plains of the Amargosa River and its tributaries, are underlain by alluvium of Quaternary age. The alluvium, consisting of lenticular deposits of clay, silt, sand, and gravel, is of unknown thickness, but on the basis of known geology in similar environments probably ranges in thickness from a featheredge along the margins of the deposits to about 200 feet, or perhaps more than 1,000 feet, in the deeper parts of the valley areas.

Due west of the Ibex Mountains several square miles of area are covered with magnificent dunes of windblown sand. The thickness of the sand deposits has not been measured, but field inspection and inspection of the topographic map of the area suggest a maximum thickness of 100 to 200 feet.

With reference to the quality of water, Thompson (1929, p. 587-588) states:

"The water from the springs has a peculiar, unsatisfying taste that is neither especially bitter nor salty. This taste is probably due to a fortuitous combination of certain proportions of sodium sulfate and sodium chloride in such a way as to disguise the characteristic tastes of those substances. The water from the large spring has a stronger taste than that from the two small springs, and water for drinking is generally obtained from the smaller springs. An analysis of a sample from the first spring east of the main spring shows that the water is highly mineralized and contains 3,100 parts per million of total solids. It is high in sodium sulfate and rather high in chloride. The water is of poor quality for domestic use, but members of the Geological Survey have camped at the springs for several weeks and have used it regularly for drinking without serious effects.

"The water from all the springs is warm. The temperature of the large spring appears to be rather uniform within about 1°, for several observations by the writer and others reported to him by Hoyt S. Gale showed readings between 82° and 83°F. The temperature of the water in the small pools that have little or no outflow may be subject to more variation. The large spring with its abundant supply of warm water makes an inviting bathing pool at all seasons."

Four complete chemical analyses of water from Saratoga Spring are given in table 1. The earliest analysis was made from water collected in 1917; the most recent, from water collected December 31, 1964. These analyses show virtually no change in chemical quality or temperature for the period of record. The analyses also show that the dissolved-solids content of the water is several times greater than that allowed by the drinking-water standards of the U.S. Public Health Service (1962, p. 7). Therefore, even though the oldtime Geological Survey field crews drank the water from the spring for several weeks without ill effects, the water is not considered suitable for domestic use.

Date of collection	Water temperature (°F)	… as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Laboratory and laboratory number or source of data
U.S. Public Health S… drinking-water sta…							
Sept. 8, 1917	83	25	--	--	--	--	Thompson (1929, p. 588)
Dec. 22, 1955	--	22	--	--	4,640	8.1	Scott and Barker (1962, p. 27)
Sept. 2, 1963	--	22	--	--	--	8.0	CDPH-6400
Dec. 31, 1964	83	28	0	89	4,680	7.9	USGS-48214

a. Sodium and

b. The limits… U.S. Public Health Service (1962, p. 8).

Table 1.--Chemical analyses of water from Saratoga Spring

($18N/5E-2E1$; 35°41'48" N., 116°25'36" W.)

Laboratory: CDPH California Department of Public Health; USGS U.S. Geological Survey

Date of collection	Water temperature (°F)	Values in parts per million																	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Laboratory and laboratory number or source of data
															Dissolved solids							
		Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Calculated (Sum of determined constituents)	Residue on evaporation at 180°C	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$				
U.S. Public Health Service drinking-water standards (1962)			0.3							250	250	(b)	45		500	500						
Sept. 8, 1917	83	70	0.17	31	36	a994	--	410	22	1,040	657	--	1.7	--	--	3,100	225	--	--	--	--	Thompson (1929, p. 588)
Dec. 22, 1955	--	44	.03	33	34	970	30	420	0	1,040	680	2.2	4.7	--	--	3,080	222	--	--	4,640	8.1	Scott and Barker (1962, p. 27)
Sept. 2, 1963	--	--	0	35	33	955	32	406	--	1,050	647	3.9	2.7	--	3,100	--	222	--	--	--	8.0	CDPH-6400
Dec. 31, 1964	83	41	0	34	35	990	32	416	0	1,040	690	3.1	5.1	9.6	3,080	--	228	0	89	4,680	7.9	USGS-48214

a. Sodium and potassium, calculated.

b. The limits for fluoride concentration are controlled by the average of maximum daily air temperatures, as shown in the following table by the U.S. Public Health Service (1962, p. 8).

Annual average of maximum daily air temperatures[1]	Recommended control limits fluoride concentration in mg/l		
	Lower	Optimum	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	.8	1.1	1.5
58.4-63.8	.8	1.0	1.3
63.9-70.6	.7	.9	1.2
70.7-79.2	.7	.8	1.0
79.3-90.5	.6	.7	.8

[1]Based on temperature data obtained for a minimum of 5 years.

GROUND WATER

Occurrence

Two sites, about 500 and 1,000 feet south of the Superior Mine, shown on figure 2 as "water" are large tanks for the storage of hauled water. In December 1964 the area was deserted and the tanks were dry. A third site, about a mile east of the Superior Mine in the SW¼ sec. 19, T. 19 N., R. 6 E., shown as "water" is a drilled well. In December 1964 the well, 8 inches in diameter, was capped and its depth could not be measured. However, sounding the well with a thin steel tape through a small slot in the casing showed that the well was dry to a depth of 200 feet below the top of the casing. Whether or not the well was deeper than 200 feet or contained water at a depth greater than 200 feet is not known.

With reference to the occurrence of ground water, Thompson (1929, p. 586) states:

"The channels of Amargosa River are dry for most of the time. Near Saratoga Springs and for about 10 miles southeast and probably also for most of its course northwest of the springs, ground water is evidently near the surface, as is shown by the presence of patches of salt grass and mesquite and of alkali on the surface, which in other parts of the Mohave Desert region generally indicate that the depth of the water table is less than 10 feet. It is believed that an abundance of water could be obtained from dug or drilled wells on the flat land along the channels of Amargosa River, but there is little question that the water is of poor quality. The water that is found in places in the river canyon above Sperry is reported to be salty. Water from a salt spring in or near sec. 30, T. 18 N., R. 7 E., in a tributary channel to the river from the southeast, is highly mineralized, containing 5,380 parts per million of total solids, most of which was ordinary salt. The water elsewhere along the river is probably about as highly mineralized, if not more so."

Source and Movement

Thompson (1929, p. 588) states:

> "The presence of salt grass and tules shows that ground water is near the surface over a large area on the valley flat near the springs. Whether the water that emerges in the springs is derived from this body of ground water, which may be considered underflow of Amargosa River, or whether it comes from some independent source is uncertain. The situation of the springs, especially the three smaller ones, in relation to the nearby rock hills, which have been faulted, and the warmness of the water suggest that the water may rise along fractures in the rock."

Scott and Barker (1962, p. 25) suggest that the probable source of the water for Saratoga Spring is deeply circulating meteoric water.

Observations and conclusions in this report, based on the reconnaissance of December 1964, are in substantial agreement with Thompson (1929, p. 586-588) and Scott and Barker (1962, p. 25). Additional observations during this reconnaissance study are not adequate to describe fully or demonstrate the hydrology of the area. They do, however, provide an adequate basis for a working hypothesis regarding the source, occurrence, and movement of ground water in the Saratoga Spring area.

A Working Hypothesis

The ultimate source of all the ground water in the area, including Saratoga Spring, is considered to be precipitation within the tributary areas. Even though the total dissolved-solids content of the water of Saratoga Spring is several times that of the acceptable limits of potability and even though the water temperature of 83°F undoubtedly is several degrees above the mean annual air temperature of the region, nothing in the chemical quality or temperature suggests other than a meteoric source for the water. Both the dissolved-solids content and the temperature can be easily accounted for by the circulation of meteoric water to depths of only a few hundred feet below land surface.

Though the data in the area are not conclusive, hydrologic principles and experience in similar areas support the conclusion that the principal movement of ground water in the area is from southeast to northwest in the alluvium beneath the Amargosa River (fig. 2). Also, ground water moves from the tributary area north of the Amargosa River generally south or southwesterly through the alluvium toward the river, and some also probably moves through the fractured consolidated rocks toward Saratoga Spring.

The quantity of ground water moving through the fractured consolidated rocks, relative to the quantity moving through the alluvium, probably is small. Also, much, or perhaps most, of the ground water moving through the fractured consolidated rocks, upon encountering relatively unfractured talc of the contact metamorphic zone, would rise to a spill level or discharge point. Saratoga Spring is considered a discharge point in this hypothesis. Whether or not spill occurs at a level lower in altitude than Saratoga Spring cannot be demonstrated by this study. However, the measured flow of about 13,000 to 22,000 gallons per day at the developed orifice of Saratoga Spring (Robinson, 1957, p. 9) is insufficient to maintain the total evapotranspiration of about 200 acre-feet per year for the entire spring area (Robinson, 1957, p. 17). Accordingly, some leakage or spill in addition to the measured discharge must occur.

According to T. W. Robinson (written commun., April 27, 1965), there is an unmeasured flow from numerous small springs and seeps at about the same altitude as the developed orifice. In addition, discharge occurs from the pond below the developed spring shown by Robinson (1957, fig. 1A). According to Robinson (written commun., April 27, 1965), measurement of the quantity of discharge from the pond was not possible because of the vegetation. However, with the exception of a small quantity (probably about 10 percent of the total) along the south side of the ridge south of the spring, the visible evidence for discharge is a narrow strip of phreatophytes starting at the pond and continuing northeast for about 800 feet.

Other working hypotheses might be considered. For example, one might consider that ground water rises along a north-trending fault at or a few hundred feet west of Saratoga Spring. However, the same general conditions, as described herein, would prevail with regard to the remainder of the area and would not affect the testing and drilling program suggested in the following section.

PROPOSED DRILLING AND TESTING

To determine if water of potable quality and in sufficient quantity for Park Service needs occurs in the area of Saratoga Spring, it is suggested that the Park Service arrange to test pump or bail test and collect a sample of water for chemical analysis from the well in the SW¼ sec. 19, T. 19 N., R. 6 E.

If potable water can be pumped from the well or if the well is dry, further testing or drilling in the area to the south should be considered. Any site south of section 19 will probably have a shallower water table, but as one moves south the quality of the water can be expected to be increasingly saline. If the water from the well is nonpotable,[1] further testing or drilling in the area to the south nearer Saratoga Spring is not suggested. However, test drilling about 3 miles south of Saratoga Spring would have merit. Any convenient site in sections 23 and 24 in the vicinity of BM 343 (fig. 1), at an altitude of about 300 feet, is suggested. Water, if present, might be of better quality than that along the Amargosa River and could be supplied to Saratoga Spring by gravity flow in a pipeline.

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[1]On May 12, 1965, the well was bailed and sounded to determine its depth. The well was 268 feet deep. The depth to water was 256.25 feet below the top of the casing. A brief partial chemical analysis indicated a chloride content of 785 ppm (parts per million), a conductivity of 5,800 micromhos, a hardness of 153 ppm, and a pH of 8.2. Because the water is not potable, no further drilling or testing in the area is suggested. As an alternative, the Park Service should consider using nonpotable water for sanitary facilities and for

irrigation of plants having a high salt tolerance. To provide drinking water that meets U.S. Public Health Service standards, the quality of the nonpotable water would have to be improved by desalination.

No drilling or testing is suggested in the immediate area of Saratoga Spring. First, because the quality of the water developed probably would not meet U.S. Public Health Service standards; and, second, because the Saratoga Spring area is a unique climax ecologic community. In particular, Saratoga Spring is the only known habitat of *Cyprinodon nevadensis nevadensis*, a subspecies of the rare[1/] desert-dwelling pupfish. Any change in the regimen of the spring or uncontrolled activity of man in this area probably would upset the delicate ecologic balance and nullify the principal reason the Park Service wishes to preserve the area.

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1. The Park Service estimates the total population of this subspecies is about 700 individuals.

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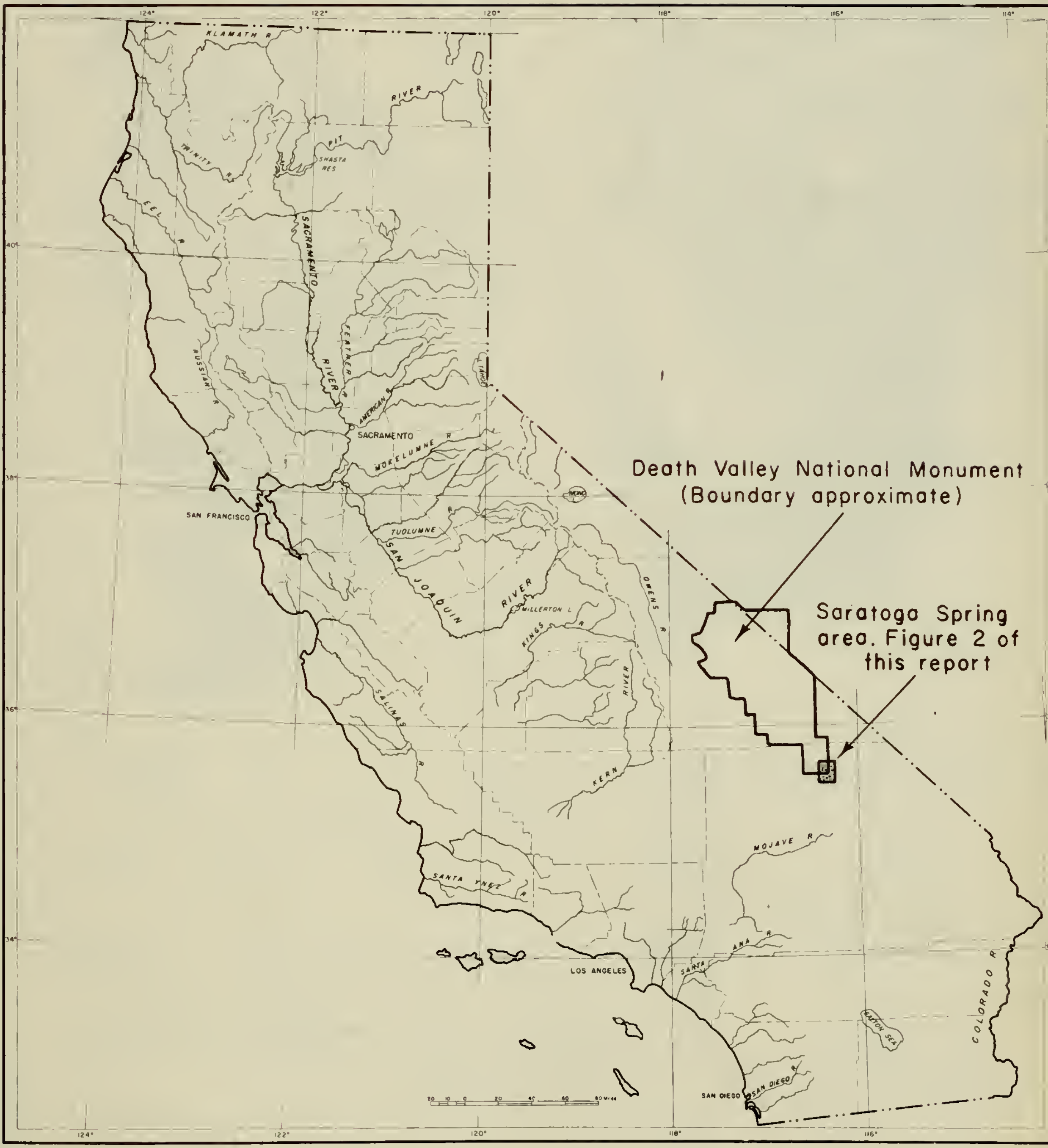
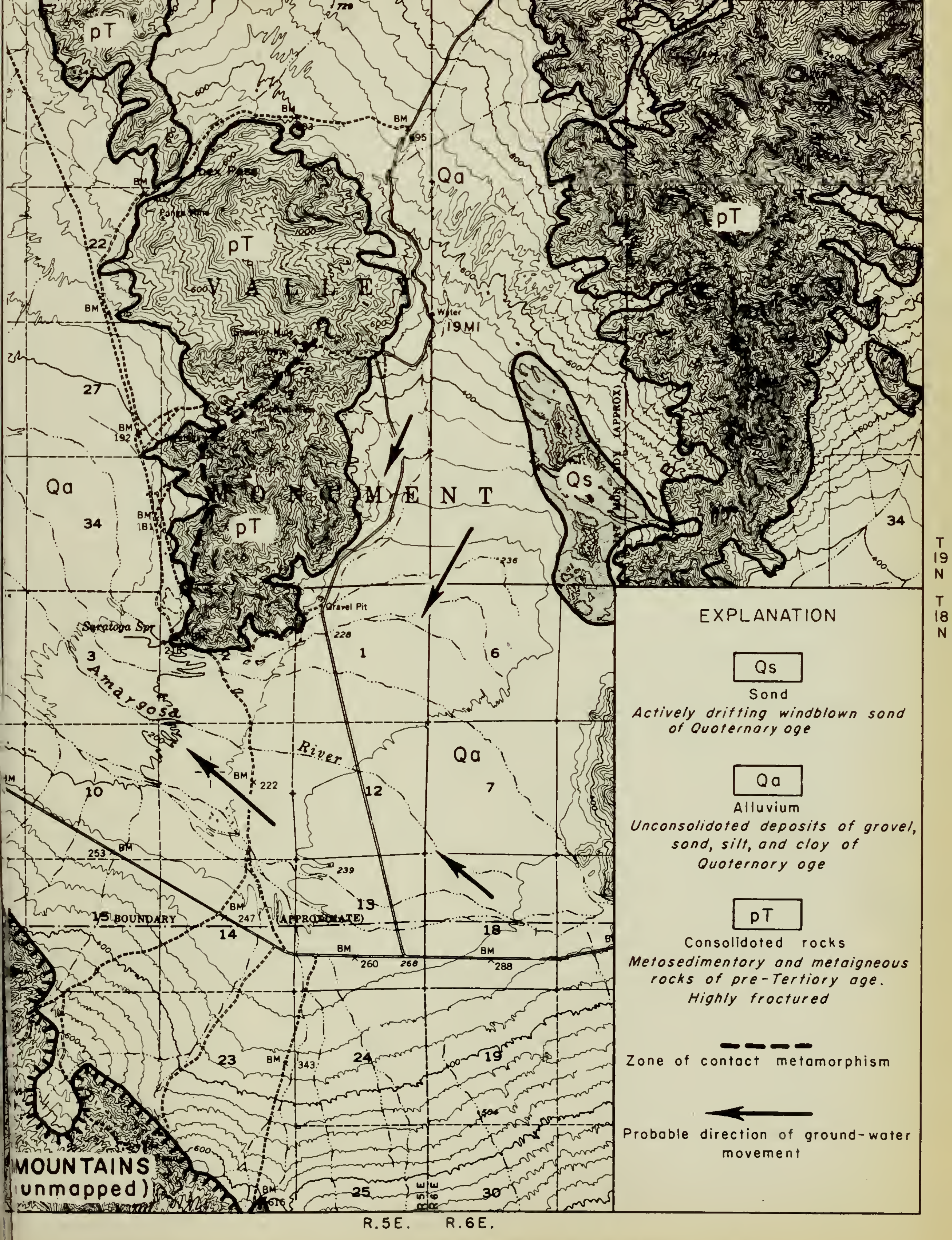


INDEX MAP OF CALIFORNIA



GEOLOGIC MAP OF THE SARATOGA SPRING AREA

APPENDIX

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

DETERMINATION OF THE FLOW OF SARATOGA SPRING IN DEATH VALLEY NATIONAL MONUMENT, CALIFORNIA

By

T. W. Robinson

Prepared in cooperation with the
National Park Service

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ILLUSTRATIONS

DETERMINATION OF THE FLOW OF SARATOGA SPRING IN DEATH VALLEY NATIONAL MONUMENT, CALIFORNIA

By T. W. Robinson

INTRODUCTION

In connection with condemnation of a tract of land including Saratoga Spring, the National Park Service requested that the writer make a determination of the flow of the spring. The request was made by A. van V. Dunn, Chief, Water Resources Section, National Park Service, in a letter dated April 22, 1957, to Dr. John C. Reed, Staff Coordinator, Geological Survey. Approval of the request was contained in a reply by the Staff Coordinator to the Chief, Water Resources Section, dated May 10, 1957.

DESCRIPTION OF SPRING AND HISTORY OF INVESTIGATION

Saratoga Spring is in the NW$\frac{1}{4}$ sec. 2, T. 18 N., R. 5 E., San Bernardino base and meridian, at the south end of Death Valley and on the north edge of the Amargosa River flood plain. The altitude of the spring is about 200 feet above sea level. The spring consists of a main orifice and many small seeps, some concealed, some visible. The main orifice and seeps occur along the base of a rock ridge that extends west from the south end of a much larger, north-south-trending rock mass. Although water emerges on both sides of the rock ridge, by far the greater part emerges on the north side. The main orifice is on the north side near the west end of the ridge. Here a short tunnel has been dug into the rocky base of the ridge, and the water collected in a concrete trough. Water is discharged from the trough through six circular orifices on the north side near the top, and flows into a pool about 20 feet in diameter and about 10 feet deep, some 25 feet west. A small spring house encloses the tunnel entrance and concrete collecting trough.

The discharge from the springs is sufficient to maintain a combined water-surface area and vegetated area of water-loving plants of nearly 23 acres. It is not possible to measure the flow of the spring directly, so its flow must be arrived at indirectly by determining the combined discharge from the water-surface area and vegetated area.

Such a determination was made by Mr. Dunn in the fall of 1952. On October 25 of that year he made a stadia survey of the spring area from which he prepared a map showing the water-surface and vegetated areas. Later, in November, he prepared a report entitled "Water Resources on Saratoga Springs Tract, Death Valley National Monument," in which he estimated the flow of the spring. This report was later sent to the writer for review and comment. The results of the review are contained in a letter dated March 16, 1955, to Mr. B. F. Manbey, Regional Chief of Lands, National Park Service.

METHOD OF INVESTIGATION

A field investigation of the springs and associated water-surface and vegetated areas was made on June 12, 1957, by the writer assisted by Messrs. Robert Sellers, Joe Rockwell, and Linn Spaulding of the National Park Service. In the course of the investigation nine test holes were bored to determine the depth to the water table, the water-surface and vegetated areas were mapped, and the flow of the developed spring at the spring house was measured. In mapping the water-surface and vegetated areas, the map prepared by Mr. Dunn in 1952 was used as the base.

It was apparent, from an inspection of the spring discharge area, that the largest water losses occurred from the open water surface and the areas of dense reed growth in which the water stood from half a foot below to somewhat above the land surface. These areas constitute nearly 70 percent of the discharge area, and from them about 88 percent of the annual discharge of water occurs. (See beyond.)

The vegetated areas were mapped according to species or associated species of plants, and water level. In most of the area the water level ranged from at or above the surface to 2 feet below the surface. Numerous small holes were dug with a shovel to determine the water level. Most of the vegetated area was mapped according to the following three positions of the water level: at or above the land surface, between the land surface and a depth of 0.5 foot, and between depths of 0.5 foot and 2.0 feet. Two parcels, in which the depth to water was greater, were mapped separately.

In mapping the vegetated areas, the density of plant growth was considered. With the exception of that in five parcels, all the vegetation was estimated as having a growth density of 100 percent. The density in these parcels, two of saltgrass, one of reeds, rushes, and saltgrass, and two of saltgrass, weeds, and mixed grasses ranged from 50 to 75 percent (see map). In all, 25 parcels, including the free water surface, were mapped and are shown in color on the accompanying map. These 25 parcels were grouped into 11 categories. The categories and area of each are given in the following table.

Category	Depth to water (feet)	Area (acres)
Open water surface	-	6.80
Reeds, large; water level at or above land surface	0	6.65
Reeds, large	0.0 - 0.5	2.49
Saltgrass	.0 - .5	1.09
Saltgrass	.5 - 2.0	.75
Saltgrass, 75-percent density	.5 - 2.0	.38
Saltgrass, 50-percent density	.5 - 2.0	1.92
Reeds, rushes, and saltgrass	2.0 - 4.0	.38
Saltgrass, weeds, and mixed grasses	.5 - 3.0	2.21
Saltcedar (athel trees)	-	.17
Bare ground (seep area) [a]	-	.14
Total		22.98

a/ In this parcel, upward-seeping spring water was discharged by evaporation from the wetted soil surface.

The location of the test holes, with notations as to the depth to the water level in each, also is shown on the map.

The discharge of the developed spring was measured volumetrically using a 5.4-gallon container and a stopwatch. It was not possible to measure the discharge through all six orifices in the concrete trough at one time, but it was possible to measure the discharge by pairs of orifices. Following is a record of the measurement made at 12:30 p.m. on June 12, 1957:

Orifice	Time required to fill 5.4-gallon container (seconds)		Discharge (gallons a minute)
Two east orifices	90		3.6
Two middle orifices	112		2.9
Two west orifices	132		2.5
		Total	9.0

This rate is equivalent to a discharge of 12,960 gallons a day. It is considerably less than the 21,450 gallons a day obtained in the measurement by Hopper and Wakefield on May 27, 1951, or the 21,750 gallons a day measured by Mr. Dunn on October 25, 1952, as noted in Mr. Dunn's report. The decrease in flow of about 60 percent may be due to the drought that has persisted in this area for the past several years, or it may be due to the use of water by the phreatophytes at the spring, particularly the large saltcedars (*Tamarix aphylla*). These trees are high water users, the use being greatest at midday when the air temperature is highest, and least in the early morning. As the measurement was made at 12:30 p.m., it is possible that draft by the saltcedars may have reduced the flow. The effect of use by the saltcedar trees on the flow of the spring could be determined by periodic measurements of the spring flow over a 24-hour period.

UNIT VALUES OF EVAPOTRANSPIRATION

In estimating the annual discharge of the spring the acreage in each of the categories of use was multiplied by a unit value of evaporation or transpiration for that category. The unit values are based on the best available information that would be applicable to the Saratoga Spring area. In selecting the values, consideration was given not only to data for other localities in the Southwest but also to the high temperature and low humidity that prevail in this part of Death Valley. Both these factors are conducive to high rates of evaporation and transpiration. The unit values of evapotranspiration for each of the categories will be discussed separately in the following pages.

Open water surface.--The annual rate of evaporation is estimated as 120 inches a year. This estimate is based on records of pan evaporation at Silver Lake, Calif., about 30 miles south and some 800 feet higher in altitude. In connection with a study to determine coefficients for converting pan evaporation to lake evaporation, pan-evaporation data were collected from May 1938 to April 1939 at a Class A Weather Bureau evaporation station (Blaney, 1957). The pan evaporation during this period was 130.58 inches. During the same period, the evaporation from Silver Lake, a body of water about 7 miles long and 3 miles wide, having a maximum depth of 7 feet, was 79.46 inches. The evaporation from the pan is believed to be more nearly comparable with the evaporation of the open water at

Saratoga Spring than that from Silver Lake. The open water surface at Saratoga Spring totals 6.8 acres and has a length of about 700 feet and a width of about 500 feet. In addition, it is quite shallow, the maximum depth being estimated as 2.5 feet and the average about 1.5 feet. The high water level is believed to be about 1 foot above the water level on June 12, 1957, as indicated by the watermark on a post at the water's edge on the west side of the pond, shown on the accompanying photo. The post is about 100 feet east of the clump of saltcedar. The depth of the water in the pond was estimated as 1.0 to 1.5 feet at the time.

Mr. Dunn in his report used a coefficient of 0.85 to correct pan evaporation to evaporation from the open water surface. This was based on the recommendation of Mr. W. B. Langbein, of the Geological Survey, as a result of his study of stock-watering ponds. However, the conditions of high temperature, low humidity, and shallow depth of water at the pond favor a higher rate of evaporation than that from stock-water ponds in general. For this reason, the correct coefficient is believed to be nearer 0.90 percent.

The evaporation during the period of record at Silver Lake, May 1938 through April 1939, probably represents fairly well the long-term average. This is shown by comparison of the long-term average of three evaporation stations in the Southwest, as shown in the following table.

Station	Long-term normal (inches)	1938-39 (inches)	Departure (percent)
Bachus Ranch, Calif.	116.6	121.3	+ 4.0
Boulder City, Nev.	120.3	120.2	- .1
Yuma Citrus Station, Arizona	115.4	115.2	- .2

On the basis of a coefficient of 0.90 and the pan evaporation of 130.58 inches at Silver Lake, the annual evaporation from the open pond at Saratoga Springs is computed as 117.5 inches, and rounded off to 120 inches.

Reeds, large, water level at or above land surface.--The vegetation in this category is almost entirely the common reed Phragmites communis, often referred to in the Southwest as carrizo. It was growing very luxuriantly and ranged in height from 5 to 8 feet. In some places, the growth was so dense that the stems would support the weight of a man.

There are no data on the use of water by Phragmites in the Southwest, so far as the writer is aware. However, there are data on tules and cattails, which are similar in habitat and, it is believed, in water use, at several places in the Southwest. As temperature is the most important climatological factor affecting transpiration, the mean monthly temperature records of all localities, where water-use data were available for tules and cattails. were examined. On this basis, the locality most nearly comparable was Mesilla Dam, N. Mex., where,on the average, the temperature (Fahrenheit)was about 14° less than that computed for Saratoga Spring.

The mean monthly temperature for Saratoga Spring was computed by correcting the temperature at Silver Lake for the period May 1938 through April 1939, for departure from normal, on the basis of the long-term record at Greenland Ranch in Death Valley, and using the average of the two localities. The computed mean monthly temperatures for Saratoga Spring are given below in degrees F.:

January	50	July	98
February	55	August	96
March	63	September	88
April	70	October	72
May	82	November	58
June	89	December	50

The use of water, by Phragmites, was computed for Saratoga Spring on the basis of the data for Mesilla Dam, N. Mex., using the Blaney-Criddle method. In this method, the differences in temperature and in daylight hours at the two localities are taken into account. On this basis, the annual use of water was computed as 156 inches or 13 feet for these plants when the water level is at or above the land surface.

Reeds, large, depth to water 0 to 0.5 foot.--In this category, the common reed is the dominant vegetation, although some associated rushes also were included. However, they were neither as tall nor as luxuriant as in the parcels where the water level was at or above the land surface. The difference in density of growth was greater than was the difference in height. The density ranged from about 50 percent to about 75 percent, and averaged about 67 percent of that of the category just discussed. Using the density of growth as a guide, the annual use of water by the reeds in this category was estimated as two-thirds of 156 inches. This amounts to 104 inches or 8-2/3 feet a year.

Saltgrass, depth to water 0 to 0.5 foot.--The saltgrass in this category occurred for the most part on land adjacent to the water in the pond. It was dense and luxuriant. The use of water was estimated from a graph prepared by the writer (Robinson, 1957, in press), which shows the relation of evapotranspiration by saltgrass, grown in tanks, to depth to water table and the average temperature during the growing season. On the basis of this chart, the use of water for this category was estimated as 6.5 feet a year.

Saltgrass, depth to water 0.5 to 2.0 feet.--The saltgrass in this category was not as luxuriant as that just described, but was still considered to have a growth density of 100 percent. On the basis of the greater depth to water, the use was estimated from the graph as 5.5 feet a year.

Saltgrass, depth to water 0 to 2.0 feet, density of growth 75 percent.--The use of water by saltgrass in this category was taken from the graph, and on the basis of density reduced to about 75 percent of that for a 100-percent growth density. The use was estimated as 4.0 feet a year.

Saltgrass, depth to water 0 to 2.0 feet, density of growth 50 percent.--The use here was estimated as 50 percent of that for 100-percent growth density for the same depth to water, or 2.75 feet a year. In a small part of this parcel, the depth to water was greater than 2 feet.

Reeds, rushes, and saltgrass.--This was an association of the common reed, *Phragmites communis*, the rush *Juncus cooperi*, and saltgrass, *Distichlis stricta*. The area occupied by the association was on the slope of the rock point. Several trenches had been dug to develop small seeps, in the bottom of a few of which water was observed. The depth to water, estimated from the trenches, ranged from 2 to 4 feet. The plant growth was spotty, ranging from dense to sparse. The range in density and in depth to water made it difficult to estimate water use; however, it is believed to be about equal to use by saltgrass of 75-percent density with a depth of water of .5-2.0 feet. On this basis, the use is estimated as 4 feet a year.

Saltgrass, weeds, and mixed grasses.--In these two parcels, the depth to the water was from land surface to 3 feet. The average depth to water appeared to be about 2.5 feet. The color of the vegetation for the most part was brown, rather than green, and did not give the impression that much water was being transpired. Mr. Dunn, in page 9 of his report, refers to the area as "lacking almost all the green color of life." Some water is probably discharged by evapotranspiration but the amount is small. The use for this category is estimated as 1 foot a year.

Saltcedar.--The use of water by the two small clumps of *Tamarix aphylla* was estimated on the basis of temperature and studies in the Safford Valley, Ariz., as about 8 feet a year (Gatewood, Robinson, Colby, and others, 1950).

Bare ground, seep area.--In this parcel of land, water seeping from the hillside kept the land surface moist. The loss by evaporation was estimated on the basis of soil evaporation as reported by Lee (1912) in Owens Valley, Calif. The loss by evaporation from two tanks, in which the average water level was 1.34 and 1.94 feet below the surface, was 3.59 and 3.56 feet respectively. On this basis, the evaporation for the parcel was estimated as 3.5 feet a year.

Using the unit values for evapotranspiration just described and the acreage for each category, the following table was prepared to show the estimated annual use of water, by categories, and for the area of discharge as a whole.

Category	Area (acres)	Annual rate of use (acre-feet per acre)	Annual use (acre-feet per year)
Open water surface	6.80	10	68.0
Reeds, large, water level at or above land surface	6.65	13	86.5
Reeds, large, depth to water level 0-0.5 foot	2.49	8.67	21.6
Saltgrass, depth to water 0-0.5 foot	1.09	6.5	7.1
Saltgrass, depth to water 0.5-2 feet	.75	5.5	4.1
Saltgrass, depth to water 0.5-2 feet, density 75 percent	.38	4.0	1.5
Saltgrass, depth to water 0.5-2 feet, density 50 percent	1.92	2.75	5.3
Reeds, rushes, and saltgrass	.38	4.0	1.5
Saltgrass, weeds, and mixed grasses	2.21	1.0	2.2
Saltcedar	.17	8.0	1.4
Bare ground, seep area	.14	3.5	.5
Totals	22.98 Say, 23		199.7 Say, 200

SEEPAGE LOSS

In the course of the field examination, the possibility of discharge of water underground by seepage from the spring or discharge area was given consideration. Any seepage likely is toward the west, for only in that direction does the land surface slope away from the area. The two test holes indicate that the water-bearing material to the west is fine grained, largely a mixture of clay and sand. The permeability of this type of material is low and movement through it would be quite slow. The vegetation west of the mapped area, largely saltgrass with an occasional clump of rushes, was sparse and did not indicate a plentiful supply of water. On the basis of these observations, it is believed that there is little seepage loss from the spring or discharge area.

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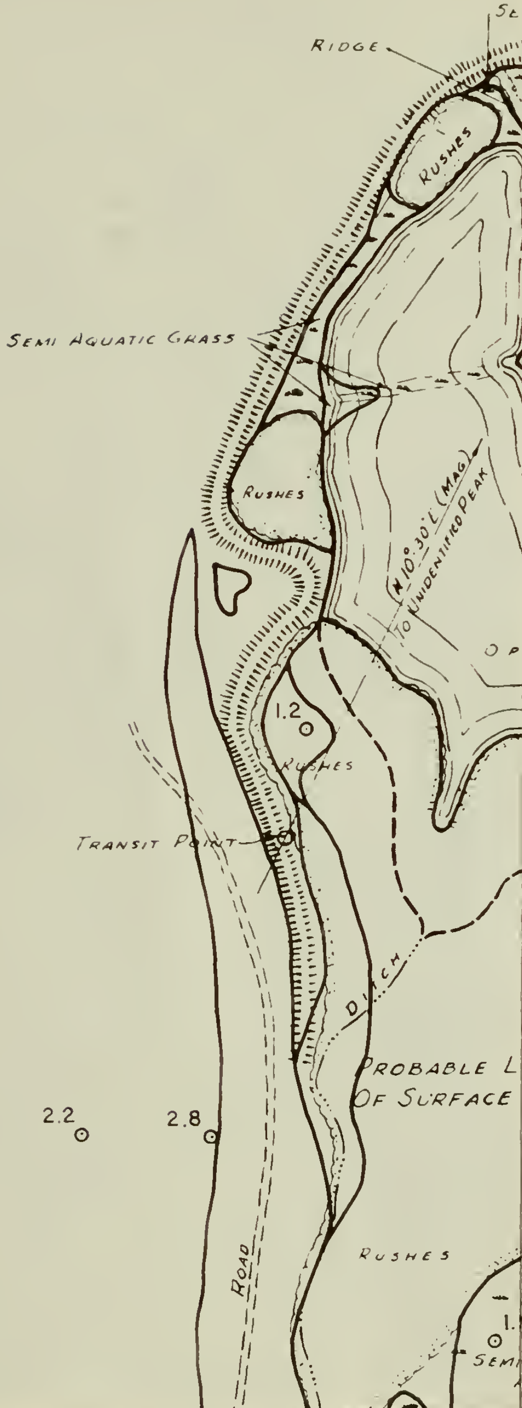


LANATION

pen water

eeds, large
r above land surface

eeds, large
2ft below land surface

Saltgrass
2ft below land surface

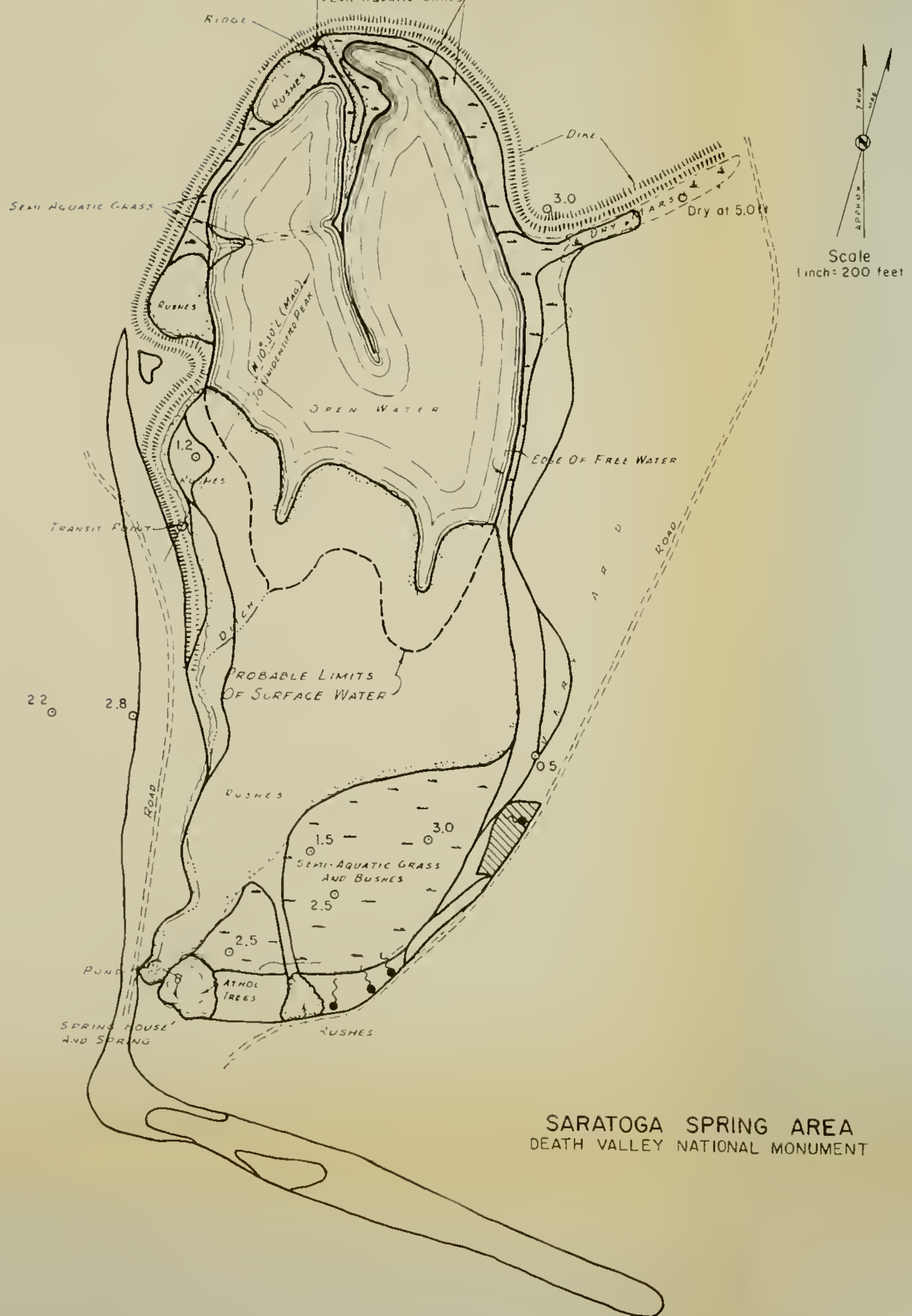
Saltgrass
2ft below land surface

hes, and saltgrass

, and mixed grasses

Saltcedar

ound, seep area



Open water

Reeds, large
Water level at or above land surface

Reeds, large
Water level 0-1/2 ft below land surface

Saltgrass
Water level 0-1/2 ft below land surface

Saltgrass
Water level 1/2-2 ft below land surface

Reeds, rushes, and saltgrass

Saltgrass, weeds, and mixed grasses

Saltcedar

Bare ground, seep area

Spring orifice

2.2
Test hole
Figure is depth to water, in feet below land surface

SARATOGA SPRING AREA
DEATH VALLEY NATIONAL MONUMENT

Base map from Park Service drawing $\frac{NM-DV}{6969}$, Region 4, October 26, 1952

Distribution of phreatophytes by Robinson, 1952