Geology and Hydrology of Agua Caliente Spring Palm Springs, California

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1605

Prepared in cooperation with the U.S. Bureau of Indian Affairs

Dutcher and Bader—GEOLOGY AND HYDROLOGY OF AGUA CALIENTE SPRING, CALIF.—Geological Survey Water-Supply Paper 1605

Geology and Hydrology of Agua Caliente Spring Palm Springs, California

By L. C. DUTCHER *and* J. S. BADER

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1605

Prepared in cooperation with the U.S. Bureau of Indian Affairs

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library catalog card for this publication appears after page 43.

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

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND HYDROLOGY OF AGUA CALIENTE SPRING, PALM SPRINGS, CALIFORNIA

By L. C. Dutcher and J. S. Bader

ABSTRACT

Agua Caliente Spring, on land belonging to the tribe of Agua Caliente Indians, flows from a low mound that rises only a few feet above the nearly featureless alluvial plain of Coachella Valley. The temperature of the water is about 107° F, and the total flow is about 25 gpm (gallons per minute).

Near the spring the granitic rocks of the basement complex that are exposed in the San Jacinto Mountains just to the west are moderately to highly fractured. The evidence indicates that precipitation on the mountains to the west is the source of the water discharged at the spring.

Deep water wells have been drilled on all sides of the spring. These wells penetrate more than 600 feet of unconsolidated alluvial deposits that contain the main ground-water body of the region. The top of the zone of saturation in the main ground-water body, however, is nearly 200 feet lower than the altitude of the spring discharge.

The fine-grained deposits of the spring mound contain ground water that is in hydraulic continuity with the water in the orifice of the spring; continuity was determined by observing water-level declines in the shallow wells when the spring was pumped.

The chemical quality of the spring water is greatly different from the chemical quality of the water pumped from nearby deep wells, which obtain their supply from permeable alluvial deposits which, near the site of the spring, probably are at least 630 feet thick. The deep ground water is of the calcium bicarbonate type, has low dissolved-solids content, and is soft to moderately hard. The spring water is of the sodium bicarbonate type, of relatively low mineral content and very soft. The water is for the most part typical of slightly mineralized meteoric water that gets underground and is heated in contact with granite and chemically similar rocks.

The construction work at the spring included the drilling of 11 shallow test wells into the spring mound and the excavation of a hole about 40 feet in diameter and 12 feet deep at the orifice of the spring. A steel water-collector tank 20 feet in diameter and 10 feet deep was installed in the hole and covered after the work was finished.

Two distinct types of spring-mound deposits were exposed during the excavation. The deposits consist mainly of dark greenish-gray clayey sandy silt, called the peripheral deposits, because they surround the active spring orifice and extend to the periphery of the spring mound. The central part of the deposits of the spring mound includes light-gray silty fine sand which occurs in irregularly shaped almost vertical conduits through which the spring water rises to the surface. These are called orifice deposits and are surrounded laterally by the peripheral deposits. The orifice deposits have a field coefficient of permeability of about 140 gpd per

sq ft (gallons per day per square foot) and the peripheral deposits have a field coefficient of permeability of only about 0.7 gpd per sq ft, according to laboratory tests.

The geologic and hydrologic setting of the spring, although probably not unique, is very interesting and well documented by ground-water data. The orifice and peripheral spring deposits probably were progressively washed to the surface by thermal spring water rising through the alluvial deposits. The finer grained parts of the alluvium may have been the source of most of the deposits of the spring mound, but part may have been derived from fine materials in fractures in the crystalline rocks which underlie the alluvium or from material blown into the spring area.

However, mechanical analyses and microscopic examination suggest that virtually none of the deposits are windblown sand. It is thought that fine silty sand was carried to the surface by the hot-spring water and, during the Recent epoch at least, accumulated at a rate sufficient to maintain a low mound that probably was constantly higher than the surrounding surface of the alluvial fan. The finer deposits were washed to the margin of the spring mound where they formed an effective chimney of very low permeability around the vertical conduits of permeable washed sand through which the water rose to the surface. No evidence of a calcareous or other cemented chimney surrounding the spring orifice was observed during the extensive excavation to a depth of 12 feet at the site, but cementation may occur at depth.

So far as could be determined by measurement, the construction work at the spring did not increase or decrease the discharge of the spring.

It seems possible that pumping a deep well drilled near the spring orifice might salvage considerable water. Some water probably percolates laterally to the regional ground-water body and is thus not recovered by the water-collector tank at the spring orifice.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report summarizes the findings of an investigation of Agua Caliente Spring and the general geologic and hydrologic conditions of the area near the spring at Palm Springs, Calif. The land upon which the spring is located is owned by the tribe of Agua Caliente Indians and is held in trust by the U.S. Bureau of Indian Affairs. Consequently, the investigation and report were financed under an agreement with the Bureau.

The general objectives and related problems of the investigation were to determine the possible means and methods whereby it might be possible to (1) Increase the spring flow; (2) salvage the entire flow of the spring by preventing seepage from the spring and water collector beneath nearby Indian Avenue; (3) provide a means whereby a central pump could be used to provide water to the spa under pressure; (4) prevent silt, dirt, and debris from mixing with the spring water; and (5) provide a central water-collecting system of sufficient reservoir capacity to provide an adequate supply of spring water to the bathhouse during short periods of peak demand in excess of the natural flow of the spring.

In May 1958 the U.S. Geological Survey was requested by the Bureau of Indian Affairs to assist in technical aspects of the planning for the new facilities at the spring and to offer continuing advice to the Bureau after the construction began. Specifically, the Geological Survey was requested to make an investigation of the spring area, as follows:

1. Review all proposals for construction at or near the spring and provide a geologist to act as technical adviser during all periods of construction that might affect the flow of the spring.
2. Provide technical assistance during the construction of shallow observation wells and measuring devices needed for collecting data during construction at the spring; make measurements of water levels in observation wells; make periodic measurement of the spring discharge; and supply other geologic and hydrologic data, should the construction work at the site indicate a need for additional information.
3. Prepare a report summarizing the geologic and hydrologic findings of the investigation, the construction work and facilities installed at the spring, and the effect of the work on the spring.

Before July 1958, several conferences were held among the representatives of the Bureau of Indian Affairs and the Geological Survey to discuss the proposed plans for constructing a water collector in the spring orifice. Because of the lack of information concerning the origin of the spring and the possibility that excavating at the orifice might impair the flow, cause the spring to shift position, or cause it to escape laterally at depth, it was decided to construct a large caisson or open-end tank that could be lowered into the spring orifice to a depth of about 10 feet. It was decided to place properly sized gravel in the bottom of the tank to prevent the pumping of silt when a pump is ultimately installed in the tank. It was emphasized also that great care should be taken during the excavation of the hole for the tank so as not to affect the flow or position of the spring and to preserve what was believed to be a cemented impermeable chimney surrounding the spring orifice.

The fieldwork was begun in June 1958 and completed in May 1959. Before the start of the construction work, 11 test wells were drilled near the spring, and discharge measurements of the spring flow were recorded. While the work was in progress samples of the spring water were collected for chemical analysis, periodic water-level measurements were made in the test wells, one automatic water-level recorder was installed and operated at one of the test wells, samples of the materials composing the spring mound were collected and tests were made to determine their hydrologic character, the water levels in wells in the vicinity of the spring were measured, and a reconnaissance map showing the geologic and hydrologic features of the area was prepared.

This study was made under the general supervision of H. D. Wilson, Jr., district engineer for California, and under the immediate supervision of Fred Kunkel, geologist in charge of the Long Beach subdistrict office.

WELL-NUMBERING SYSTEM

The well-numbering system used in the Agua Caliente Spring area conforms to that used in virtually all ground-water investigations made by the Geological Survey in California since 1940. It has been adopted as official by the California Department of Water Resources and by the California Water Pollution Control Board for use throughout the State.

Wells are assigned numbers according to their location in the rectangular system for the subdivision of public land. For example, in the number 4/4–1N1, assigned to a well shown on plate 1, the part of the number preceding the slash indicates the township (T. 4 S.), part between the slash and the hyphen indicates the range (R. 4 E.), the number between the hyphen and the letter indicates the section (sec. 1), and the letter indicates the 40-acre subdivision of the section as shown in figure 1.

Within the 40-acre tract the wells are numbered serially as indicated by the final digit. Thus, well 4/4–1N1 is the first well to be listed in the SW¼SW¼ sec. 1, T. 4 S., R. 4 E., San Bernardino base line and meridian.

LOCATION AND GENERAL FEATURES OF THE AREA

Agua Caliente Spring is at Palm Springs, Calif., in the western part of the Coachella Valley. Palm Springs is a desert-resort community at the east base of the San Jacinto Mountains in Riverside County, Calif., about 120 miles east of Los Angeles (fig. 2).

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

FIGURE 1.—Well-numbering system.

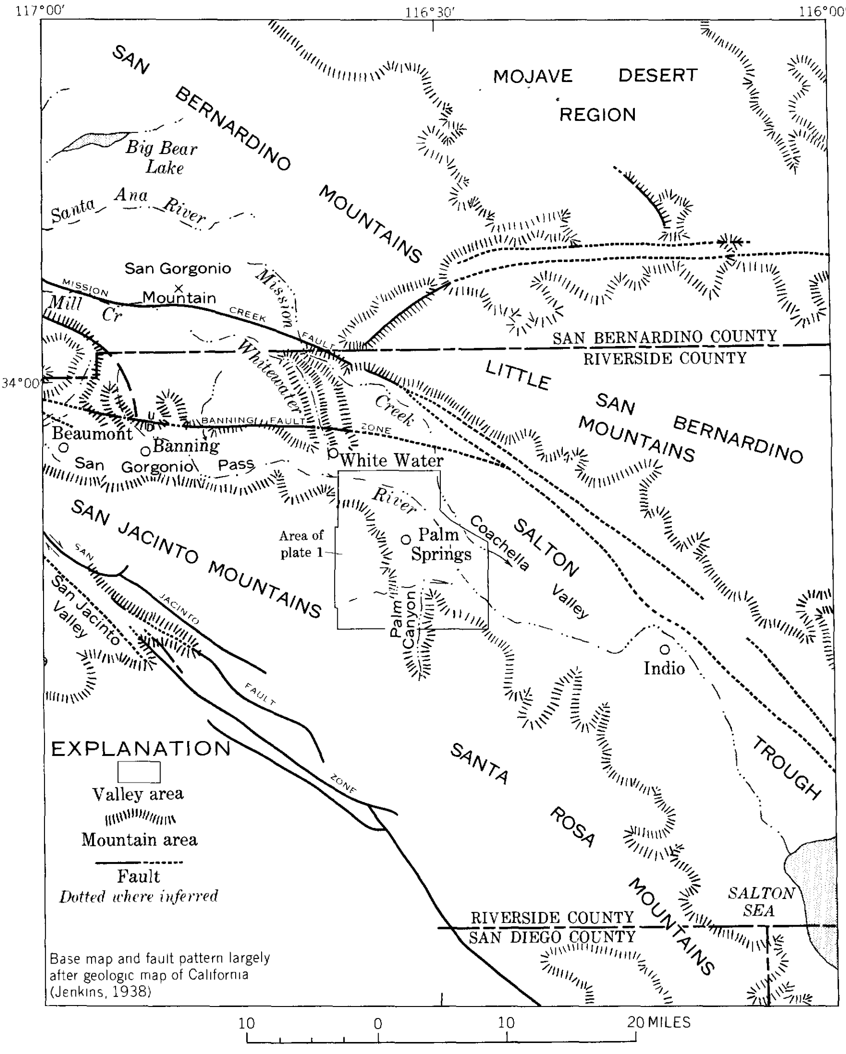


FIGURE 2.—Map of a part of southern California showing generalized geographic and geologic features.

The Agua Caliente Spring area, as considered in this report, includes part of the eastern slope of the San Jacinto Mountains and part of Coachella Valley (pl. 1). The area is shown on the U.S. Army, Corps of Engineers Palm Springs and Edom quadrangle maps (1942 and 1941, respectively), scale, 1:62,500. Access to the area is by State Route 111.

The Agua Caliente Spring area is bordered on the west by the high nearly barren San Jacinto Mountains, which have steep canyons sloping toward the floor of Coachella Valley on the east. According to Brown (1923, p. 22), some of the streams that drain the east slope of the mountains have gradients steeper than any other in the United States. Chino Canyon in the northwestern part of the area (pl. 1) has an average gradient of about 1,140 feet per mile. The small alluvial fan extending into Coachella Valley from Chino Canyon north of Palm Springs has an average surface gradient of about 500 feet per mile for a short distance downslope from the mouth of the canyon. Palm Canyon, which enters Coachella Valley from the south, however, has a much lower gradient that averages only about 80 feet per mile in the area.

The narrow steep-sided canyon of Tahquitz Creek in the San Jacinto Mountains southwest of Agua Caliente Spring is typical of the canyons carved by streams which drain the east face of the mountains west of Palm Springs. The lower reaches of the canyon cut in the consolidated rocks by Tahquitz Creek may be buried beneath alluvium which has accumulated in Coachella Valley to a depth of several hundred feet. However, the bottom of the now-buried canyon may directly underlie Agua Caliente Spring where the canyon intersects a concealed fault that probably strikes parallel to the east flank of the San Jacinto Mountains. The possible relationship of the fault and the now-buried part of Tahquitz Creek Canyon to Agua Caliente Spring is discussed in the section on the possible mode of occurrence of the spring.

OTHER INVESTIGATIONS

There are few historic data available concerning Agua Caliente Spring. Wheeler (1876), Waring (1915), and Brown (1923) made brief reference to the spring and collected samples of the water for chemical analysis. Brief memorandum reports by Garrett and Dutcher (1951), Dutcher (1953), and Poland and Dutcher (1953) describe a temporary displacement of the spring orifice when road improvements were made at the edge of the spring mound.

GEOLOGIC SETTING OF THE AREA

Agua Caliente Spring issues from a low spring mound that rises only a few feet above the surface of the southeast-sloping alluvial plain of Coachella Valley, which has a gradient of about 100 feet per mile. The alluvial plain has been built of materials which, for the most part, are highly permeable sand and gravel. These materials have been deposited principally by the Whitewater River, which drains the southeastern part of the San Bernardino Mountains; and in small part by minor streams which drain the eastern slopes of the San Jacinto Mountains.

GEOLOGIC UNITS

Because of the unusual fact that Agua Caliente Spring issues from the nearly featureless floor of the Coachella Valley through several hundred feet of highly permeable alluvial deposits, a reconnaissance geologic map of the area near the spring was prepared to show the relationship of the spring to the rocks and deposits of the area and the structural features. The geologic units of the Agua Caliente Spring area, which are shown on plate 1, have been differentiated with respect to their hydrologic properties and lithologic character.

The oldest of the geologic units is the basement complex (or bedrock) which consists of moderately to highly fractured igneous and metamorphic rocks, chiefly gneiss, schist, quartz monzonite, granite, and quartzite, which are cut by many dikes of variable composition. The rocks of the basement complex are virtually impermeable and do not contain water except in fractures. However, the rocks are intricately fractured, and thus water probably flows in the fractures from the mountains to the valley. The water in these fractures may encounter a fault zone concealed beneath the alluvium where it rises to the surface through the orifice deposits of the spring. It is probable that water flowing through the fractured rocks of the basement complex is the source of all water discharged at the spring.

Unconsolidated deposits overlie the basement complex in the Coachella Valley and tributary canyons. Downstream from the canyon mouths near the mountains, alluvial fans have been formed which commonly contain boulders as much as 15 to 20 feet in largest dimension. The largest and most conspicuous of the smaller fans that extend into the valley is downstream from the mouth of Chino Canyon (pl. 1). The bouldery fan deposits consist mainly of unsorted boulders, gravel, and sand; the materials are very poorly sorted and the bouldery fan deposits probably are unpromising sources of ground water.

Most of the central part of Coachella Valley is underlain by alluvium which consists of unconsolidated moderately permeable gravel, sand, silt, and clay (pl. 1). Characteristically, the material grades from bouldery gravel near the mountains to fine sand and silt beneath the lower reaches of the valley. The alluvium ranges in thickness from 0 at the contact with the basement complex to at least 630 feet in the area east of Agua Caliente Spring. The permeable gravel and sand of the alluvium constitutes the principal source of ground water pumped from wells in the area.

The channels of the Whitewater River and the smaller streams of the area are underlain by highly permeable sand and gravel. These deposits, subject to transport during infrequent period of large runoff, are only a few feet thick and are entirely above the water table. However, large seepage losses from the river and the minor streams occur through the channel deposits during infrequent floods.

In addition to the principal geologic units of the area shown on plate 1, the orifice and peripheral spring deposits occupy a small area near Agua Caliente Spring and presumably extend downward from land surface to the basement complex. The orifice and peripheral spring deposits were exposed during the development work at the spring and are described on pages 17 to 23.

STRUCTURE

The mode of occurrence and location of Agua Caliente Spring are probably associated with faulting in the basement complex beneath the alluvium that underlies central Coachella Valley. A fault, concealed a short distance northeast of the mountain front, probably has uplifted the mountains on the southwest in relation to Coachella Valley on the northeast (pl. 1). Brown (1923, p. 198) also postulated the existence of a fault along the east side of the mountains, and Waring (1915, p. 40) suggested that the spring is associated with a fault. However, no direct evidence of faulting can be observed near the spring, because the trace probably is concealed beneath the alluvium. The trace of the fault on plate 1 is arbitrarily shown passing through the spring a short distance east of the present mountain front.

HYDROLOGIC SETTING OF THE AREA

GROUND WATER IN THE ALLUVIUM

Data for 10 deep water wells in the vicinity of Palm Springs are given in table 1. The locations of these wells are shown on plate 1, and logs of three of the wells are given in table 2. In addition, data for 11 shallow test wells drilled in 1958 in the immediate vicinity of Agua Caliente Spring before the start of the development work at the spring are given in table 1 and the logs are given in table 2. The locations of these test wells and other test wells drilled in 1951 before the work on nearby Indian Avenue are shown on plate 2.

Except in well 4/4–15H1, the measured depth to water level in each of the deep wells shown on plate 1 is in excess of 176 feet below the surface. It was not possible to measure the depth to water in well 15H1; however, the water level is reported to be more than 150 feet below the surface. These water levels indicate that the water body in the alluvium surrounding the materials of the spring mound is more than 200 feet lower than the altitude of the spring outlet. The deep wells are west, southeast, east and northeast of the spring; the nearest, well 4/4–15H1, is only about 750 feet northwest of the spring.

The relatively great depth to water in the deep wells in the area originally led to the belief that some type of calcareous or other cemented chimney existed about the spring orifice. It was believed likely that the spring water rose to the surface though a cemented chimney that probably would be encountered during the excavation of a pit in which the water collector was to be installed at the spring. No evidence of a calcareous cemented chimney was found during the development work.

Water-level contour lines, which show the configuration of the main water table, are shown on plate 1. These contours, based on water-level measurements in wells (table 1), show that the direction of ground-water flow is southeastward down the main part of Coachella Valley north of Palm Springs and northeastward down Palm Canyon toward Palm Springs. Beneath the city, near the spring, the ground water from the two sources joins to flow generally eastward to the main part of Coachella Valley east of the Agua Caliente Spring area. The depth to ground water ranges from about 175 feet below land surface at well 4/5–19D1 southeast of the spring to more than 255 feet below land surface at well 4/4–11K1 northeast of the spring.

GROUND WATER IN THE SPRING MOUND

In 1951 the city of Palm Springs desired to widen Indian Avenue which passes very near Agua Caliente Spring. Because the proposed construction involved widening the street to within a few feet of the spring to include all the area west of the then-existing bathhouse (pl. 2), it was decided that it would be necessry to collect data on the water levels in the vicinity of the spring, and particularly on the altitude of the water levels in the materials beneath the proposed new roadbed which was designed to be several feet lower than the pool of water in the spring orifice only a few feet away. Accordingly, 18 test wells were drilled in August 1951 in the vicinity of the spring, and water-level measurements were made periodically to determine the altitude and configuration of the water body in the spring mound. Five of the test wells were drilled at considerable distance from the spring and did not reach water. Thirteen of these wells and three other wells that previously existed near the spring are shown on plate 2. The altitude of the water surface in each is given in the table below.

Data for 15 shallow wells drilled near the spring, August 1951 [1]

[All data supplied by W. P. Rowe, consulting engineer, San Bernardino, Calif.]

Well	Altitude of reference point	Date of measurement	Altitude of water surface
		1951	
4/4–14E12		Sept. 11	[1] 449.73
14E13	451.66	do	444.47
14E14	452.71	do	443.39
14E15	454.76	do	451.45
14E16	454.20	do	450.88
14E17	454.42	do	450.01
14E18	452.17	do	442.26
14E19		do	[2] 451.28
14E20	453.66	Aug. 21	452.46
14E21	456.22	Sept. 11	453.73
14E22	454.98	do	453.24
14E23	455.57	do	447.83
14E24	458.85	do	[3] 453.35
14E25	451.92	do	[3] 441.92
14E26	449.37	do	[3] 439.37
Spring		do	[4] 450.90

[1] Well formerly was used for domestic water, is presumed to be considerably deeper than test wells, and measurements were not used for drawing water-level contours.

[2] Not a test well; was existing hole beneath street used to collect water for use elsewhere on Indian-owned land.

[3] Dry at altitude indicated.

[4] Altitude of the water surface of the pool near the spring.

Water-level contours for 1951 and 1959, based on water levels in the shallow wells, are shown on plate 2. The contours show that before Indian Avenue was widened a ground-water mound extended southwest from the spring orifice to a point beneath Indian Avenue. The highest ground-water level in 1951 was 453.73 feet above sea level in well 4/4–14E21, near the east curb of the street, and about 35 feet southwest of the spring orifice. The level of the water in the pool at the orifice was about 2.8 feet lower. Presumably seepage from the main spring orifice and minor orifices in the area of the ground-water mound shown on plate 2, flowed through the fine-grained peripheral deposits and then percolated downward through the permeable sand and gravel of the alluvium to the main ground-water table more than 200 feet below.

After the new grade for the wider street was completed in 1953, a large sump was installed beneath the street from which porous drainage tiles radiated to collect the water. The sump, radiating drainage tiles, gravel pack for the tiles, and manhole at the top of the sump are shown in figure 3.

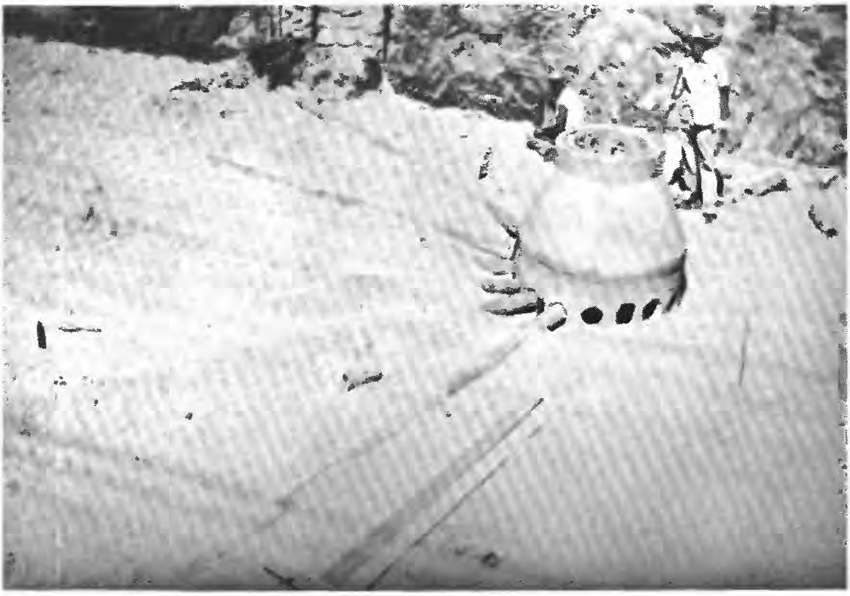


FIGURE 3.—View of the gravel-packed drainage tiles beneath Indian Avenue. The roadcut, central water collector, gravel-packed drainage tiles, and manhole that were installed as part of the water-collecting system to prevent hydrostatic uplift of the new street and to drain water to the Indian land are shown. The sandbags in the top-central part of the photograph were used to fill the large hole washed from beneath the bathhouse when pumping was temporarily interrupted and silty material flowed into the street from the spring orifice.

Figure 4 is a sketch map showing the site plan of the bathhouse, spring, existing facilities for collecting water, and the streets near the spring as they were after the roadwork in 1951 and before the development work at the spring in 1958–59.

CHEMICAL QUALITY OF GROUND AND SPRING WATER

Chemical analyses of two water samples collected from the spring and chemical analyses of ground water from three nearby water wells are given in the table on page 13.

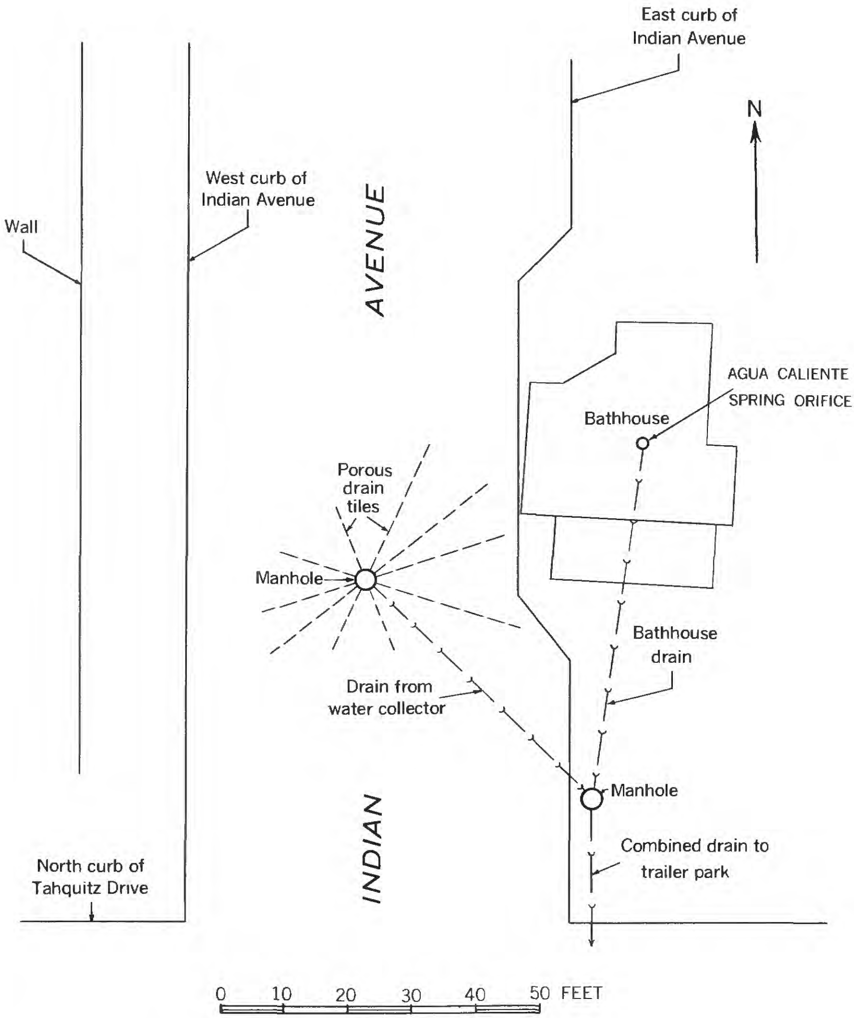


FIGURE 4.—Site plan of Agua Caliente Spring after road construction.

The chemical analyses show that the quality of the spring water is greatly different from the chemical quality of the water pumped from nearby deep wells. The analyses of the water pumped at wells 4/4–15J1 and 23E1, given in the following table, indicate that the ground water in the Agua Caliente Spring area is soft to moderately hard, has low dissolved-solids content, and is of the calcium bicarbonate or calcium sodium bicarbonate type. It is suitable for most domestic supplies, for irrigation of most crops, and for many industrial uses.

Chemical analyses of water from Agua Caliente Spring and ground water from wells, Palm Springs, Calif.

Constituents: Constituents are in parts per million (ppm) and equivalents per million (epm). Constituents shown in parentheses are calculated by the Ground Water Branch. Where the value of sodium is preceded by the letter *a*, it indicates sodium and potassium expressed as sodium. The sum of determined constituents is the arithmetic total of tabulated constituents, the bicarbonate being converted to carbonate by dividing by the factor 2.03. All values have been rounded, where necessary, to conform to the standards of the Geological Survey, Quality of Water Branch.
Analyzing laboratory: B, E. S. Babcock, Los Angeles, Calif.; *DWR,* California Department of Water Resources; *GS,* Geological Survey, Quality of Water Branch.

	4/4-15J1		4/4-23E1		Agua Caliente Spring				4/4-14E27	
	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
Silica (SiO_2)	12				41		20			
Iron (Fe)					1.5					
Calcium (Ca)	43	(2.15)	15	0.75	4.2	0.210	0	0	1.7	0.085
Magnesium (Mg)	14	(1.15)	3	.25	2.5	.206	0	0	.2	.016
Sodium (Na)	a 47	(2.04)	8	.35	68	2.957	70	3.05	72	3.132
Potassium (K)			2.3	.059	1.3	.033	.4	.01	1.4	.036
Bicarbonate (HCO_3)	268	(4.39)	76	1.24	51	.836	46	.76	56	.918
Carbonate (CO_3)	0	0	0	0	21	.700	24	.80	20	.667
Sulfate (SO_4)	32	(.67)	3	.06	36	.749	37	.78	(48)	(1.000)
Chloride (Cl)	11	(.31)	4	.11	20	.564	24	.68	24	.677
Fluoride (F)	.4	(.02)	.2	.011	2.4	.126	2.5	.13		
Nitrate (NO_3)			4.5	.072	2.5	.040	0	0	.4	.006
Boron (B)	.04	(.01)	.06		0	0	.11			
Dissolved solids			94				235			
Sum of determined constituents	(291)		(77)		225		(201)		(196)	
Hardness as $CaCO_3$	166		(50)		21		0		5	
Percent sodium (Na)	38		(25)		(98)		99+		96	
Specific conductance (micromhos at 25°C)	481		135		323		332		332	
pH			6.9		9.5		9.0		9.2	
Temperature (°F)			60		108		105		89	
Date collected	1951		6-15-54		10-28-53		6-15-58		10-28-53	
Depth of well, in feet	438		488							
Analyzing laboratory	B		DWR		GS		DWR		GS	
Laboratory No	510420H		4354		9419		9339		9449	

654098 O—62——2

The analysis of the sample collected from the spring during October 1953 indicates that the water was soft (hardness, 21 ppm). The analysis of the sample collected during June 1958 indicates that the water contained no calcium or magnesium and a zero hardness. However, the complete lack of calcium and magnesium indicated by the analysis may be somewhat misleading.

The spring water is soft, has relatively low dissolved-solids content, and, except for relatively high fluoride content of 2.4 to 2.5 ppm and a slight odor of hydrogen sulfide gas, is suitable for many uses. The average water temperature is 107° F and, for this reason, is greatly prized for its reported therapeutic value and for bathing.

The chemical quality of the spring water is characterized by high pH, high percent sodium, high temperature, and relatively high fluoride. The water is for the most part typical of slightly mineralized meteoric water that gets underground and is heated in contact with granite and chemically similar rocks. The water probably has circulated to considerable depth and has caused some hydrolysis of the silicate minerals with which it has come in contact. This causes a rise in pH, changes the carbonate equilibrium, and results in precipitation of calcium and magnesium. Because of the latter, some leaching of fluoride usually occurs. This is indicated by the fluoride content of 2.4 to 2.5 ppm.

DESCRIPTION OF THE SPRING BEFORE 1958

Before the first use of the spring water by man, it is probable that a desert oasis existed at the site in which palm trees, saltgrass, and other vegetation grew in profusion. No record is available of man's first use of the spring, but it is reported that the Agua Caliente Tribe has attached great significance to the spring since the earliest history of the area. The date of the first commercial use of the spring water for hot "mineral baths" and related uses is not recorded. Many structures had been built at or near the spring orifice during the long period of use before 1958. During 1951 (Garrett and Dutcher, 1951) a substantial bathhouse, containing four separate bathing rooms, shower rooms, dressing rooms, and a massage salon, was in use at the site. The arrangement of the bathing rooms was such that the spring orifice and surrounding pool of water were beneath a central opening in the floor of the bathhouse, and the pool was accessible in the corner of each of the four rooms.

The spring water, rising to the surface of the pool, had sufficient head to keep the fine sand grains in suspension near the orifice. Thus, bathers were able to step into the pool, partly submerge themselves in the water and sand at the orifice, and enjoy the heat, bubbling water, and large gas bubbles that periodically escaped from the orifice.

Overflow from the spring was carried away by a buried tile pipe which connected to a small sump where another pipe drained seepage water from a water collector beneath Indian Avenue (fig. 4). The entire flow was then carried by a pipe to a trailer park about 300 feet south of the spring where it was used in a series of "Roman baths."

In 1953 the city of Palm Springs secured a right-of-way through land owned by the Indian Tribe so that nearby Indian Avenue could be widened. Because the grade for the new roadbed was to be several feet lower than the old road and much closer to the spring, it was necessary to provide a water collector to be placed in the saturated materials beneath the finished street. The collector made possible the building of a firm base for the roadbed, thus preventing possible damage to the spring owing to compaction of the materials in the spring mound (figs. 3, 4). However, at one stage of the construction work an accident occurred that caused considerable concern. A series of well points had been driven along the margin of the new roadcut near the spring and were connected to a central pump. The head in the spring and surrounding area was lowered by pumping so that construction could proceed. However, on one occasion the pump failed during the night, and, when the head recovered in the spring, the saturated soil between the spring and the new roadcut washed out from beneath the bathhouse into the new roadbed. The pump was started again and after the head was lowered, the "washout" between the spring and the roadbed was backfilled with sand, silt, old timbers, sandbags, and other debris. By the time the new roadbed was finished and the water collector beneath the street was operating, however, the spring orifice had shifted to a new position, and the area near the spring orifice was unstable. By jetting with a pipe on the end of a long hose the sand was loosened at the site of the old orifice, and the spring was restored to its original position where it remained until the new development was started in 1958.

DEVELOPMENT WORK AT THE SPRING IN 1958–59

Because reports of previous construction work at the spring nearly always indicated temporary damage to the commercial value of the spring for bathing, or included accounts that the point of discharge of the spring was shifted a greater or lesser distance, conferences were held among members of the Bureau of Indian Affairs, the Geological Survey, and representatives of the building contractor to discuss the possible methods whereby the development work could be done without permanent damage to the spring.

It was agreed that the work should proceed with great caution so that any calcareous or other cemented chimney, which was believed to surround the spring orifice, would not be damaged. Furthermore, it was believed likely that damage to the chimney might result in the permanent loss of the spring by lateral escape into the alluvium where the water level is about 200 feet below land surface. To accomplish safely all the desired improvements, it was agreed that a large water-collecting tank should be installed in the ground in a carefully excavated hole at the spring orifice.

A steel tank, open at the bottom, was therefore constructed by the contractor and placed in the excavation above the spring orifice. The tank is about 20 feet in diameter and 10 feet deep, and includes a collection system, overflow, distribution pumps, and controls. In the future, water from the tank will flow by gravity out of a discharge pipe or will be pumped to baths in a new building.

After the drilling of the test wells (pl. 2) and preliminary pumping from the spring to determine its rate of flow, which was about 25 gpm (gallons per minute), the site was cleared of trees and the old bathhouse was removed. The excavation for the water tank was dug with a clamshell bucket, and the water was pumped from the hole as digging progressed. After the digging was started, the location of the main orifice of the spring was clearly exposed. It occupied an oval-shaped area about 10 feet long and 5 feet wide and had a vent near each end. No digging was done directly from the orifice. The main orifice of the spring, as it was exposed, is shown in figure 5. The hole, when completed, was about 40 feet in diameter and about 12 feet deep. Many logs, timbers, chunks of cement from foundations

FIGURE 5.—View of the main orifice of the spring during excavation. Diameter of orifice about 12 inches

built for several successive bathhouses, and other debris were removed from the hole during the digging. The sides of the hole remained nearly vertical surrounding the entire excavation, except for caving of the west wall where saturated sandy silt slumped into the hole from the area of the ground-water mound underlying Indian Avenue (pl. 2). No evidence was found that a cemented chimney of any sort surrounded the spring orifice. The water continued to issue from vents in the orifice area during the period of work, and the peripheral deposits of the spring mound seem to provide the poorly permeable walls that retain the orifice deposits which form the conduit through which the water rises.

By probing with poles, several large blocks of concrete were detected just beneath the surface in the spring orifice when the excavation was completed. Much more debris probably remains at depth in the spring conduit. Because these did not interfere with the spring or the construction work, they were left in place, and the tank, set on several concrete footings, was installed; the open bottom of the tank is covered with coarse gravel. The tank now collects the entire flow of the spring. The water is free of silt, dirt, and debris and flows by gravity out of a discharge pipe in the tank or will be pumped under pressure to the proposed spa when completed. Also, for short periods of time the peak demand of the proposed bathhouse can exceed the natural flow of the spring by pumping from the limited storage in the tank.

DEPOSITS OF THE SPRING MOUND EXPOSED DURING DEVELOPMENT WORK

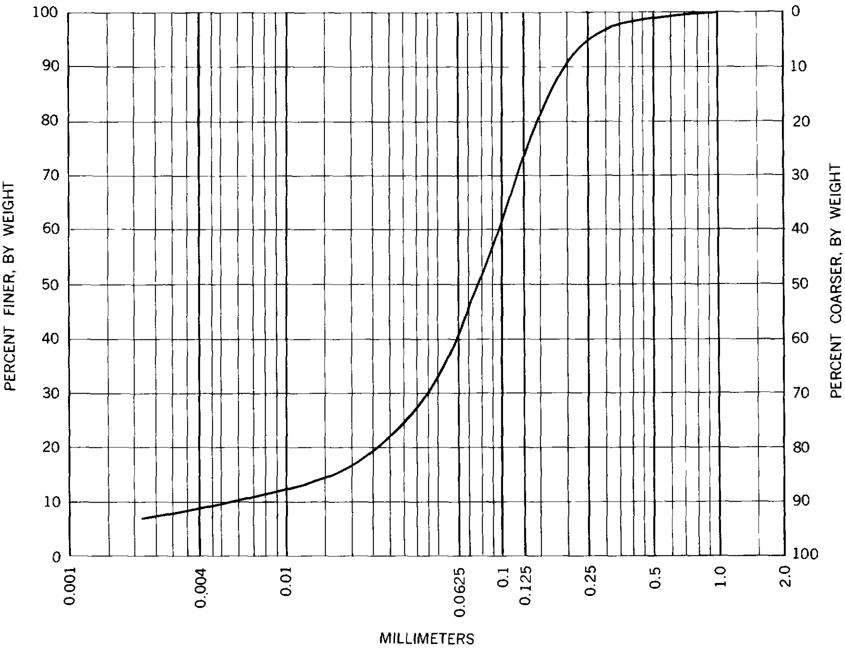
The spring deposits consist of material greatly different in character from the surrounding alluvial deposits and probably do not include appreciable amounts of windblown material. A few cobbles and small boulders were found embedded in the deposits during the excavation of the hole. These may have been left at the site during infrequent periods when the spring area was temporarily flooded by runoff from the nearby mountains.

The materials that make up the spring mound and which were exposed in the sides of the excavation are of two distinct types. The bulk of the material is mainly dark green-gray clayey very fine sand and silt. These are called peripheral deposits, because, in general, they form the peripheral part of the spring mound that surrounds the active orifice as well as other orifices that are presently unused but were exposed during the excavation of the hole. The remainder of the material, which occupies very irregular but nearly vertical channels in the darker silt deposits, consists mainly of fine sand and silt and is called the orifice deposits. The light-gray sand and silt deposits are called orifice deposits because they occupy the active and formerly active orifices of the spring and serve as conduits through which the spring water washes the small amounts of material to the surface, which adds to the overall size of the spring mound.

The relationship between the orifice deposits and peripheral deposits is shown in figure 6. In the photograph, the light area is the washed sand constituting the orifice deposits, and the dark area is the unwashed fine-grained peripheral deposits.

FIGURE 6.—View of the unused orifice and peripheral deposits of the spring mound exposed in vertical wall of dug pit.

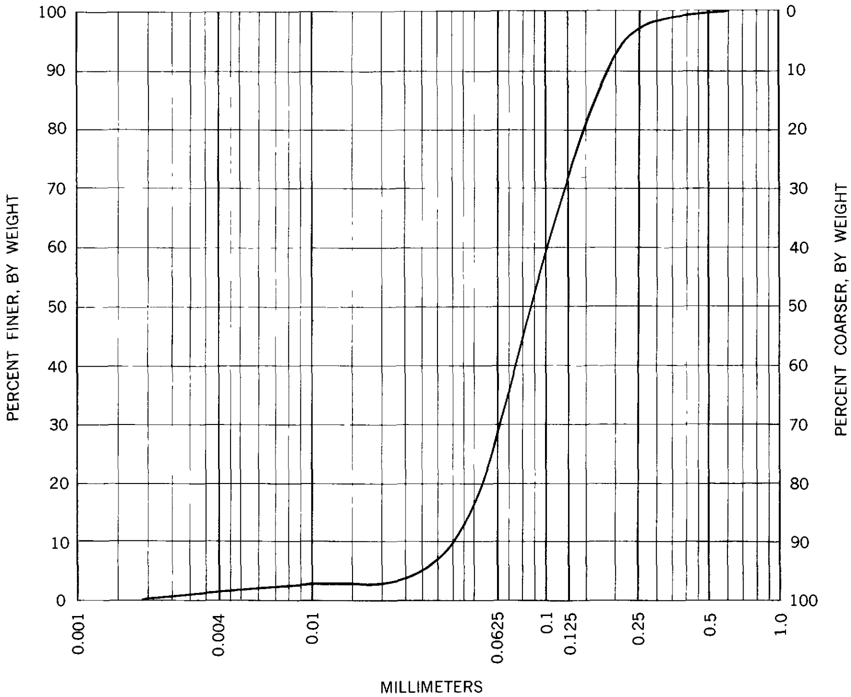
Figures 7 and 8 are particle-size distribution curves for samples of the deposits of the spring mound. The samples were collected near the bottom of the wall of the excavation. Figure 7 shows that the peripheral deposits are relatively poorly sorted, and that the particles range in size from clay (less than 0.0004 mm) to very coarse sand (about 1 to 2 mm). Figure 8 shows that the orifice deposits are



PARTICLE-SIZE DIAMETER, IN MILLIMETERS

	Clay sizes	Silt sizes	Sand sizes				
	<0.004	0.004-0.0625	Very fine 0.0625-0.125	Fine 0.125-0.25	Medium 0.25-0.5	Coarse 0.5-1	Very coarse 1-2
PERCENT OF SIZE	9.0	32.4	33.4	19.8	4.6	0.6	0.2

FIGURE 7.—Particle-size distribution curve of sample of the peripheral deposits.



PARTICLE-SIZE DIAMETER, IN MILLIMETERS

	Clay sizes	Silt sizes	Sand sizes			
	<0.004	0.004–0.0625	Very fine 0.0625-0.125	Fine 0.125-0.25	Medium 0.25-0.5	Coarse 0.5-1
PERCENT OF SIZE	1.4	27.0	44.0	24.8	2.6	0.2

FIGURE 8.—Particle-size distribution curve of sample of the orifice deposits.

fairly well sorted and consist of more than 70 percent sand, ranging generally from very fine to fine sand (0.0625 to 0.25 mm).

Other laboratory determinations of the hydrologic properties of the deposits included moisture content, specific yield, specific retention, and coefficient of permeability. These data are tabulated in the two tables given below.

Summary of laboratory analysis of deposits of Agua Caliente Spring, California

Laboratory No.	Depth (feet)	Field description of material	Specific retention (percent)	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gpd per sq ft)	Field coefficient of permeability (gpd per sq ft)
59CAL1	10	Peripheral deposits.	29. 7	47. 1	17. 4	0. 4	0. 7
2	10	Orifice deposits.	5. 4	48. 2	42. 8	80	140

Data on capillary fringe relation

[Disturbed samples used in tension-plate apparatus; tension applied to sample was used to plot capillary-fringe curve of moisture content against height above water table, in feet of water (fig. 9)]

Height above water table (feet)	Moisture content, percent by dry weight in—	
	Peripheral deposits	Orifice deposits
1.7	44. 8	31. 0
3.4	41. 1	25. 8
5.1	31. 7	7. 3
6.8	26. 2	4. 0
11.3	22. 0	3. 4
33.9	17. 2	3. 3

The moisture-tension data, presented graphically in figure 9, show that the fine-grained peripheral deposits have much greater capillarity than the coarser orifice deposits. This, of course, is due to the presence of the smaller pores in the peripheral deposits.

In the peripheral deposits more than 65 percent of the grains are in the range of silt and very fine sand (0.004 to 0.125 mm). The coefficient of permeability [1] is only 0.4 gpd per sq ft at 60 °F, and the field coefficient of permeability at the prevailing temperature of 107 °F is only about 0.7 gpd per sq ft.

The data in the table summarizing the laboratory analysis show that the naturally washed sand of the orifice deposits has a porosity greater than 48 percent. This seems abnormally high. However, close examination of the unused orifices revealed that numerous small spherical voids were preserved in the sand, which probably were formerly occupied by gas bubbles entrapped in the water and sand mixture when the conduits served as active orifices. The coefficient of permeability of the orifice deposits tested is 80 gpd per sq ft (at

[1] The coefficient of permeability is the rate of flow of water through a cross sectioned area of 1 square foot of the material in 1 day under a hydraulic gradient of 100 percent at a temperature of 60 °F and is expressed in gallons per day per square foot.

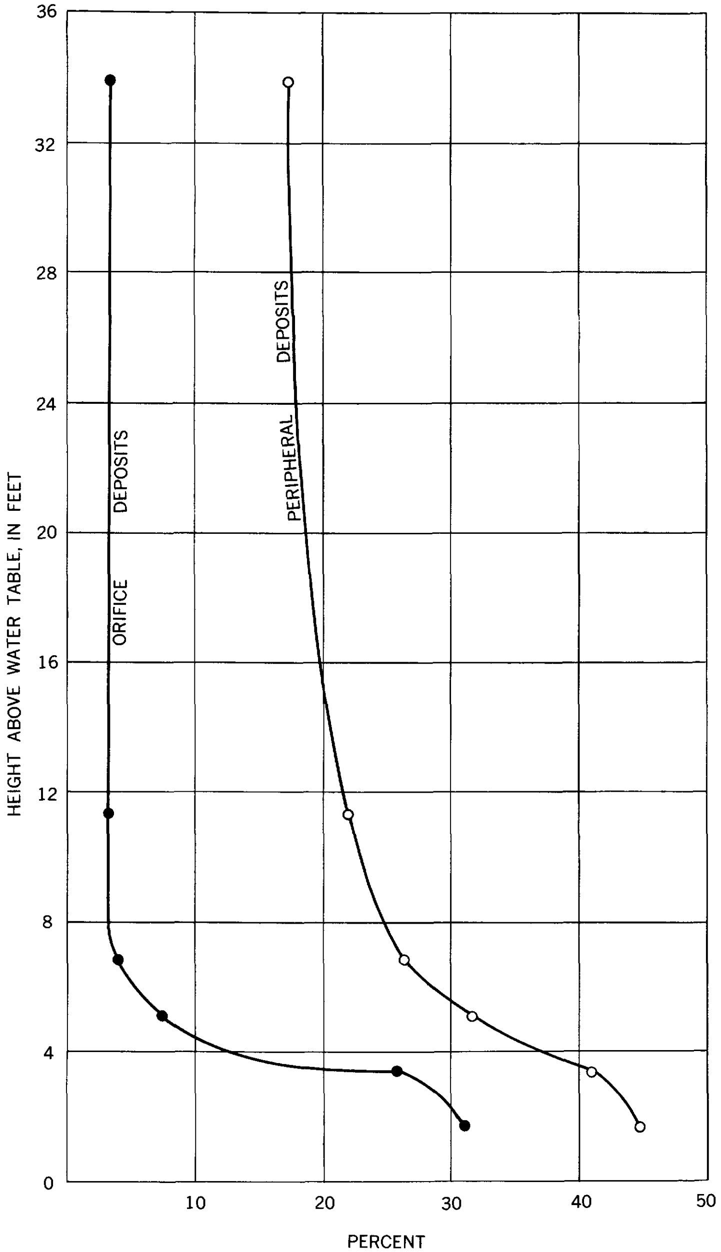


FIGURE 9.—Capillary rise as determined by moisture-tension methods.

60° F), and the field coefficient of permeability at the prevailing temperature of 107° F is about 140 gpd per sq ft.

In comparison with the peripheral deposits, the orifice deposits are much more porous and permeable. An examination of the peripheral deposits exposed in the excavation indicates that part of the peripheral deposits possibly contain much more clay and have a permeability even lower than that of the sample analyzed. The peripheral deposits appear to surround the margin of the spring mound and to be of such low permeability that very little water is lost from the orifice deposits as the water rises to the surface. In the uppermost 12 feet at least, the peripheral deposits effectively form a "chimney" of very low permeability around the washed-sand conduits of the orifice deposits (fig. 5); whether the peripheral deposits are cemented at depth, is not known. The authors postulate that the presence of possible cemented materials at depth does not contribute greatly to the confinement of the water in the orifice deposits. However, it is possible that confinement by the peripheral deposits, formed by the winnowing of fine-grained materials, is augmented by some precipitation of $CaCO_3$ well away from the main channels where the leaking thermal water presumably mixes with the regional body of ground water.

WATER-LEVEL FLUCTUATIONS IN WELLS CAUSED BY PUMPING DURING DEVELOPMENT WORK

During the period June 10, 1958, through April 1959, pumping from Agua Caliente Spring was carried on intermittently. Work preliminary to excavating the hole at the spring included drilling test wells and pumping the spring during the period June 10–15, 1958, to observe the effects on the spring flow and on ground-water levels in the deposits of the spring mound. The data collected during the preliminary pumping are given in the following table.

Log of pumping at Agua Caliente Spring, Palm Springs,' Calif., June 10–15, 1958

Date and time	Rate of pumping from spring orifice (gpm)	Depth to water below measuring point in well 4/4-14E27 (feet)	Drawdown in spring (feet)
June 10			
9:39 a.m.	0	3.86	-----
9:40	16½	-----	-----
9:55	12½	-----	-----
9:58	12½	3.89	-----
10:10	12½	-----	-----
10:15	15	-----	-----
10:17	15	3.98	-----
10:38	15	3.94	-----
10:52	19	-----	-----
11:00	19	3.97	-----
11:41	19	4.03	-----
11:47	20	-----	-----
12:00	37½	-----	-----
12:57 p.m.	37½	4.08	-----
1:20	37½	4.19	-----
1:35	43	-----	-----
1:42	43	4.20	-----
2:10	0	-----	-----
3:03	25	-----	-----
3:05	25	4.23	-----
June 10—Continued			
3:21	20¼	-----	-----
3:33	20¼	4.29	-----
3:34	16	-----	-----
3:55	16	-----	1.75
4:14	16	4.30	-----
4:19	0	-----	1.04
4:48	0	-----	.73
5:51	0	-----	.21
6:27	0	3.90	.04
June 11			
7:50 a.m.	0	3.88	-----
June 15			
8:20 a.m.	33½	-----	-----
9:45	19½	-----	1.0+
4:00 p.m.	0	-----	-----

After the shallow test wells were drilled, periodic measurements of water level were made in each well and these are given in table 3. An automatic water-level recorder was installed at well 4/4–14E11 (test well 12) and was operated intermittently until May 1959. Because the shallow test wells were drilled by the rotary method and gravel packed by washing water through the slotted casings, some of the first measured water levels do not seem to be representative of the true water levels in the deposits of the spring mound. However, measurements made thereafter are belived to show the true water level.

Figure 10 is a hydrograph of test well 4/4–14E11 during and immediately following the construction work. The water-level records, which show a decline of water level in the nearby wells when the spring is pumped, demonstrate that the deposits of the spring mound are in hydraulic continuity with the water in the spring orifice.

In the latter part of January 1959, when the old bathhouse was removed from the spring mound and the altitude of the land surface at the spring orifice was lowered somewhat, the water level in well 4/4–14E11 declined a small amount (fig. 10). When the pumping and excavation work began, however, the rate of decline increased, and the water level in the well reached a low on February 20 that was about 7.5 feet below the level at the start of the excavation work on February 4. After the excavation was finished and the water-collection tank was installed, the space between the water-collection tank and the sides of the hole was backfilled with material removed during construction and pumping from the spring was stopped.

As shown by the hydrograph (fig. 10), the water level in the spring mound began a slow recovery which continued throughout April, but by the end of April the water level in the well still had not recovered to the level observed at the start of the work. The record for short intervals during April shows the effect of pumping from the tank. However, the small amount of pumping from the water-collector tank was not principally responsible for the slow recovery. Rather, the volume of water required to fill the tank, the water needed to replenish the ground-water storage capacity in the spring-mound deposits depleted by pumping during the work, and the volume of water pumped after the tank was installed contributed to the slow recovery of the water levels in the spring mound. The data in table 3, however, show that by May 14 the water level in the well had recovered to the original level. Presumably the future level will be controlled by the amount of pumping from the water-collector tank and the overflow level of the tank.

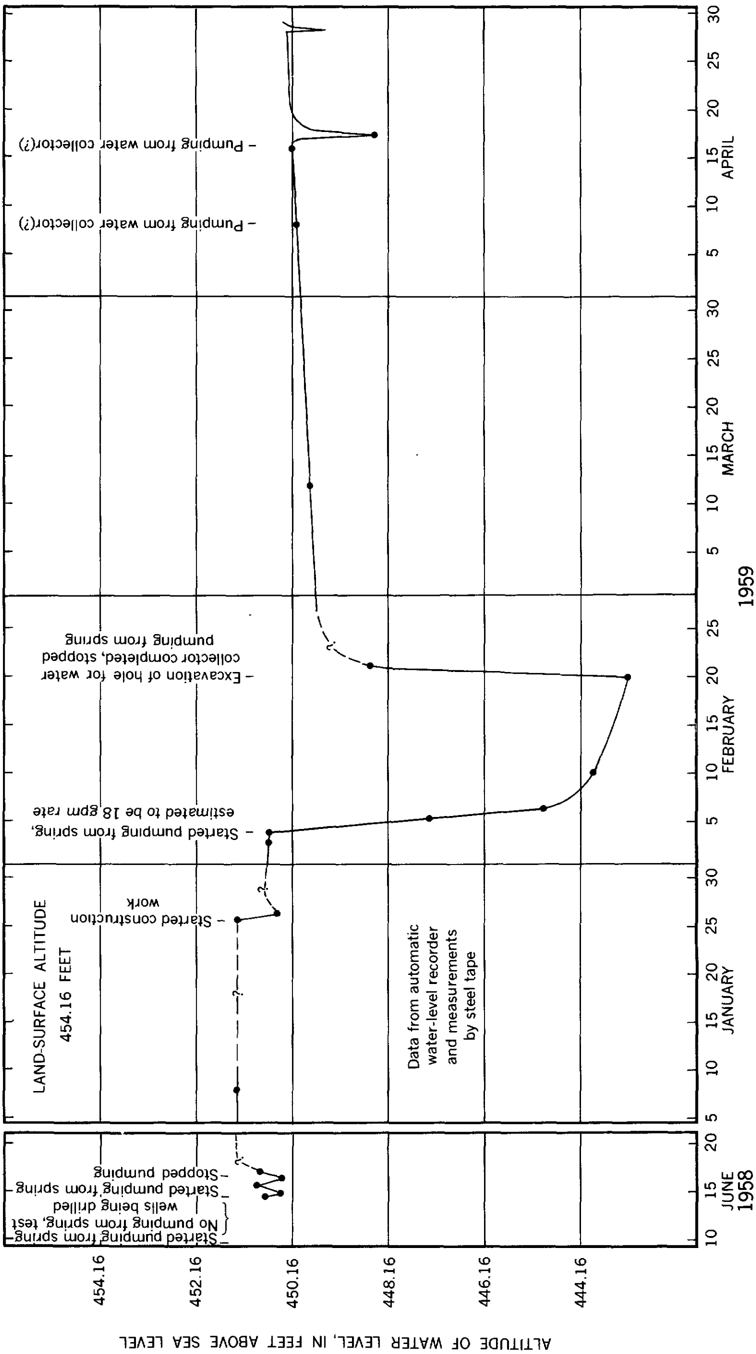


FIGURE 10.—Hydrograph of test well 4/4-14E11.

POSSIBLE MODE OF OCCURRENCE OF THE SPRING

The mode of occurrence of Agua Caliente Spring affords interesting geologic and hydrologic speculation because of its setting. Documented evidence of similar springs having similar modes of occurrence is not common in the geologic or hydrologic literature. In 1959 the spring discharged water at the surface of a low mound surrounded by permeable gravelly alluvial deposits. The water was discharged at a constant rate of about 25 gpm and at a temperature of about 107° F. The alluvial deposits are at least 630 feet in thickness and unsaturated in about the upper 200 feet.

It is postulated that when the spring originated, fine materials carried to the surface from the alluvium or bedrock fractures by the spring water probably formed a low mound down the sides of which the spring water flowed. The flowing water carried the finer material to the margins of the mound; the coarser material remained near the spring orifice. The low spring mound kept increasing in size and height as the spring deposits accumulated, but, concurrently, rock debris eroded from the mountains was also being deposited on the valley floor as alluvium. The alluvium eventually buried the fault trace near the spring. However, the spring deposits accumulated sufficiently rapidly that the top of the spring mound probably remained at an altitude slightly above the surrounding alluvial surface nearly at all times during the last phases of the deposition of alluvial materials.

Regardless of the source, the natural sorting of the deposits by the spring water has continued throughout the history of the spring. The finest deposits were continuously washed to the margins of the spring mound and now represent the peripheral deposits. They are of very low permeability and presumably effectively confine the rising spring water within the coarser more permeable orifice deposits near the center but probably are not cemented to any great degree.

Many sand-filled orifices surrounded by clayey sandy silt were observed during the excavation at the spring (fig. 4). Large blocks of the peripheral deposits that at one time had been broken and moved about as the orifice changed position were also observed in the walls of the hole. The intervening cracks, some of which were several inches wide, commonly were filled with washed light-gray sand typical of the orifice deposits. During work on the spring in 1953, the senior author observed one such block that included several cubic yards of silt and very fine sand.

The spring orifice is not surrounded near the surface by a cemented chimney of any type, as shown by the excavation of a hole 12 feet deep and 40 feet in diameter at the spring. Rather, the spring water probably rises through a washed-sand conduit of its own making; the spring water in the sand-filled orifice is confined laterally by poorly permeable sandy silty clay that was also deposited or reworked by the spring water. Whether the peripheral deposits are cemented below the depth of 45 feet, penetrated in the test wells (table 2), is not known. Based on studies of the spring deposits and the chemical quality of the spring water, however, the authors believe it unlikely that extensive cementation of the peripheral deposits has occurred at depth. However, minor cementation of the deposits at depth near the margins of the spring mound may have occurred.

Figure 11 is a generalized sketch showing a hypothetical geologic and hydrologic setting that may correspond to the occurrence of the Agua Caliente Spring. It seems possible that before deposition of the alluvium the spring originally flowed from an opening along a fault in the bedrock. However, the spring may be younger than much of the alluvium and may have issued from the surface of the alluvial plain after faulting of the alluvial deposits overlying bedrock.

The few granitic cobbles found in the spring deposits during the excavation were greatly different from those in the nearby alluvium;

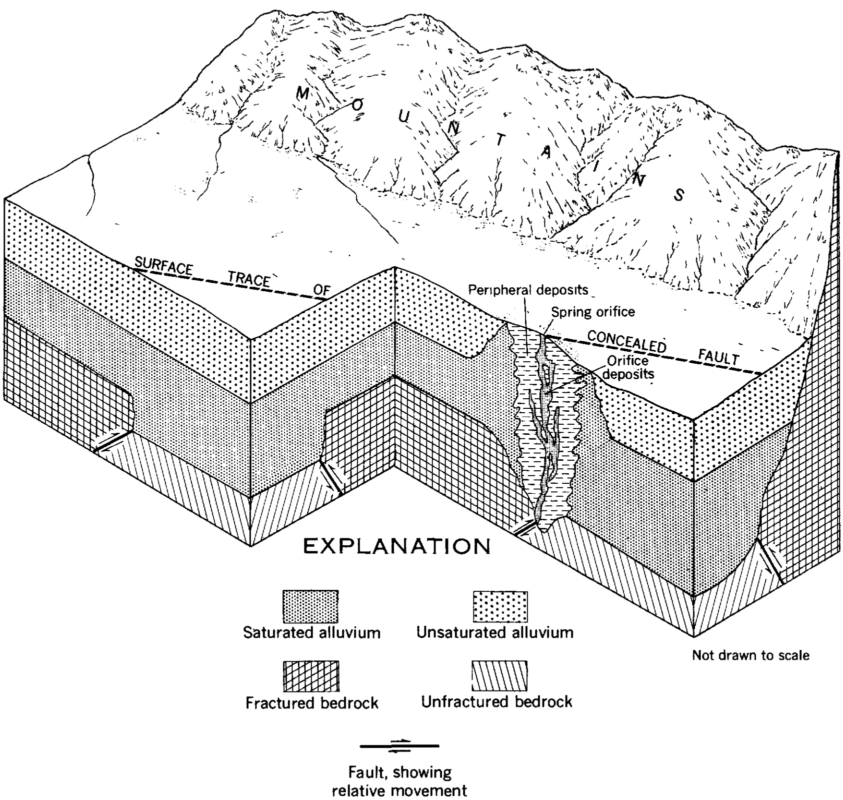


FIGURE 11.—Generalized sketch showing possible relation of spring to geology.

all crumbled easily with the slightest pressure of the hand, which was not true of the resistant cobbles in the alluvium. Mica flakes are very abundant and may constitute a large percentage of the total spring deposit; the reason for the abundance of mica is unknown.

In degree of sorting, grain size, and color, the peripheral and orifice deposits are completely dissimilar to the gravelly alluvial deposits which surround the spring (table 2). It is difficult, therefore, to explain the origin of the deposits of the spring mound. At the beginning of the work it was believed likely that much of the spring deposit was windblown sand and silt which accumulated in the moist and vegetated area near the spring. However, on the basis of size distribution and angularity of the sand grains, virtually none of the materials are believed to be windblown. The orifice and peripheral deposits may have originated mainly from one or both of two sources. One possible source is from fine-grained materials washed from fractures in the bedrock underlying the alluvium. The original spring may have flowed from the fractured rocks at a low point where an old stream channel, such as Tahquitz Creek, crossed the fault. In any case, the water probably originally flowed from the rocks at high temperature and may have carried fault gouge and abrasion products of fine sand, silt, and clay derived from the fractures in the basement complex. Evidence that the spring water periodically carries sand, silt, and clay to the surface is inconclusive.

On the other hand, it is difficult to explain the presence of a column of material more than 600 feet in thickness and about 50 feet in diameter, roughly 1 to 1.5 million cubic feet, being derived from decomposition products in the basement complex and carried to the surface by the spring. Even though the mechanical analyses (figs. 7, 8) and microscopic examination seem to preclude the possibility of windblown material, it might be a minor source of the deposits. Many other spring mounds in the southwestern deserts probably represent accumulations of some windblown material. Accordingly, windblown material cannot be dismissed as a possible source for the accumulation of some of the spring deposits, provided that an explanation can be found for the apparent nonwindblown character of the material.

A second possible source of the deposits of the spring mound is fine-grained material washed and reworked from the alluvium. The winnowing and washing of the finer alluvial materials in spring-water "boils" is not uncommon. In some areas near the San Jacinto fault northwest of the Palm Springs area where as much as 2,000 feet of older alluvial deposits have been exposed by uplift and erosion, the senior author has observed old sand "chimneys" and pipes that probably represent the former sites of old spring conduits. Thus, the orifice and peripheral deposits may have been washed from the alluvium by spring water under high pressure. This mode of occurrence seems likely for the deposits of Agua Caliente Spring if a confined or pressure system exists that has enough head to lift the spring water to a height of about 200 feet above the water table.

The head of the water in the spring system must be very high, judging from the present altitude of the spring flow—possibly 630 feet higher than the bedrock opening. Because the spring discharge is at an altitude some 200 feet higher than the regional water table, it is theorized that the fault zone is connected at depth with confined fractures in the bedrock that extend to and far up the sides of the San Jacinto Mountains where recharge occurs and where the head of water is nearly 200 feet higher than that of the ground water near the spring. However, in some thermal spring systems density differences due to temperature differences between the spring water and ground water cause a pressure differential between the rising column of hot water and the surrounding colder column of ground water. The pressure differential theoretically causes a mounding effect of warmer water, entirely separate from the usual concept of confinement and artesian flow. The magnitude of the mounding of the hotter water is controlled by the permeability of the channel walls between the hotter and colder waters and the maximum depth of circulation in the system.

At Agua Caliente Spring, the known temperature difference between the spring water at the spring discharge and the regional body of ground water is about 47° F. Assuming that the total depth of circulation in the system is 3,000 feet, and the geothermal gradient causes a temperature rise of 1 to 2° F per hundred feet, a density difference of about 0.2 to 0.3 percent can account for a probable maximum "mounding" of only about 20 to 35 feet. This maximum is far short of the approximately 200 feet observed and seems to demand a confined system of some sort. However, considerable gas escapes with the water discharged at the spring. Presumably the gas is carbon dioxide, and its presence might greatly increase the density difference between the hot and cold columns and might account to a large extent for the "mounding" of the spring water. Gas, presumably carbon dioxide, escapes from solution as the hot water rises in the orifice deposits. The gas may provide some lift for the spring water and thus may contribute to the high head above the water table.

Based on a possible maximum depth of circulation of about 3,000 feet, a density difference of about 0.7 percent between the hot spring water and colder ground water would be required to cause the spring water to rise to a height of about 200 feet above the water table. The

654098 O—62——3

height to which the spring water might rise, if it could be contained and the pressure determined, is problematical. No data were obtained during the construction that indicated the head of the spring.

RECOVERY OF SPRING WATER LOST BY SUBSURFACE FLOW

As a part of the investigation of the Agua Caliente Spring the Geological Survey was requested to determine the means and methods whereby it might be possible to increase the spring flow or recover spring water that now is lost by subsurface flow to the ground water. Based on data collected during the excavation at the spring, it appears that the water-collector tank now operating recovers most of the spring water available near the surface. Also, it appears that attempts to recover additional water without drilling deep wells would be unsuccessful.

The rate of water loss by lateral percolation from the orifice deposits is not known. It could be small or it could be greatly in excess of the combined discharge of about 25 gpm from the spring orifice and drain tiles (fig. 4). The amount of water now lost by subsurface flow that could be salvaged is problematical—the chief concern, if drilling is attempted, would be to protect the confining walls of the orifice deposits. If these were penetrated at depth by drilling, loss of the entire flow might result.

If it is necessary to attempt to recover spring water in excess of the present yield of the water-collector tank, consideration should be given to the drilling of a deep well in the spring deposits. A large-diameter gravel-packed well drilled by the cable-tool method probably would be the best means of recovering the water, inasmuch as the orifice deposits are very fine grained and the sand-filled channels through which the spring water rises are probably not vertical. If the confining walls are breached during drilling and loss of the spring is threatened, grouting with cement probably would prevent loss of the spring. However, the danger that the spring might be permanently damaged should be considered before any drilling is undertaken.

According to a report by White and Brannock (1950), the average natural surface discharge of the thermal springs at Steamboat Springs, Nev., was only about 250 gpm. The total discharge, including leakage and production from wells, is about 750 gpm. Present spring discharge is about 75 gpm and well production is about 450 gpm; much of this is recovery of leakage.

Whether an increased quantity of water could be developed by drilling wells near Agua Caliente Spring, is not known; however, some recovery of water now leaking to ground water is probably likely.

SUMMARY

Based on the field inspections of the work, estimates of spring flow, and water levels in observation wells, the construction and installation of the water-collector tank caused neither an increase nor decrease in spring flow. The five objectives of the investigation outlined on page 2 were met and are described below:

1. It was impossible to make an accurate measurement of the spring discharge during the construction. However, insofar as it was possible to measure the discharge, it did not seem that the flow was appreciably changed from the 25 gpm measured before the construction began. Also, pumping from the spring during the periods when construction lowered the head in the spring 10 or 12 feet did not seem to cause an appreciable change in discharge. However, continuing and accurate records of discharge from the water-collector tank should be kept to determine the flow. These records will be of value in future tests and in answering problems that might rise in the operation of the spring.
2. The original flow of the spring before construction is now salvaged by the water-collector tank.
3. The water-collector tank provides a means whereby a central pump can be used to provide water to the spa under pressure.
4. The sand and gravel filtration bed in the open bottom of the collector prevents silt, dirt, and debris from mixing with the spring water.
5. The water-collector tank provides a central water-collecting system of small reservoir capacity, and for short periods pumping from the collector can exceed the natural flow of the spring.

In addition, the geologic and hydrologic setting of the spring and its mode of occurrence indicate that it is unlikely that the construction of the additional buildings and facilities near the spring, as proposed, will result in harm to the spring or cause the orifice to shift from its position beneath the water-collector tank. Any excavation near the spring, however, should be undertaken with due caution. A deep excavation in the peripheral deposits might cause the spring to shift its position to that site, particularly if an old conduit containing orifice deposits were encountered.

REFERENCES CITED

Brown, J. S., 1923, The Salton Sea region, California: U.S. Geol. Survey Water-Supply Paper 497, 283 p.

Dutcher, L. C., 1953, Memorandum on the flow of Agua Caliente spring after road improvement at Palm Springs, Calif.: U.S. Geol. Survey open-file report, 7 p.

Garrett, A. A., and Dutcher, L. C., 1951, Possible effect of a road improvement on the flow of the Augua Caliente spring, at Palm Springs, Riverside County, Calif.: U.S. Geol. Survey open-file report, 8 p.

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

Poland, J. F., and Dutcher, L. C., 1953, Second memorandum on the flow of Agua Caliente spring after road construction at Palm Springs, Calif.: U.S. Geol. Survey open-file report, 8 p.

Waring, G. A., 1915, Springs of California: U.S. Geol. Survey Water-Supply Paper 338, 40 p.

Wheeler, G. M., 1876, Geology: U.S. Army, Eng. Dept., Report upon U.S. geographical surveys west of the 100th meridian, v. 3.

White, D. E., and Brannock, W. W., 1950, The sources of heat and water supply of thermal springs, with particular reference to Steamboat Springs, Nevada: Am. Geophys. Union Trans., v. 31, p. 566–574.

BASIC DATA

TABLE 1.—*Data on water wells*

Altitude: The altitude given is the altitude of land-surface datum at the well. Altitudes given to the nearest 5 ft were interpolated from topographic maps having 40-ft contour intervals. Altitudes given to the nearest tenth of a foot were determined by spirit leveling during the present investigation.
Depth: Depths of wells given in whole feet were reported by owners, drillers, or others; depths given in feet and tenths were measured below land surface by the Geological Survey.
Type well and diameter: Type of well construction is indicated by the following symbols: *C* cable-tool drilled, *R* rotary drilled, gravel packed. Well diameter is given in inches.
Pump type and power: The type of pump is indicated first, as follows: *N* none, *S* submersible turbine, *T* turbine. The type of power is indicated second, as follows: *N* none; where a number appears in this column it indicates the rated horsepower of an electric motor.
Use of well: *A* air conditioning, *Ob* observation, *Ps* public supply, *Un* unused.
Measuring point: The point from which water-level measurements are made is described as follows: *Hpb* hole in pump base, *Na* no access, *Tap* top of access pipe, *Tc* top of casing, *Tcc* top of casing cover. The distance of the measuring point above or below (−) land-surface datum is given in feet and tenths.
Water level: The water level is given in feet below land-surface datum; that is, the height of the measuring point above or below land-surface datum has been subtracted from or added to the water level as measured in the field. Reported or approximate depths to water are given in whole feet, and measured depths to water are given in feet, tenths, and usually hundredths.
Other data: *C* chemical analysis, *L* log (table 2), *W* periodic water-level records (table 3).

USGS No.	Date of observation	Owner or user	Year completed	Depth (feet)	Type, diameter (inches)	Pump type and power	Yield (gpm)	Use	Measuring point (feet)	Altitude of land surface datum (feet)	Water level below land surface datum (feet)	Other data
		T. 4 S., R. 4 E.										
4/4-1N1	Feb. 10, 1959	Palm Springs Water Co.; Well 7				T 150		Ps	Tap −8.0	500	264	
11K1	Feb. 5, 1959	Well 4		470	C 16	T 125	800	Ps	Tap −8.0	490	255.84	
11Q1	do	Well 5	1948	600	C 16	T 150	1,250	Ps	Tap 8.0	470	233	L
13P1	Feb. 10, 1959	Palm Springs High School				T 30		Ps	Hpb .6	415	185.74	
		Augua Caliente Tribe:										
14E1	June 10, 1958	Test well 1	1958	33.0	R 1½	N N		Ob	Tc .1	454.83	16.53	L, W
14E2	June 11, 1958	Test well 2	1958	45.0	R 1½	N N		Ob	Tc .1	455.14	17.00	L, W
14E3	do	Test well 3	1958	45.0	R 1½	N N		Ob	Tc .2	455.09	23.06	L, W
14E4	do	Test well 4	1958	45.0	R 1½	N N		Ob	Tc .5	455.23	15.42	L, W
14E5	June 12, 1958	Test well 5	1958	35.0	R 1½	N N		Ob	Tc .2	454.33	15.91	L, W
14E6	do	Test well 6	1958	25.0	R 1½	N N		Ob	Tc .3	454.02	3.02	L, W
14E7	do	Test well 7	1958	15.0	R 1½	N N		Ob	Tc .6	454.18	3.92	L, W
14E8	do	Test well 8	1958	35.0	R 1½	N N		Ob	Tc .1	453.89	3.68	L, W
14E9	June 14, 1958	Test well 9	1958	15.0	R 1½	N N		Ob	Tc 0	454.40	4.11	L, W
14E10	do	Test well 10	1958	45.0	R 1½	N N		Ob	Tc 0	453.91	24.82	L, W
14E11	June 13, 1958	Test well 12	1958	45.0	R 6	N N		Ob	Tc 3.0	454.16	3.45	L, W
15H1	Jan. 8, 1959	Desert Inn	1928	630	C 12	T 20	270	Un	Na	460		
15J1	Dec. 3, 1958	Bullock's Inc	1946	438	14	S 30	200	A	Tcc 8.0	450	231.32	C, L
		Palm Springs Water Co.:										
23D1	Feb. 5, 1959	Well 2	1926	425	C 16	S 150	1,050	Ps	Na	435	196	L
23E1	do	Well 6	1954	488	C 20	T 300	2,250	Ps	Tap 1.0	439	203.95	C
		T. 4 S., R. 5 E.										
		Palm Springs Water Co.:										
4/5-17L1		Well 1				N N		Ob	Na	385		
19D1	Feb. 10, 1959	Well 3				T 150		Ps	Tap 8.0	395	176.87	

TABLE 2.—*Logs of wells drilled near Agua Caliente Spring*

[Materials classified by Geological Survey unless otherwise indicated]

	Thickness (feet)	Depth (feet)
4/4-11Q1. Palm Springs Water Co., well 5		
[Altitude about 470 ft. Drilled by James Wright, Jr., in 1948. 16-in. casing, perforated 302 to 402 ft. Log from files of Palm Springs Water Co.]		
Sand	26	26
Sand and gravel	70	96
Sand and clay	34	130
Rocks and sand	82	212
Sand and clay	18	230
Gravel, coarse; ½ to 4 in	22	252
Sand and clay	48	300
Gravel, ½ to 3 in	102	402
Clay	10	412
Gravel	6	418
Clay	72	490
Clay, sandy	18	508
Clay	16	524
Clay, sandy	70	594
Clay	6	600
4/4-14E1. Agua Caliente Indian Tribe, test well 1		
[Altitude 454.83 ft. Drilled by B & R Drilling Co., June 10, 1958. Set 32 ft of 1½-in. pipe with torch-cut perforations 30 to 33 ft. Gravel packed]		
Sand, fine, micaceous; and brown silt	13	13
Sand, fine, micaceous; and gray silt	2	15
Sand, fine, micaceous; and bluish-green silt; some clay	7	22
Sand, fine, micaceous; silt and gray clay	11	33
4/4-14E2. Agua Caliente Indian Tribe, test well 2		
[Altitude 455.14 ft. Drilled by B & R Drilling Co., June 11, 1958. Set 42 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Sand, fine, micaceous; and brown silt	12	12
Sand and silt, fine, micaceous; some gray to bluish-green clay	23	35
Sand and silt, fine, micaceous, silvery blue-gray to gray	10	45
4/4-14E3. Agua Caliente Indian Tribe, test well 3		
[Altitude 455.09 ft. Drilled by B & R Drilling Co., June 11, 1958. Set 42 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Sand, fine, micaceous; and brown silt	10	10
Sand, fine, micaceous; and golden-brown silt	6	16
Sand, fine, micaceous; and brown silt	10	26
Sand, fine, micaceous; some clay and grayish-brown coarse sand	1	27
Sand, fine, micaceous; and bluish-gray silt	8	35
Sand, fine, micaceous; and silvery blue-gray silt	10	45

TABLE 2.—*Logs of wells drilled near Agua Caliente Spring*—Continued

	Thickness (feet)	Depth (feet)
4/4-14E4. Agua Caliente Indian Tribe, test well 4		
[Altitude 455.23 ft. Drilled by B & R Drilling Co., June 11, 1958. Set 40 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Lost bottom 5 ft of hole because of caving. Gravel packed]		
Soil, brown	2½	2½
Sand, fine, micaceous; and brown silt	2½	5
Sand, fine, micaceous; and gray silt	5	10
Sand, fine, micaceous; and dark-gray silt	14	24
Sand, fine, micaceous; and dark greenish-gray silt	18	42
Sand, fine, micaceous; and light greenish-gray silt	3	45
4/4-14E5. Agua Caliente Indian Tribe, test well 5		
[Altitude 454.33 ft. Drilled by B & R Drilling Co., June 12, 1958. Set 31 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Soil, brown	6	6
Sand, fine, micaceous; and brown silt, (lost circulation briefly; using much water)	2	8
Sand, fine, micaceous; and brown silt	1	9
Sand, fine, micaceous; and dark-gray to black silt	12	21
Sand, fine, micaceous; and grayish-green silt	3	24
Sand, fine, micaceous; and light-gray silt	3	27
Sand, fine, micaceous; and dark-gray silt	8	35
4/4-14E6. Agua Caliente Indian Tribe, test well 6		
[Altitude 454.02 ft. Drilled by B & R Drilling Co., June 12, 1958. Set 21 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Soil, brown	3	3
(Lost circulation at 3 ft; at 6 ft water coming up in hole to 3 ft, no overflow at top; not getting any cuttings; water slowly coming up in hole at 10 ft, no mud showing up in spring; regained circulation at 14 ft)		
Sand, fine, micaceous; and dark-gray silt; greenish black near bottom	22	25
4/4-14E7. Agua Caliente Indian Tribe, test well 7		
[Altitude 454.18 ft. Drilled by B & R Drilling Co., June 12, 1958. Hole drilled to 15 ft, but because of caving only 9.5 ft of 1½-in. pipe set with torch-cut perforations in bottom 3 ft. Gravel packed]		
Soil, brown	2½	2½
Sand, fine, micaceous; and silt (lost circulation; bouncing on large cobbles)	½	3
4/4-14E8. Agua Caliente Indian Tribe, test well 8		
[Altitude 453.89 ft. Drilled by B & R Drilling Co., June 12, 1958. Set 33 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Soil, brown	2	2
Sand, fine, micaceous; and brown silt	4	6
Sand, fine, micaceous; and dark-gray silt	29	35

TABLE 2.—*Logs of wells drilled near Agua Caliente Spring*—Continued

	Thickness (feet)	Depth (feet)
4/4-14E9. Agua Caliente Indian Tribe, test well 9		
[Altitude 454.40 ft. Drilled by B & R Drilling Co., June 14, 1958. Set 12 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Soil, brown	1	1
Sand, fine, micaceous; and black silt	14	15
4/4-14E10. Agua Caliente Indian Tribe, test well 10		
[Altitude 453.91 ft. Drilled by B & R Drilling Co., June 13, 1958. Set 41 ft of 1½-in. pipe with torch-cut perforations in bottom 3 ft. Gravel packed]		
Sand, silt, and brown clay; alluvial	2½	2½
Sand, fine, micaceous; and brown silt	10½	13
Sand, fine, micaceous; and olive-gray silt	3	16
Sand, fine, micaceous; and yellowish olive-gray silt	3	19
Sand, fine, micaceous; and bright golden-yellow silt	2	21
Sand, fine, micaceous; and yellowish-gray silt	1	22
Sand, fine, micaceous; and light greenish-gray silt (somewhat harder drilling at 22 ft)	1	23
Sand, fine, micaceous; and silvery-gray silt	1	24
Sandstone(?), hard, light-gray	1	25
Sand, fine, micaceous; and silvery-gray silt	6	31
Sand, fine, micaceous; and light-blue silt	1	32
Sand, fine, micaceous; and slate-gray silt	1	33
Sand, fine, micaceous; and dark-gray silt	½	33½
Sand, fine, micaceous; and blue-gray silt	11½	45
4/4-14E11. Agua Caliente Indian Tribe, test well 12		
[Altitude 454.16 ft. Drilled by B & R Drilling Co., June 13-14, 1958. Pilot hole was drilled to a depth of 45 ft then reamed to a depth of 30 ft. Set 6-in. casing with torch-cut perforations in bottom 3 ft and bullnose on bottom. Gravel packed]		
Soil, brown	2	2
Sand, fine, micaceous; and dark grayish-brown silt	3	5
Sand, fine, micaceous; and dark-gray silt; thin layer of medium-gray loose rocks at 21 ft	16	21
Sand, fine, micaceous; and light-gray silt near top, black at greater depth; layer of rocks at 24 ft	3	24
Sand, fine, micaceous; and black silt	11	35
Sand, fine, micaceous; and light greenish-gray silt	10	45
4/4-15J1. Bullock's Inc.		
[Altitude about 450 ft. 14-in. casing, perforated 164 to 344 and 415 to 435 ft]		
Sand	49	49
Clay, sandy	16	65
Gravel	8	73
Clay, yellow	12	85
Gravel	25	110
Clay, yellow	31	141
Clay, sandy	37	178
Sand, coarse	28	206
Clay, sandy	25	231
Gravel	87	318
Clay, yellow	10	328
Clay, yellow, and sand	110	438

TABLE 2.—*Logs of wells drilled near Agua Caliente Spring*—Continued

	Thickness (feet)	Depth (feet)
4/4-23D1. Palm Springs Water Co., well 2		
[Altitude about 435 ft. Drilled by Roscoe Moss Co. in 1926. 16-in. casing, perforated 190 to 408 ft. Log from files of Palm Springs Water Co.]		
Sand and boulders	80	80
Sand and clay	31	111
Sand and gravel	54	165
Clay and gravel	23	188
Sand and coarse gravel	32	220
Sand and boulders	32	252
Sand, clay, and a few boulders	143	395
Boulders, sand, and clay	30	425

TABLE 3.—*Water-level measurements in test wells*

[Measurements preceded by asterisk were made when the spring was being pumped]

4/4-14E1 (test well 1)

[Altitude 454.83 ft. Measuring point is top of 1½-in. pipe, 0.1 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1958*		*1959*	
June 11:		June 14:		Jan. 8	16.92
10:05 a.m.	15.10	7:30 a.m.	16.35	Feb. 3	17.53
11:48	15.24	6:17 p.m.	16.39	4	17.42
3:49 p.m.	15.54	June 15:		5	19.09
June 12:		7:12 a.m.	16.53	6	20.80
7:32 a.m.	16.14	8:26	*16.56	10	22.92
2:28 p.m.	16.16	10:29	*16.55	18	23.65
5:07	16.12	3:48 p.m.	*16.55	19	23.90
June 13:		4:13	16.55	Mar. 12	17.40
8:02 a.m.	16.32	7:00	16.59	Apr. 8	17.35
5:18 p.m.	16.24	Oct. 7	16.43	May 14	17.90
		Dec. 3	16.61		

4/4-14E2 (test well 2)

[Altitude 454.83 ft. Measuring point is top of 1½-in. pipe, 0.1 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1958*		*1959*	
June 11:		June 14	16.86	Jan. 8	17.62
10:28 a.m.	14.26	June 15:		Feb. 3	18.21
3:50 p.m.	16.09	7:13 a.m.	17.00	4	18.11
June 12:		8:27	*17.04	5	19.79
7:30 a.m.	16.67	10:31	*16.71	6	21.12
5:08 p.m.	16.61	3:58 p.m.	*16.99	10	22.01
June 13:		7:07	17.03	18	22.33
8:04 a.m.	16.77	Oct. 7	17.02	19	22.38
5:17 p.m.	16.67	Dec. 3	17.44	May 14	19.65

TABLE 3.—*Water-level measurements in test wells*—Continued

4/4-14E3 (test well 3)

[Altitude 455.09 ft. Measuring point is top of 1½-in. pipe, 0.2 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1958*		*1959*	
June 11	21.49	June 15:		Jan. 8	23.55
June 12:		7:14 a.m.	23.06	Feb. 3	23.35
7:28 a.m	22.34	8:29	*23.07	4	23.74
5:10 p.m	22.33	10:33	*23.12	5	24.16
June 13:		3:51 p. m	*23.08	6	24.53
8:05 a.m	22.40	7:08	23.17	10	25.23
5:16 p.m	22.30	Oct. 7	22.73	18	24.48
June 14:		Dec. 3	23.23	19	25.56
7:29 a.m	22.46			Mar. 12	24.18
6:14 p.m	22.87			Apr. 8	25.30
				May 14	25.26

4/4-14E4 (test well 4)

[Altitude 455.23 ft. Measuring point is top of 1½-in. pipe, 0.5 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1958*		*1959*	
June 12:		June 15:		Jan. 8	15.16
7:25 a.m	7.96	7:15 a.m	15.42	Feb. 3	15.71
5:11 p.m	9.09	8:31	*15.40	4	15.71
June 13:		10:34	*15.44	5	16.14
8:06 a.m	10.18	3:52 p.m	*15.49	6	16.90
5:14 p.m	10.72	7:09	15.48	10	18.95
June 14:		Oct. 7	14.91	18	20.68
7:22 a.m	14.07	Dec. 3	15.15	19	20.75
6:22 p.m	15.61			Mar. 12	16.37
				Apr. 8	15.95

4/4-14E5 (test well 5)

[Altitude 454.33 ft. Measuring point is top of 1½-in. pipe, 0.2 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1958*		*1959*	
June 12:		June 15:		Jan. 8	16.14
11:56 a.m	12.55	7:16 a.m	15.91	Feb. 3	16.39
5:12 p.m	15.32	8:33	*15.89	4	17.34
June 13:		10:39	*15.91	5	16.44
8:07 a.m	16.09	3:54 p.m	*16.07	6	17.20
5:12 p.m	15.06	7:10	17.17	10	19.25
June 14:		Oct. 7	15.97	18	20.98
7:26 a.m	16.01	Dec. 3	15.87	19	21.05
6:23 p.m	16.39			Mar. 12	16.67
				Apr. 8	16.25

4/4-14E6 (test well 6)

[Altitude 454.02 ft. Measuring point is top of 1½-in. pipe, 0.3 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1958*		*1959*	
June 12:		June 15:		Jan. 8	1.40
11:58 a.m	1.82	7:16 a.m	3.02	Feb. 3	1.59
5:13 p.m	1.68	10:40	*2.82	4	1.62
June 13:		3:54 p.m	*3.62	5	1.64
8:09 a.m	2.59	7:11	2.48	6	2.44
5:09 p.m	1.78	Dec. 3	1.39	10	4.48
June 14:				18	11.12
7:25 a.m	1.59			19	11.02
6:24 p.m	5.30			May 14	3.93

TABLE 3.—*Water-level measurements in test wells*—Continued

4/4–14E7 (test well 7)

[Altitude 454.18 ft. Measuring point is top of 1½-in. pipe, 0.6 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land surface datum (feet)
1958		*1958*		*1959*	
June 12:		June 15:		Jan. 8	3.88
2:27 p.m	3.89	1:18 a.m	3.92	Feb. 3	4.03
5:14	3.92	10:00	*4.04	4	4.04
June 13:		3:55 p.m	*4.05	5	Dry
8:20 a.m	3.93	7:12	3.93		
5:06 p.m	3.93	Oct. 7	3.90		
June 14:		Dec. 3	3.89		
7:24 a.m	3.91				
6:25	3.92				

4/4–14E8 (test well 8)

[Altitude 453.89 ft. Measuring point is top of 1½-in. pipe, 0.1 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land surface datum (feet)
1958		*1958*		*1959*	
June 12:		June 15:		Jan. 8	2.05
5:15 p.m	4.57	7:19 a.m	3.68	Feb. 3	2.62
June 13:		10:01	*3.67	4	2.57
8:22 a.m	2.54	3:56 p.m	*2.88	5	4.97
5:05 p.m	2.47	7:12	2.74	6	7.58
June 14:		Oct. 7	2.34	10	8.77
7:22 a.m	2.46	Dec. 3	2.10	18	9.76
6:26 p.m	2.92			19	9.72
				Mar. 12	3.53
				Apr. 8	3.36
				May 14	2.74

4/4–14E9 (test well 9).

[Altitude 454.40 ft. Measuring point is top of 1½-in. pipe, at land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land surface datum (feet)
1958		*1958*		*1959*	
June 14:		Dec. 3	3.75	Mar. 12	4.13
6:30 p.m	4.67			Apr. 8	3.97
June 15:		*1959*		May 14	3.01
7:20 a.m	4.11	Jan. 8	3.44		
10:03	*4.23	Feb. 3	3.89		
3:56 p.m	*4.57	4	3.87		
7:13	4.46	10	9.91		
		18	Dry		

4/4–14E10 (test well 10)

[Altitude 453.91 ft. Measuring point is top of 1½-in. pipe at land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land surface datum (feet)
1958		*1958*		*1959*	
June 13:		June 15:		Jan. 8	25.59
12:43 p.m	24.76	7:21 a.m	24.82	Feb. 3	25.55
5:03	22.83	8:43	*24.88	4	25.53
June 14:		10:04	*24.96	5	25.57
7:20 a.m	23.85	3:58 p.m	*25.80	6	25.75
6:37 p.m	23.75	7:17	25.97	10	26.31
		Oct. 7	23.74	18	26.57
		Dec. 3	25.30	19	26.82
				Mar. 12	26.08
				Apr. 8	26.24
				May 14	26.27

TABLE 3.—*Water-level measurements in test wells*—Continued

4/4-14E11 (test well 12)

[Altitude 454.16 ft. Measuring point is top of casing 3.0 ft above land-surface datum]

Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)	Date and time	Depth to water below land-surface datum (feet)
1958		*1959*		*1959*	
June 15:		Jan. 8	2.48	Feb. 19	10.66
8:00 a.m	3.45	Feb. 3	3.15	20	10.65
7:15 p.m.	3.77	4	3.18	Mar. 12	3.98
June 16	3.82	5	6.48	Apr. 8	3.69
Oct. 7	2.81	6	8.97	May 14	2.96
Dec. 3	2.68	10	9.87		
		18	10.57		

INDEX