A Brief Geologic and Hydrologic Reconnaissance of the Furnace Creek Wash Area, Death Valley National Monument California

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1779-Y

Prepared in cooperation with the National Park Service, Department of the Interior

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By M. A. PISTRANG *and* FRED KUNKEL

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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CONTENTS

ILLUSTRATIONS

TABLES

A BRIEF GEOLOGIC AND HYDROLOGIC RECONNAISSANCE OF THE FURNACE CREEK WASH AREA, DEATH VALLEY NATIONAL MONUMENT, CALIFORNIA

By M. A. PISTRANG and FRED KUNKEL

ABSTRACT

The Furnace Creek Wash area, Death Valley National Monument, Calif., consists in large part of a pediment slope formed on folded sedimentary rocks of Tertiary age, locally capped by gravel of Quaternary and Recent age. Sixty points of ground-water discharge, including artificial diversions, springs, seeps, and phreatophyte areas, are described and mapped. The total measured and estimated discharge from these points is a minimum of 5.6 cubic feet per second. Except for Salt Springs, the spring water is of the sodium bicarbonate sulfate type and contains dissolved solids of about 600 to 1,400 parts per million.

Adequate precipitation falls on the tributary drainage area to supply all the recharge. The springs occur in all the unconsolidated and semiconsolidated deposits, and four hypotheses to explain the occurrence, source, and movement of the ground water are as follows: The first assumes that water from precipitation at higher altitude percolates into a network of faults and fractures and discharges where the faults and fractures intersect the surface at lower altitude. The second hypothesis is similar to the first but assumes that, from faults in the bedrock, water is conducted to the surface in pipes of travertine that were formed contemporaneously with the deposition of alluvial material. The third hypothesis assumes that water from precipitation percolates into the alluvial deposits, replenishes the water table, and occurs as springs where the water table intersects the surface. The fourth hypothesis assumes a combination of the first three.

During November 1958 a well was drilled by the National Park Service to a depth of 250 feet to test the thickness, character, and water-yielding properties of the alluvial deposits north of Travertine and east of Texas Springs. The water level in the well was 74.5 feet below land-surface datum. After 76 hours of continuous pumping at rates up to 390 gpm (gallons per minute) the well yielded 140 gpm with 15 feet of drawdown.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

In October 1955 the National Park Service requested the U.S. Geological Survey to determine the conditions relating to the occurrence of ground water in the Furnace Creek Wash area and the

National Park Service headquarters area, with particular reference to Travertine, Texas, and Nevares Springs, Death Valley National Monument, Calif.

The scope of the investigation was as follows:

1. Make the geologic studies necessary to map the extent, structure, and character of the water-bearing deposits and geologic structure affecting the occurrence of ground water in the Furnace Creek Wash area.
2. Inventory all springs, wells, and other sources of water, and collect all available hydrologic data and records.
3. Measure directly, if possible, or estimate by indirect means the quantity of water discharged by Travertine, Texas, and Nevares Springs.
4. Collect water for chemical analysis, where necessary, to determine the water quality and its suitability for domestic and irrigation use.
5. After preliminary study, consider the need and advisability for drilling test wells to supply additional hydrologic and geologic information.
6. Prepare a report to (a) discuss the geology of the Furnace Creek Wash area and its relation to the hydrologic conditions of the area, (b) furnish information on ground-water occurrence and movement, (c) supply estimates of the discharge from Travertine, Texas, and Nevares Springs, and (d) furnish an estimate of ground-water storage capacity of the Travertine and Texas Springs area if sufficient data are available.
7. Be available to the Park Service personnel for technical assistance concerning ground-water problems.

Field studies were begun in November 1956. All springs, wells, phreatophyte areas, and other ground-water discharge points were canvassed, flows were measured or estimated, and geologic mapping and other field studies were completed in June 1957. In November 1958 the Park Service drilled a test well at a site suggested by the Geological Survey. This report summarizes the findings of items 1–7 above and presents all available data through January 1964.

This study was made by the U.S. Geological Survey, starting under the general supervision of G. F. Worts, Jr., former district geologist, and completed under the general supervision of H. D. Wilson, Jr., district engineer. The entire study was under the immediate supervision of Fred Kunkel, geologist in charge of the Long Beach subdistrict office.

LOCATION AND GENERAL DESCRIPTION OF THE AREA

The Furnace Creek Wash area considered in this report includes a part of the alluviated slope on the eastern side of Death Valley, Inyo County, Calif., between long 116°47′ and 116°53′ W. and lat 36°25′ and 36°32′ N. The area studied is shown on figure 1 and includes parts of the Furnace Creek and Chloride Cliff quadrangles (scale 1:62,500) of the Geological Survey.

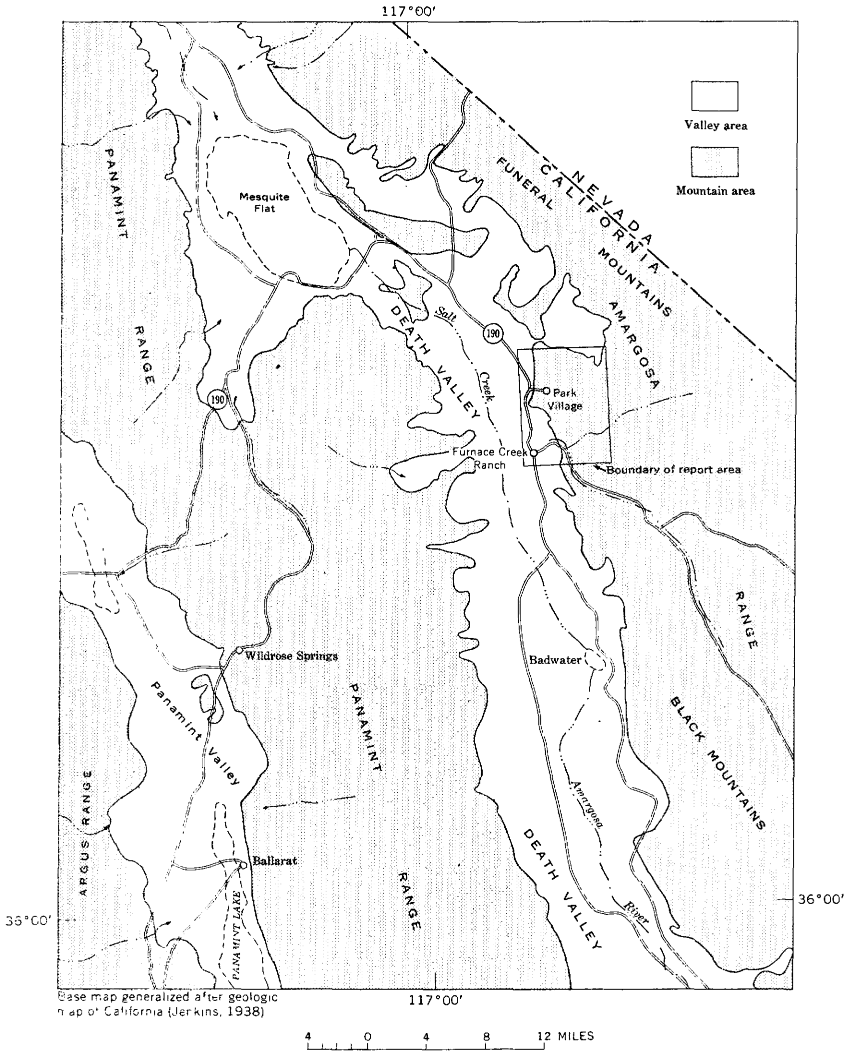

FIGURE 1.—Map of part of southern California, showing area covered by this report.

The area consists predominantly of a west-southwesterly sloping pediment covered by alluvium derived from the Funeral Mountains on the northwest. It is bordered by the northern end of the Black Mountains on the southwest and the floor of Death Valley on the west. Furnace Creek Wash, trending northwest, traverses the area along the northeast base of the Black Mountains.

The altitude of the area ranges from more than 260 feet below sea level on the floor of Death Valley to approximately 3,000 feet above in the Black Mountains. The altitude of the alluvial fans and pediment cover ranges from about 200 feet below sea level to about 2,000 feet above.

Furnace Creek Ranch and Furnace Creek Inn, at the mouth of Furnace Creek Wash, are the principal resorts of Death Valley. The National Park Service maintains a headquarters area and employee residences approximately 3 miles north of Furnace Creek Ranch and a public campground (Texas Spring Campground) about a mile east of the ranch.

State Highway 190 traverses the east side of the floor of Death Valley as far south as Furnace Creek Inn where it enters Furnace Creek Wash, and then on to Death Valley Junction, which is east of the area shown on plate 1. At Furnace Creek Inn a paved road leads southward along the valley floor to Shoshone and Baker which are outside of the area shown on plate 1. Several side roads lead to points of scenic or historic interest.

OTHER INVESTIGATIONS AND ACKNOWLEDGMENTS

There are no published studies specifically concerning the geology and ground water of the Furnace Creek Wash area of Death Valley National Monument. However, the Park Service (written commun., 1941) made a water-use study of the area, and T. W. Robinson (written commun., 1951) made a study of the Nevares Springs. Both of these reports have been useful in this study, and where possible the present measurements of waterflow have been correlated with measurements of waterflow given in those reports. A report by the California Division of Mines (1954) covers briefly the general geology of the Death Valley area.

Geologic studies of the Death Valley area are being made under the direction of C. B. Hunt, Geologic Division, U.S. Geological Survey, who gave many helpful suggestions and freely gave the use of his unpublished geologic and plant-distribution maps. J. F. McAllister, also of the Geologic Division, made available unpublished mapping of the area which was used for stratigraphic correlation. Unpublished mapping of T. P. Thayer, Geologic Division, was consulted also.

The U.S. Borax and Chemical Corp., through R. S. Brown, geologist, furnished records of discharge measurements for Travertine, Texas, and other springs and allowed access to all their installations for purposes of making additional measurements and geologic studies.

The California Department of Water Resources and the National Park Service furnished copies of chemical analyses from their files.

DISCHARGE-POINT NUMBERING SYSTEM

The system of numbering ground-water discharge points used in this report conforms to the well-numbering system used in virtually all ground-water investigations made by the Geological Survey in California since 1940. This system 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.

The discharge points are assigned numbers according to their location in the rectangular system for the subdivision of public land. For example, in the number 27/1–3A1, which was assigned to Cow Spring, the part of the number preceding the slash indicates the township (T. 27 N.), the part between the slash and the hyphen is the range (R. 1 E.), the number between the hyphen and letter indicates the section (sec. 3), and the letter indicates the 40-acre subdivision of the section as shown in the following diagram.

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

Within each 40-acre tract the discharge points are numbered serially as indicated by the final digit. No distinction has been made to differentiate between springs, phreatophyte areas, or other types of discharge points in the numbering system. Thus, discharge point 27/1–3A1 is the first discharge point to be listed in the NE¼NE¼ sec. 3. The entire Furnace Creek Wash area of this report lies north and east of the San Bernardino base and meridian lines, and therefore the foregoing abbreviation of the township and range is sufficient.

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GEOLOGY

STRUCTURE AND LANDFORMS

The alluviated pediment slope that constitutes most of the Furnace Creek Wash area is formed on folded sedimentary rocks of Tertiary age (pl. 1). In general these sedimentary rocks fill a synclinal trough whose position has been controlled by the northwest-trending fault zone between the Funeral Mountains on the northeast and the Black Mountains on the southwest. This fault zone, shown on plate 1, is one of the major structural features of the Furnace Creek Wash area. The pediment slope is thoroughly dissected into hills which locally are capped by gravel of Quaternary and Recent age derived from the Funeral Mountains on the northeast. The rocks of both Tertiary and Quaternary age are offset by the numerous northwest-trending faults.

The sedimentary rocks of Tertiary age in general dip to the northeast, but dips to the southwest are common where the rocks have been affected by faulting. A prominent horseshoe-shaped hill about half a mile northeast of the Texas Spring Campground marks the nose of a southeast-plunging syncline, one of the more prominent features in the area. An accompanying anticlinal fold is exposed immediately to the north.

Many of the springs in the area are associated with faults, but, except for their hydrologic and topographic expression, the faults themselves are mostly obscured at the surface by unconsolidated gravel deposits or the mud "icing" characteristic of the weathering of fine-grained, poorly consolidated strata in an arid climate. The northwest-trending row of low hills behind the upstream Travertine Springs is indicative of one of these inferred faults (pl. 1).

Along the northeast boundary of the alluviated pediment slope the sedimentary rocks of Tertiary age are in fault contact with the folded and faulted sedimentary rocks of Paleozoic age of the Funeral Mountains.

The northern end of the Black Mountains is composed of sedimentary and volcanic rocks of Tertiary age having a complex internal structure. The Black Mountains constitute a wedge-shaped fault block that has been raised between the northwest-trending fault zone on the east and a fault zone on the west.

GEOLOGIC UNITS

In the following description the geologic formations or units of the Furnace Creek Wash area have been differentiated with respect to their hydrologic properties as well as lithologic characteristics. The reconnaissance geologic map (pl. 1) shows the areal distribution of these units.

CONSOLIDATED OR SEMICONSOLIDATED ROCKS

Basement complex (principally Cambrian).—Rocks of the basement complex form the Funeral Mountains in the eastern part of the area. These consist of metamorphic rocks, mostly dolomite and quartzite of Cambrian age, which have been intensively folded and faulted. These rocks are virtually non-water bearing, although minor amounts of ground water may percolate along fractures, joints, and faults which may function as conduits. The main hydrologic significance of this unit is that it underlies the mountainous area which receives the major part of the precipitation that falls in the region. It is the runoff from this precipitation that flows onto the unconsolidated alluvial deposits and contributes most of the recharge to ground water.

Continental deposits (Pliocene and Pleistocene).—The northern end of the Black Mountains is underlain by continental deposits which are composed mainly of lacustrine beds of Tertiary age. These are light-colored fine-grained beds of silt and clay and also include numerous flows of basalt and volcanic agglomerate. Extensive veins of borate minerals are associated with the volcanic rocks and the sedimentary rocks interbedded with them. It is possible that this formation may be a faulted section that repeats the lacustrine beds of Pliocene to Pleistocene age described below. In either case, the beds in the Black Mountians do not control the hydrologic features of the Travertine, Texas, and Nevares Springs.

Resting on the lacustrine beds and dipping generally to the northeast away from the Black Mountains, the Funeral Formation, a conglomerate bed, is exposed and has been variously termed the Funeral Fanglomerate or the Inn Conglomerate, or has been included as a member of the Furnace Creek Formation (C. B. Hunt, J. F. McAllister, and T. P. Thayer, unpub. mapping, 1956). The Funeral Formation is best exposed in the vicinity of Furnace Creek Inn. It is about 750 feet thick and contains abundant boulders and cobbles of several types of lava as well as rocks of Paleozoic age. The abundance of lava boulders is a distinguishing characteristic by which this conglomerate of Pliocene and Pleistocene(?) age may be differentiated from the gravel of Pleistocene age overlying it. Northwestward the Funeral Formation interfingers with beds of light-colored sand and silt and is distinguished by an upper green unit and a lower brown unit. The conglomerate contains much fine-grained material throughout and therefore would be a poor aquifer (water-bearing unit), except for local permeable zones along fractures and faults.

On the northern and eastern parts of the reconnaissance geologic map (pl. 1) other conglomerate and sandstone of undetermined relationship and probably of Tertiary age have been mapped and are included with this unit.

Lacustrine deposits (Pliocene and Pleistocene).—Overlying the conglomerate of the continental deposits are playa beds of Pliocene or Pleistocene age consisting of yellowish to gray or white beds of tuffaceous silt and clay. This unit ranges in thickness from about 1,000 feet in the vicinity of Texas Springs to about 100 feet southeastward along Furnace Creek. The abundance of fine-grained and argillaceous material of which this unit is composed makes the main body of the formation virtually non-water-bearing. However, underground drainage has developed an extensive system of enlarged cracks and fissures, miniature caverns of a true karst topography, in which some ground water could be stored or transmitted. Evidence of this can be seen at spring 27/1–23F1. (For description of discharge-point numbering system see p. Y5.) Ground-water discharge at this spring probably is supplied by underflow in the wash that can be traced upgradient through scattered clumps of mesquite and other phreatophytes to phreatophyte areas 27/1–23B4 and 27/1–23G1. Immediately upstream from the spring, beds of the lacustrine deposits are exposed in an ephemeral waterfall; the floor of the wash is bare of any overlying gravel. Ground water discharges along the vertical face of the dry waterfall at the base of a jointed and fissured tuffaceous silt, overlying impermeable clay beds. The underflow is transmitted entirely through the fissures in the lacustrine beds for at least the 15 or 20 feet along the wash where the overlying gravel is absent.

Fanglomerate (Pleistocene).—A formation of fanglomerate, or poorly sorted silt to boulders deposited in an alluvial fan of Pleistocene age, in many places overlies the lacustrine deposits of Pliocene and Pleistocene age in the Furnace Creek Wash area. The beds commonly are tilted and considerably faulted. The surface usually is deeply dissected, and as a result the original fan form is obscure. The materials range in size from silt to boulders and are moderately to strongly cemented throughout. Good exposures can be seen in the canyon of Cow Creek, east of the National Park Service headquarters, where the deposits are thoroughly cemented and veined with travertine or onyx. The cementation and poor sorting make this formation generally non-water-bearing, except along cracks and fissures.

Travertine (Pleistocene and Recent).—Travertine is composed of calcium carbonate that is precipitated in and around spring orifices where the issuing waters lose carbon dioxide because of release of pressure and agitation, and also to some extent through the activity of algae living in the water. Travertine deposits are associated with most of the springs in the area, and also at localities that were evidently sites of former springs. An easily accessible exposure of travertine is the huge slumped block in Furnace Creek Wash northwest of seep

27/1–23L1. These deposits are of limited areal extent and are not water bearing.

UNCONSOLIDATED DEPOSITS

Older alluvium (Pleistocene).—Loose, unconsolidated fan gravel of Pleistocene age mantles a large part of the Furnace Creek Wash area. The deposits commonly are tilted, faulted, and considerably dissected. Desert varnish on the larger clasts is common on uneroded surfaces. The material ranges in size from pebbles to boulders and contains interstitial sand and silt. The material is moderately to poorly cemented, and although the presence of sand and silt filling in a part of the void spaces between the pebbles reduces somewhat the water-bearing capacity of the deposit, it is considered an aquifer (water-bearing bed) where saturated.

Younger alluvium (Recent).—Gravel of Recent age covers that part of the area that is being alluviated at the present time. It is composed largely of alluvial-fan deposits, such as at the mouth of Furnace Creek Wash, and stream-channel deposits in the washes. The material is unconsolidated and is composed mainly of well-rounded cobbles and pebbles containing few boulders and little sand or silt. A good exposure of gravel of Recent age can be seen at 27/1–26B1 where sumps have been excavated into the deposits of Furnace Creek Wash to tap the water table. The small amount of fine-grained interstitial material in this deposit makes it a good aquifer (water-bearing bed) where saturated.

GROUND WATER

OCCURRENCE, MOVEMENT, AND SOURCE

Ground water may be defined as the water contained in the pores, cracks, and other void spaces in the rocks that lie below the water table. Although water is to be found everywhere below the top of the saturated zone, it is not everywhere available for withdrawal. The capacity of earth materials to absorb, store, transmit, and yield water depends on the number, size, and arrangement of interconnected void spaces in the materials.

Coarse-grained unconsolidated deposits, such as sand and gravel, contain numerous large well-connected pore spaces which make them highly permeable and usually good aquifers. Examples of this type in the Furnace Creek Wash area are the gravel of Recent and Pleistocene age comprising the younger and older alluvium, which may contain the main body of ground water in the area. If silt and clay occupy the spaces between the larger particles of sand and gravel, the transmission of water is retarded. Fine-grained deposits, such as very fine sand, silt, or clay, may contain as much or more water per unit of volume as coarse sand or gravel, but because of the much smaller pores, they may restrict the movement of ground water to such an extent that the permeability is vastly reduced and the effectiveness of the deposit as an aquifer is greatly diminished.

Consolidated rocks generally are nonporous and impermeable, except for local zones along cracks, fractures, and faults; elsewhere most of the pore spaces are filled with the cementing or indurating material. The fanglomerate of Pleistocene age and the continental deposits of Pliocene and Pleistocene age are cemented, indurated, or filled with interstitial material to such a degree that they are virtually non-water-bearing, except along cracks and fissures. In the lacustrine deposits, however, widened cracks and fissures are so extensive that they constitute a considerable part of the total volume of the deposit. The rocks of the basement complex, exposed in the Funeral Mountains, are thoroughly cemented and indurated and are very poor aquifers, although they transmit small amounts of water through cracks and fractures.

Ground water is nearly always in motion, percolating slowly from points of highest head, which are at the sites of recharge, to points of lowest head, where it discharges naturally through springs and seeps, by evaporation from moist ground, and by transpiration of phreatophytes. The source of the ground water discharged by the Texas, Travertine, and Nevares Springs cannot be demonstrated, but all the evidence indicates that the source of the water is precipitation falling on the mountainous areas to the east and southeast. The possibility that the source of the water is primary or juvenile—that is, water that has originated deep within the earth and is rising toward the surface for the first time—can be discounted.

The high temperature of the discharging ground water (up to 104°F at Nevares Spring, 28/1–36G1), which is approximately 28°F warmer than the long-term mean annual temperature at Furnace Creek Ranch recorded by the U.S. Weather Bureau, can be explained by the normal geothermal gradient, 1° to 2°F increase for about every 100 feet of depth, or less depth if the water came in contact with heated igneous rocks. Therefore, somewhere between the area of recharge and points of discharge the ground water has reached a depth, possibly along a fault, sufficient to raise its temperature by the required amount. Water of wholly or virtually primary origin is extremely high in dissolved mineral constituents and even when diluted with meteoric water usually may be differentiated by its characteristic chemical content from water entirely of meteoric origin (White, 1957). Also, primary water is extremely rare near the earth's surface; it makes up less than 1 percent of the volume of water in major aquifers. Therefore, unless the meteoric sources for a ground-water supply can be disproved, a primary-source hypothesis is unwarranted.

GROUND-WATER DISCHARGE

Prior to development by man, ground water in any area over a long-term period is in a state of dynamic equilibrium; that is, the natural ground-water discharge by all means, such as to the atmosphere, to bodies of surface water, and by underflow to adjacent ground-water areas, is equal to and dependent upon the natural recharge. In desert areas it is usually more practical to estimate the amount of discharge than the amount of recharge contributed to ground water.

Ground water in the Furnace Creek Wash area is discharged in visible measurable amounts at springs and artificial diversions, in estimable amounts through evaporation from moist ground, and by transpiration of phreatophytes. In addition, an unmeasured amount of underflow to the floor of Death Valley makes up part of the total discharge.

All known points of ground-water discharge in the area are shown on plate 1. Measurements of ground-water discharge made are presented in table 3. Table 4 shows the measured and estimated discharge for the Furnace Creek Wash area from January through March 1957, which totals 5.6 cfs (cubic feet per second), excluding the underflow to Death Valley. This rate is about 2,500 gpm (gallons per minute) or about 4,000 acre-feet per year.

TABLE 1.—*Data on points of ground-water discharge*

USGS number: For description of Geological Survey numbering system, see p. Y5. For index of ground-water discharge points by areas, see table 2.
Name: Each point of ground-water discharge inventoried by the Geological Survey is identified and is shown on plate 1.
Type of discharge: P, phreatophyte area, no observed surface flow; S, seep, flow too small to measure; F, flow, measurable amount either from spring or artificial diversion; W, well.
Altitude: Except where otherwise noted, the altitudes given are approximate, and are interpolated from Geological Survey topographic maps having an 80-foot contour interval.
Flow: The rate of flow, where measured or estimated, is given in cubic feet per second (cfs). The methods for determining the rate of flow are indicated as follows: Fm, Parshall flume; Wr, rectangular weir; B, bucket and stopwatch; Est, estimated by cross-sectional area and velocity of flow using a floating object and stopwatch.
Temperature: The temperatures given are in degrees Fahrenheit, measured at the point of discharge.

USGS No. (pl. 1)	Name	Type of discharge	Altitude (feet)	Date measured	Flow (cfs)	Temperature (°F)
	T. 27 N., R. 1 E.					
27/1- 3A1	Cow Spring (undeveloped)	F	200	3- 5-57	0.04 Est	81
3B1	Undeveloped spring	P	240			
3K1	Salt Springs (undeveloped)	S	100			
3P1	do	F	0	12- 1-56	.01 Est	73
14N1	Undeveloped spring	P	170			
14P1	do	P	240			
14Q1	do	P	400			
22H1	DVHCO [1] tunnel, Furnace Creek Inn.	F	50	3- 1-57	.33 Fm	91½
23B1	Texas Spring (tunnel)	F	380	1-22-57	.50 Wr	91
23B2	Undeveloped spring	P	400			
23B3	do	P	400			

See footnotes at end of table.

TABLE 1.—*Data on points of ground-water discharge*—Continued

USGS No. (pl. 1)	Name	Type of discharge	Altitude (feet)	Date measured	Flow (cfs)	Temperature (°F)
	T. 27 N., R. 1 E.—Continued					
27/1-23B4	Undeveloped spring—Continued	P	400			
23F1	do	F	160	2-28-57	0.01 Est	80
23G1	do	P	400			
23G2	do	P	400			
23J1	do	P	410			
23J2	do	P	410			
23K1	do	S	410			
23K2	do	F	400		.01 Est	
23L1	do	S	160			
23L2	do	P	160			
23L3	do	S	160			
23P1	NPS well dug in Furnace Creek Wash (depth of well 19.0 ft).	W	200	11-27-56 2-28-57 3-7-57 6-19-57	[2] 15.09 [2] 15.71 [2] 15.57 Dry at 19 ft	
23Q1	Undeveloped spring	S	320			
23Q2	do	S	320			
23Q3	do	F	320	12-17-56	.01 Est	72
23Q4	do	S	320			
23Q5	do	S	320			
23Q6	do	S	320			
23R1	Travertine Spring	F	400	1-19-57	.68 Wr	92
23R2	Undeveloped spring	P	410			
23R3	do	P	410			
24N1	do	S	400			
25D1	Travertine Spring	F	400			92
25D2	do	S	400	1-19-57	.23 Wr	----------
26A1	do	F	330			89
26A2	do	F	320	12-16-56	.5 Est	91½
26A3	do	F	320	12-13-56	.001 Est	89
26A4	do	F	320	12-13-56	.01 Est	94
26A5	do	F	320	11-28-56		95½
26A6	do	F	330	11-28-56	.6 Est	94
26A7	do	F	330	11-28-56		85
26B1	Sump in Furnace Creek Wash, DVHCO.	F	280	11-28-56	1.26 Wr	92
26B2	Buried tile in Furnace Creek Wash, DVHCO.	F	250	11-28-56	.45 Wr	----------
26B3	Park Service trench	F [3]	250	6-20-56	.24 Fm	----------
26B4	Undeveloped spring	S	320	----------	----------	----------
26B5	do	S	320	----------	----------	----------
	T. 28 N., R. 1 E.					
28/1-34M1	Undeveloped spring	P	0	----------	----------	----------
34N1	do	S	10	12-1-56	----------	73½
34N2	do	P	80	----------	----------	----------
34P1	do	P	100	----------	----------	----------
35E1	do	P	380	----------	----------	----------
35G1	do	P	500	----------	----------	----------
35K1	do	S	520	3-4-57	----------	76
35N1	do	F	380	3-5-57	0.01 Est	[4] 78
36G1	Nevares Springs area 1, north part, of Robinson (written commun. 1951).	F	[5] 937	12-14-56	.60 Fm	104
36G2	Nevares Springs area 1, point B, of Robinson (written commun.).	F	[5] 896	12-14-56	.05 B	102
36K1	Nevares Springs area 2, of Robinson (written commun. 1951).	S	[5] 920	12-14-56	----------	69
36M1	Nevares Springs area 3, point E, of Robinson (written commun. 1951).	F	[5] 720	12-14-56	.07 B	78
36M2	Nevares Springs area 4, point D, of of Robinson (written commun. 1951).	F	[5] 745	12-14-56	----------	84

1. Death Valley Hotel Co., Ltd.
2. Depth to water, in ft, below land-surface datum.
3. Trench destroyed by flash flood in September 1959.
4. Measurement 10 ft from source.
5. Altitude from Robinson (written commun. 1951).

TABLE 2.—*Geological Survey numbers for ground-water discharge points by areas*

Area	*Well numbers*			
Travertine Springs (diverted into DVHCO irrigation system)	27/1–23R	27/1–26A1	27/1–26A4	27/1–26A7
	25D1	26A2	26A5	
	25D2	26A3	26A6	
Undeveloped springs, seeps, and phreatophyte areas in area of Travertine-Texas Springs	27/1–14N1	27/1–23G1	27/1–23L2	27/1–23Q6
	14P1	23G2	23L3	23R2
	14Q1	23J1	23Q1	23R3
	23B2	23J2	23Q2	24N1
	23B3	23K1	23Q3	26B4
	23B4	23K2	23Q4	26B5
	23F1	23L1	23Q5	
Death Valley Hotel Co., Ltd., tunnel (Texas Spring)	27/1–23B1			
Sump in Furnace Creek Wash	27/1–26B1			
Buried tile in Furnace Creek Wash	27/1–26B2			
Furnace Creek Inn Tunnel	27/1–22H1			
NPS well in Furnace Creek Wash	27/1–23P1			
NPS trench in Furnace Creek Wash	27/1–26B3			
Nevares Springs	28/1–36G1	28/1–36K1	28/1–36M2	
	36G2	36M1		
Cow Spring (undeveloped)	27/1–3A1			
Undeveloped springs, seeps, and phreatophyte areas in area of Cow Creek	27/1–3B1	28/1–34N2	28/1–35G1	
	34M1	34P1	35K1	
	34N1	34E1	35N1	
Salt Springs (undeveloped	27/1–3K1			
	3P1			

TABLE 3.—*Periodic measurements of ground-water discharge in the Furnace Creek Wash area*

[Discharge in cubic feet per second. Measurements by Death Valley Hotel Co., Ltd., except as indicated]

27/1-23B1.—Texas Spring tunnel

[Measurement in settling box by 18-in. rectangular weir]

Date	Discharge	Date	Discharge	Date	Discharge
1926 [a]	[b]0.28	*1958*		*1961*	
1941		Jan. 9	0.50	Jan. 17	[d]0.50
Jan. 9	[a].38	Feb. 4	.50	30	.47
		Mar. 6	.50	Feb. 13	.47
1956		Apr. 6	.50	27	.47
		30	.50	Mar. 13	.47
Feb. 9	.50	May 27	.50	27	.47
23	.50	June 25	.50	Apr. 10	.47
Mar. 8	.50	July 25	.50	24	.50
Apr. 29	.50	Aug. 26	.50	May 8	.47
May 17	.50	27	.50	Aug. 7	.47
June 21	.50	Sept. 25	.50		
July 1	[c].48	Oct. 21	.50	*1962*	
22	[c].48	Nov. 13	.47		
Aug. 1	[c].48	13	[d].47	Jan. 17	[d].52
17	[c].48	24	[d].47	27	.47
26	[c].48	Dec. 9	.47	Feb. 14	.48
Sept. 7	[c].48			Mar. 8	.47
18	[c].48	*1959*		21	.50
28	[c].48			Apr. 9	.47
Oct. 8	[c].48	Jan. 6	.47	June 5	.47
18	[c].48	29	.50	19	.47
Nov. 1	[c].48	Mar. 4	.50	July 11	.50
20	[c].48	May 6	.50	30	.47
30	[c].48	June 3	.44	Aug. 13	.47
Dec. 10	[c].48	July 8	.47	31	.48
20	[c].48	Aug. 6	.47	Sept. 10	.47
31	[c].48	Oct. 29	.47	27	.47
		Nov. 9	[c,d].40	Oct. 9	.46
1957		9	[d].48		
		Dec. 4	.47	*1963*	
Jan. 10	[c].48				
18	[c].48	*1960*		Mar. 19	.47
22	[c,d].48			30	.47
26	[c].48	Jan. 11	.47	May 1	.47
Feb. 5	[c].48	12	.47	June 4	.47
6	.50	Feb. 11	.47	July 1	.47
Mar. 1	[c,d].48	Mar. 15	.50	Aug. 1	.47
21	.50	Apr. 19	.47	Oct. 1	.47
Apr. 5	[c,d].47	May 20	.47	Nov. 1	.47
5	[d].50	June 21	.47	Dec. 1	.47
June 4	.50	July 21	.47	30	.47
Aug. 22	.50	Aug. 15	.47		
Sept. 20	.50	Sept. 8	.50		
Oct. 23	.50	Oct. 9	.50		
Nov. 6	.50	Nov. 10	.50		
Dec. 5	.50	Dec. 9	.50		

27/1-22H1—Furnace Creek Inn tunnel

[Measurement in tunnel by 6-in. Parshall flume]

Date	Discharge	Date	Discharge	Date	Discharge
1957		*1958*—Continued		*1959*—Continued	
Feb. 18	0.45				
Mar. 1	[d].33	Apr. 8	0.22	Mar. 4	0.11
1	.33	30	.20	Apr. 6	.12
21	.28	May 27	.24	May 6	.12
Apr. 5	[d].28	June 25	.14	June 3	.12
June 4	.26	July 25	.10	July 8	.22
Aug. 22	.15	Aug. 26	.11	Aug. 6	.18
Sept. 20	.15	Sept. 25	.12	Oct. 28	.25
Oct. 23	.16	Oct. 21	.10	Nov. 9	[d].26
Nov. 6	.17	Nov. 13	.10	Dec. 4	.26
Dec. 5	.18	13	[d].10		
		Dec. 9	.11	*1960*	
1958				Jan. 12	.28
Jan. 9	.18	*1959*		Feb. 11	.32
Feb. 4	.18	Jan. 6	.10	Mar. 15	.31
Mar. 6	.18	28	.11	Apr. 19	.29

See footnotes at end of table.

TABLE 3.—*Periodic measurements of ground-water discharge in the Furnace Creek Wash area*—Continued

27/1-22H1—Furnace Creek Inn tunnel—Continued

Date	Discharge
1960—Continued	
May 20	0.28
June 21	.28
July 21	.26
Aug. 15	.26
Sept. 8	.26
Oct. 9	.26
Nov. 10	.28
Dec. 9	.28
1961	
Jan. 17	[d] .28
30	.28
Feb. 13	.28
27	.28
Mar. 13	.28
27	.28
Apr. 10	.28
24	.28
1961—Continued	
May 8	0.28
Aug. 7	.26
1962	
Jan. 17	[d] .29
27	.29
Feb. 14	.29
Mar. 8	.29
21	.34
Apr. 9	.34
June 5	.26
19	.26
July 11	.27
30	.25
Aug. 13	.25
31	.25
Sept. 10	.25
27	.25
1962—Continued	
Oct. 9	0.25
Dec. 28	[d] .28
1963	
Mar. 19	.28
30	.28
May 1	.28
June 4	.29
July 1	.29
Aug. 1	.25
Oct. 1	.29
Nov. 1	.29
Dec. 1	.29
30	.28
1964	
Jan. 17	[d] .29

27/1-23R1, 25D1, 25D2, and 26A1-7; combined flow

[Travertine Springs. Measured below pool by 9-in. Parshall flume]

Date	Discharge
1956	
Apr. 29	1.88
May 17	1.88
June 21	1.88
July 1	1.86
22	1.86
Aug. 1	1.86
17	1.86
26	1.86
Sept. 7	1.86
18	1.86
28	1.86
Oct. 8	1.86
18	1.86
Nov. 1	1.86
20	1.86
28	[d] 1.94
30	1.86
Dec. 1	[d] 1.94
10	1.86
12	[d] 1.92
20	1.86
31	1.86
1957	
Jan. 10	1.86
18	1.86
22	[d] 1.94
26	1.86
Feb. 5	1.86
Mar. 1	[d] 1.90
1	1.90
21	1.88
Apr. 3	[d] 1.88
June 4	1.82
20	[d] 1.82
Aug. 22	1.74
Sept. 20	1.72
Oct. 23	1.76
Nov. 6	1.76
29	[d] 1.76
Dec. 5	1.76
1958	
Jan. 8	1.76
1958—Continued	
Feb. 4	1.74
Mar. 6	1.68
Apr. 8	[e] 1.94
29	1.82
May 14	[d] 1.86
27	1.82
June 25	1.82
July 25	1.78
Aug. 27	1.82
Sept. 25	1.86
Oct. 21	1.88
Nov. 13	1.88
13	[d] 1.92
24	[d] 1.92
Dec. 9	1.88
1959	
Jan. 6	1.86
29	1.88
Mar. 3	1.86
May 6	1.78
June 3	1.82
July 9	1.78
Aug. 6	1.82
Oct. 29	1.78
Nov. 9	[d,f] 1.78
9	[d,g] 1.72
Dec. 4	1.82
1960	
Jan. 12	1.82
Feb. 11	1.94
Mar. 15	1.86
Apr. 19	1.82
May 20	1.82
June 21	1.82
July 21	1.82
Aug. 15	1.82
Sept. 8	1.82
Oct. 9	1.82
Nov. 10	1.82
Dec. 9	1.82
1961	
Jan. 17	[d] 1.86
30	1.86
Feb. 13	1.86
27	1.86
Mar. 13	1.86
27	1.86
Apr. 10	1.86
21	1.86
May 8	1.78
Aug. 7	1.82
1962	
Jan. 17	[d,i] 1.92
27	1.82
Feb. 14	1.86
Mar. 8	1.86
21	1.88
Apr. 9	1.86
June 5	1.86
19	1.86
July 11	1.82
30	1.86
Aug. 13	1.86
31	1.82
Sept. 10	1.86
27	1.86
Oct. 9	1.86
Dec. 28	[d] 1.90
1963	
Mar. 19	1.90
30	1.86
May 1	1.90
June 4	1.86
July 1	1.86
Aug. 1	1.86
Oct. 1	1.90
Nov. 1	1.86
Dec. 1	1.86
30	1.82
1964	
Jan. 17	[d] 1.90

See footnotes at end of table.

TABLE 3.—*Periodic measurements of ground-water discharge in the Furnace Creek Wash area*—Continued

27/1-26B1—sump in Furnace Creek Wash

[Measurement at outlet of settling box by 18-in. rectangular weir]

Date	Discharge	Date	Discharge	Date	Discharge
1941		*1958*		*1961*—Continued	
Jan. 9	[a] 0.97	Jan. 9	1.46	Jan. 30	1.24
		Feb. 4	1.42	Feb. 13	1.20
1956		Mar. 6	1.44	27	1.20
Apr. 29	1.20	Apr. 8	1.33	Mar. 13	1.20
May 17	1.20	30	1.33	27	1.20
June 21	1.20	May 14	[d] 1.28	Apr. 10	1.20
July 1	1.20	27	1.33	24	1.20
22	1.20	June 25	1.28	May 8	1.20
Aug. 17	1.20	July 25	1.28	Aug. 7	1.24
26	1.20	Aug. 27	1.27		
Sept. 7	1.20	Sept. 25	1.33	*1962*	
18	1.20	Oct. 21	1.33	Jan. 17	[d] 1.28
28	1.20	Nov. 13	1.42	27	1.24
Oct. 8	1.20	13	[d] 1.42	Feb. 14	1.33
18	1.20	24	[d] 1.46	Mar. 8	1.33
Nov. 1	1.20	Dec. 9	1.33	21	1.28
20	1.20			Apr. 9	1.24
28	[d] 1.26	*1959*		June 5	1.28
30	1.20	Jan. 6	1.33	19	1.28
Dec. 10	1.20	29	1.37	July 11	1.28
12	[d] 1.26	Mar. 5	1.37	30	1.28
20	1.20	May 6	1.33	Aug. 13	1.28
31	1.20	June 3	1.24	31	1.24
		July 9	1.33	Sept. 10	1.24
1957		Aug. 6	1.24	27	1.24
Jan. 10	1.20	Oct. 29	1.65	Oct. 9	1.24
15	[d] 1.26	Nov. 9	[d] 1.65	Dec. 28	[d] 1.26
18	1.20	Dec. 4	1.28		
26	1.20			*1963*	
Feb. 5	1.20	*1960*		Mar. 19	1.28
Mar. 1	[d] 1.28	Jan. 12	1.46	30	1.28
1	1.28	Feb. 11	1.37	May 1	1.33
21	1.30	Mar. 17	1.37	June 4	1.28
Apr. 3	[d] 1.30	Apr. 19	1.28	July 1	1.28
June 4	1.27	May 20	1.24	Aug. 1	1.28
20	[d] 1.28	June 21	1.24	Oct. 1	1.28
Aug. 22	1.24	July 21	1.24	Nov. 1	1.24
Sept. 1	1.30	Aug. 15	1.24	Dec. 1	1.28
Oct. 23	1.42	Sept. 18	1.24	30	1.28
Nov. 6	1.46				
29	[d] 1.46	*1961*		*1964*	
Dec. 5	1.46	Jan. 17	[d] 1.20	Jan. 17	[d] 1.30

27/1-26B2—buried tile in Furnace Creek Wash

[Measured at outlet of settling box by 12-in. rectangular weir]

Date	Discharge	Date	Discharge	Date	Discharge
1956		*1956*—Continued		*1958*—Continued	
Feb. 23	0.44				
Mar. 8	.44	Dec. 10	0.44	Feb. 4	0.45
25	.44	20	.44	Mar. 6	.47
Apr. 29	.44	31	.44	Apr. 8	.42
May 17	.44			May 27	.37
June 21	.44	*1957*		June 25	.37
July 1	.44	Jan. 10	.44	July 25	.27
22	.44	18	.44	Aug. 27	.36
Aug. 1	.44	26	.44	Sept. 25	.37
17	.44	Feb. 5	.44	Oct. 21	.37
26	.44	Mar. 1	[d] .43	Nov. 13	.37
Sept. 7	.44	21	.44	Dec. 9	.37
18	.44	June 4	.43		
28	.44	Aug. 22	.44	*1959*	
Oct. 8	.44	Sept. 20	.44	Jan. 6	.37
18	.44	Oct. 23	.42	29	.37
Nov. 1	.44	Dec. 5	.43	Mar. 5	.41
20	.44			May 6	.38
28	[d] .45	*1958*		June 3	.42
30	.44	Jan. 9	.45	July 9	.37

See footnotes at end of table.

TABLE 3.—*Periodic measurements of ground-water discharge in the Furnace Creek Wash area*—Continued

27/1-26B2—buried tile in Furnace Creek Wash—Cont.

Date	Discharge	Date	Discharge	Date	Discharge
1959—Continued		*1961*—Continued		*1962*—Continued	
Aug. 6	0.40	Jan. 30	0.43	Aug. 13	0.40
Oct. 29	.42	Feb. 13	.42	31	.40
Nov. 9	[d] .43	27	.42	Sept. 10	.40
Dec. 4	.43	Mar. 13	.42	27	.40
		27	.42	Oct. 9	.40
1960		Apr. 10	.42	Dec. 28	[d] .40
Jan. 12	.44	24	.42		
Feb. 11	.44	May 8	.31	*1963*	
Mar. 16	.43	Aug. 7	.42	Mar. 19	.42
Apr. 19	.42			30	.42
May 20	.42	*1962*		May 1	.44
June 21	.42	Jan. 17	[d, k] .37	June 4	.42
July 21	.42	27	.42	July 1	.42
Aug. 15	.42	Feb. 14	.40	Aug. 1	.42
Sept. 8	.42	Mar. 8	.40	Oct. 1	.42
Oct. 9	.43			Nov. 1	.42
Nov. 10	.43	Apr. 9	.42	Dec. 1	.42
Dec. 9	.43	June 5	.44	30	.42
		19	.44		
1961		July 11	.40	*1964*	
Jan. 17	[d] .42	30	.42	Jan. 17	[d] .43

27/1-26B3—Trench in Furnace Creek Wash

[Measured by 3-in. Parshall flume. Trench destroyed by flash flood in September 1959]

1957		*1958*—Continued		*1958*—Continued	
June 20	[d] 0.24	Feb. 4	0.23	Nov. 24	[d] 0.35
Aug. 21	.24	Mar. 6	.23	Dec. 9	.36
Sept. 20	.22	Apr. 8	.23		
Oct. 23	.22	May 1	([h])	*1959*	
Nov. 6	.23	27	.36		
29	[d] .23	June 25	.34	Jan. 29	[j] .50
Dec. 5	.23	July 25	.34	Mar. 5	.38
		Aug. 27	.35	May 6	.37
1958		Sept. 25	.35	Aug. 6	[j] .46
		Oct. 21	.35		
Jan. 9	.23	Nov. 13	[d] .35		

27/1-23R1—Travertine Spring

Measurement in ditch near source by 18-in. rectangular weir		Measurement in ditch about ¼ mile from source by 18-in. rectangular weir	
1957		*1957*	
Jan. 19	0.68	Jan. 19	0.60
Feb. 26	.60	Feb. 26	.59
Mar. 7	.64	Mar. 7	.59
Apr. 3	.60	Apr. 3	.57
June 20	Weir destroyed.	June 20	.53

See footnotes at end of table.

TABLE 3.—*Periodic measurements of ground-water discharge in the Furnace Creek Wash area*—Continued

27/1-25D1 and 26A1—Travertine Springs

[Measurements by Geol. Survey]

Measurement in ditch above area of dense phreatophyte growth by 90° V-notch weir		Measurement in ditch below area of dense phreatophyte growth by 90° V-notch weir	
1957		*1957*	
Jan. 19	0.23	Jan. 19	0.23
Feb. 26	.28	Feb. 26	.23
Mar. 7	.23	Mar. 7	.23
Apr. 3	.22	Apr. 3	.22
June 20	.23	June 20	.23

28/1-36G1—Nevares Spring

[Measurements by Geol. Survey. Measurements at point A for 1951 by 12-in. rectangular weir by Robinson (written commun.); measurements for 1956 by 3-in. Parshall flume. Apparent change in discharge may be due to change in measuring device]

Measurement in ditch near source by 3-in. Parshall flume		Measurement in ditch about 0.2 mile downsteam from source; point A of Robinson (written commun., 1956)	
1956		*1951*	
		Oct. 15	0.526
Nov. 28	0.60	17	.526
30	.61	19	.526
Dec. 14	.59	*1956*	
1957		Nov. 30	.47
		Dec. 1	.47
Jan. 21	.60	14	.47

[a] Estimated by National Park Service.
[b] Discharge from Texas Spring prior to construction of tunnel.
[c] Does not include Park Service diversion to campground.
[d] Measurement by Geological Survey.
[e] Spring cleaned out.
[f] Growth of "tules" in pool above flume.
[g] Growth of "tules" removed.
[h] Trench enlarged.
[j] Value probably too high owing to growth of vegetation.
[k] Value estimated to be 5 percent too low owing to leakage past measuring point.

TABLE 4.—*Total estimated rate of ground-water discharge in 1956–57 in the Furnace Creek Wash area*

[All values from table 3, except as indicated]

Name or general location of discharge point	*Flow (cubic feet per second)*
FURNACE CREEK DRAINAGE AREA	
Travertine Springs diverted to DVHCO irrigation system: 27/1-23R1, 25D1, 25D2, 26A1, 26A2, 27/1-26A3, 26A4, 26A5, 26A6, 26A7	1.9
Texas Spring tunnel 27/1-23B1	.5
Undeveloped springs, seeps, or phreatophyte areas (est.)	.1
Evapotranspiration above points of measurement (est.)	.5
Sump 27/1-26B1 in Furnace Creek Wash	1.3
Buried tile 27/1-26B2 in Furnace Creek Wash	.4
Furnace Creek Inn tunnel 27/1-22H1	.3
NPS well 27/1-23P1 in Furnace Creek Wash	0
Underflow to Death Valley	Unknown
Total flow, Furnace Creek drainage area, excluding underflow	5.0

TABLE 4.—*Total estimated rate of ground-water discharge in 1956–57 in the Furnace Creek Wash area*—Continued

Name or general location of discharge point	*Flow (cubic feet per second)*
COW CREEK DRAINAGE AREA	
Nevares Spring, 28/1-36G1	0.6
Cow Spring and other undeveloped springs	[a] .1
Underflow to Death Valley	Unknown
Total flow, Cow Creek drainage area, excluding underflow	.6
Combined flow, Furnace Creek and Cow Creek drainage areas, excluding unknown underflow to Death Valley	5.6

[a] This water is believed to be reemergent from Nevares Spring; it is not included in total.

GROUND-WATER RECHARGE

As already stated, ground-water recharge and discharge under long-term nztural conditions must be equal. Because the total ground-water discharge in the Furnace Creek Wash area is estimated as a minimum of 5.6 cfs, because the ground-water discharge of the springs in this area are reported to remain nearly constant,[1] and because the values indicated in table 4 do not include underflow to Death Valley, the recharge to the area considered must be at least 5.6 cfs.

Publications of the U.S. Weather Bureau show that average annual rainfall at the Cow Creek weather station at Park headquarters is approximately 2 inches. At Beatty, Nev., in the Amargosa Desert east of the Funeral Mountains, the average annual rainfall is almost 5 inches. In the desert most of the rain falls on the mountains rather than on the valley floors, but unfortunately no precipitation records are available for the Funeral Mountains. However, it is possible that a long-term average precipitation of 10 inches per year occurs on the drainage area in the Funeral Mountains tributary to the Furnace Creek Wash area.

Below Travertine Springs and downstream to the Furnace Creek Inn, ground water saturates part of the unconsolidated gravel underlying Furnace Creek. Upstream from the springs the wash appears to be devoid of underflow; near Zabriskie Point, where the drainage has been diverted to Gower Gulch, floods have swept the wash clear of gravel, and the underlying lacustrine deposits of Tertiary age are exposed at the surface. Accordingly, the area draining into Furnace Creek upstream from Zabriskie Point was omitted from consideration, and only the watershed tributary to that part of the pediment

[1] Reports by Park Service and U.S. Borax and Chemical Corp. personnel indicate no appreciable change in the discharge from the springs; however, records have not been maintained for a period long enough to verify these reports.

slope between Travertine Springs and Nevares Springs, including all the washes from Echo Creek just south of Travertine Springs to Cow Creek at Nevares Springs, was delineated and its area measured with a planimeter. This area extends a considerable distance back into the Funeral Mountains beyond the limits of the map shown on plate 1.

By arbitrarily using the 1,600-foot contour line as the lower limit of appreciable precipitation, the area was found to be about 30 square miles. Multiplying this by the crude estimate of 10 inches of rainfall gives an amount equivalent to about 300 inches on 1 square mile a year, which in turn is equivalent to a continuous flow of somewhat more than 20 cfs. This is roughly four times the amount of discharge measured in the area. However, very little of this precipitation is available for recharge. The bulk of it is evaporated, is required to satisfy soil-moisture deficiency, or otherwise is lost before reaching the ground-water table. Troxell (1954) indicates that no simple correlation exists between precipitation and recoverable water, the proportion depending largely on the absorptive and retentive conditions of the mantle rock, the altitude, the natural water losses, and many other less important influences.

There is a possibility that geologic and hydrologic conditions in Furnace Creek Wash at Zabriskie Point are similar to those in the small wash at spring 27/1–23F1. That is, there may be underflow in the wash at this point, but it is entirely in the cracks and fissures or along faults and bedding planes of the lacustrine deposits of Tertiary age. Also, dipping beds and faults striking northwest between Furnace Creek and the Funeral Mountains could conceivably furnish an adequate system of conduits bypassing Furnace Creek Wash entirely. In either case, assuming underflow past Zabriskie Point, the large Greenwater Valley drainage area between the Funeral Mountains and the Black Mountains, south of the area mapped and therefore not shown on plate 1, could be added to the watershed area and thus increase it about five times. This would give a supply from rainfall about 20 times the amount of the measured discharge. Although the amount of precipitation and the proportion that becomes recharge to ground water are unknown for the Death Valley region, there appears to be sufficient recharge from this source to explain all measured ground-water discharge in the area.

RELATION OF GEOLOGY TO THE OCCURRENCE OF SPRINGS

From the data collected and observations made during this investigation it is not possible to determine the relation of the geology to the occurrence of the springs. Points of ground-water discharge by the springs in the Furnace Creek Wash area occur in all the unconsolidated and semiconsolidated geologic units described in this report. Therefore, to explain the occurrence, source, and movement of ground water in the area four alternate hypotheses are advanced.

The first hypothesis assumes that the water from precipitation at higher altitudes within the tributary drainage area ultimately percolates into a network of interconnecting cracks, fractures, and faults, and under the influence of gravity moves toward points of lower head, in the manner shown in figure 2. Under these circumstances virtually all the water contained in ground-water storage would occur in the cracks, fractures, and faults, and only very minor amounts would occur in the permeable unconsolidated deposits. Under these conditions it generally would be impractical to develop an additional water supply by drilling deep wells at or near the springs, because it is unlikely that a sufficient number of cracks and fractures would be tapped by the well bore to yield water in usable quantities.

The second hypothesis assumes a system very similar to the first in which water is transmitted through cracks, fractures, and faults in the basement complex and possibly in some of the semiconsolidated deposits. However, it is possible that the main flow, after percolating from the basement complex into the semiconsolidated and unconsolidated alluvial deposits, is concentrated in pipes or conduits of travertine that were formed by the springs contemporaneously with the deposition of the alluvial material, in the manner shown in figure 3.

If the second hypothesis is correct, it also would be impractical to develop an additional supply of water by a well drilled into a spring zone. Even if it were possible to drill a well down the spring conduit to pump large quantities of water, it is likely that construction of the well would destroy the travertine conduits and cause the water to discharge at some other point.

The third hypothesis assumes that water from precipitation at higher altitudes within the tributary area percolates into the unconsolidated and semiconsolidated deposits and moves from the recharge area toward the points of discharge. Under these conditions all the pore spaces in the deposits beneath the water table would be saturated or full of water. Where the water table intersects the surface, springs occur in the manner shown in figure 4. However, by this hypothesis it is difficult to explain the high temperature of the water except through contact with fault zones or heated igneous rocks.

Under these circumstances it would be feasible to drill a test well at a structurally favorable geologic site, such as along the syncline southeast of Texas Springs (pl. 1), away and upgradient from the springs. If a sufficient thickness of permeable deposits were pene-

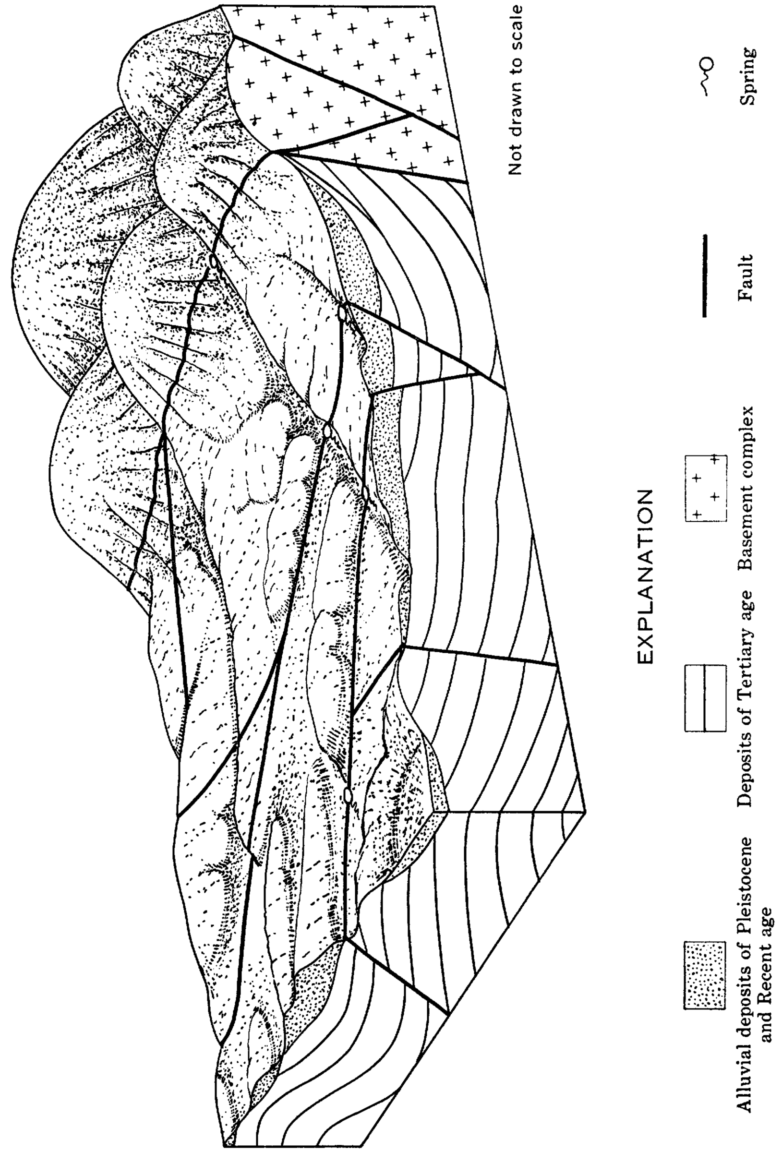

FIGURE 2.—Generalized block-diagram showing possible relation of springs to geology; hypothesis 1.

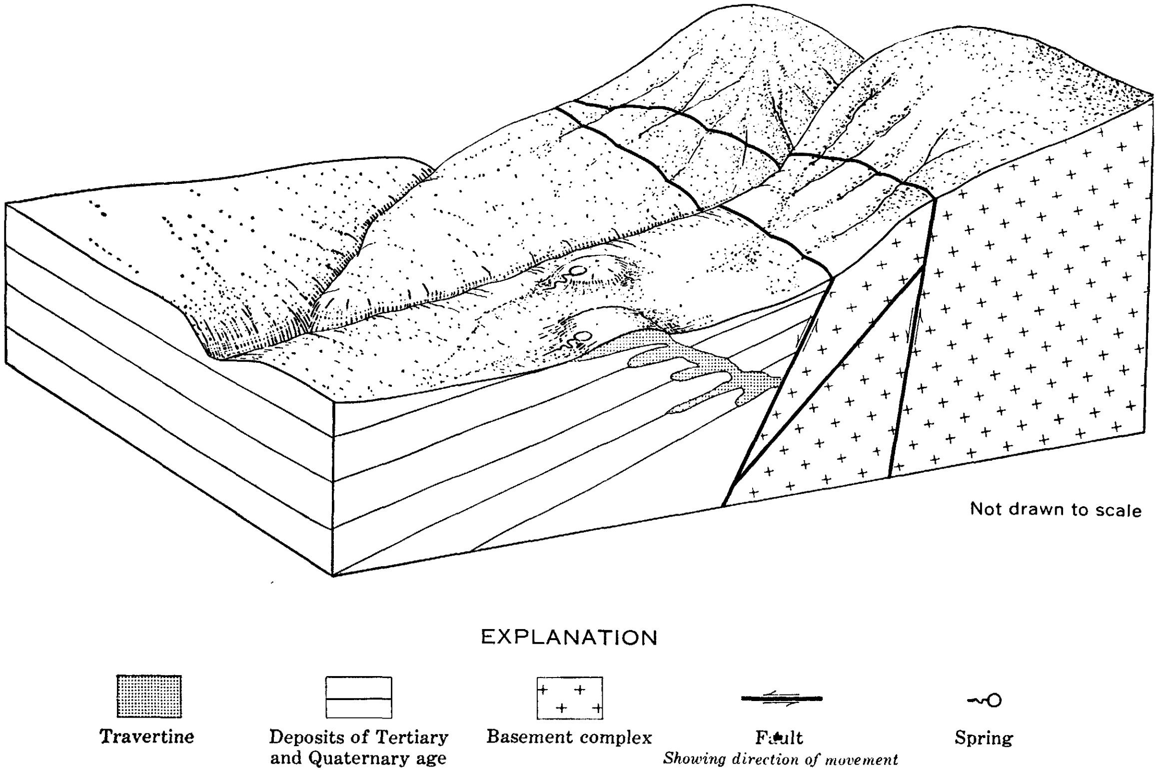

Figure 3.—Generalized block-diagram showing possible relation of springs to geology; hypothesis 2.

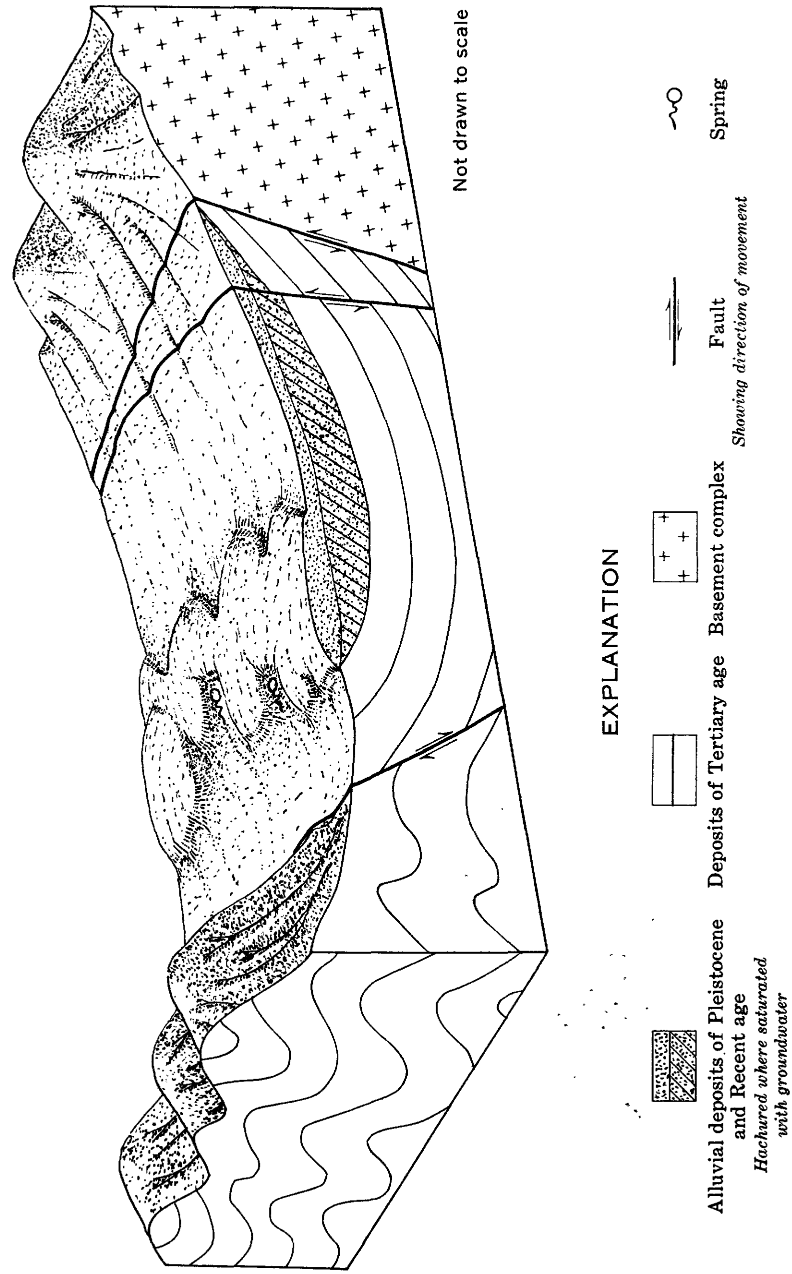

FIGURE 4.—Generalized block-diagram showing possible relation of springs to geology; hypothesis 3

trated by the well bore, it might be possible to pump large quantities of water. Depending on the quantity of water in storage and the hydraulic relationships of the stored water to the springs, it might be possible to pump large quantities of water for many years without causing an appreciable change in the rate of discharge from the springs. On the other hand, pumping of wells might cause an immediate and appreciable decline in the rate of discharge from the springs. However, if pumping from wells would cause a decrease in the rate of discharge from the springs, the wells would yield water more efficiently than the springs, because water that would normally be wasted by phreatophytes and evaporation could be salvaged. Moreover, water could be withdrawn from ground water in storage during peak demand and not wasted by natural discharge during periods of little demand. Consequently, larger quantities of ground water could be used for beneficial purposes than at present.

A fourth hypothesis assumes a combination of the first three hypotheses. The main source of the water might be from precipitation transmitted by cracks, fractures, and faults, and possibly by travertine conduits. However, some of the water might recharge the unconsolidated and semiconsolidated deposits by lateral leakage from fault zones or conduits or by return to ground water of water from springs at a higher altitude, thereby becoming available for discharge of springs at a lower altitude or for possible development by wells, as described in the third hypothesis.

All four hypotheses quite possibly may be correct for the Furnace Creek Wash area. For example, Travertine Springs 27/1–23K1, 23K2, 23J1, 23J2, 21R1, 21R2, 21R3, 24N1, 25D1, and 25D2, which are closely associated with a fault, may yield water from a fracture and fault system as described in the first hypothesis. Nevares Springs 28/1–36G1, 36G2, and 36K1, which occur in a travertine deposit but also are closely associated with a fault, may yield water from a system of fractures, faults, and travertine pipes or conduits as described in the second hypothesis.

Some of the springs along the zone between Travertine and Texas Springs may be recharged as described by the third hypothesis, which assumes direct infiltration of precipitation into the water-yielding deposits.

The fourth hypothesis, which assumes recharge of the unconsolidated deposits by leakage or return to ground water from spring discharge at higher altitudes, undoubtedly explains some of the discharge of the cooler waters (lower than 90°F) in the vicinity of Cow Creek. This also is the most likely source for the underflow in Furnace Creek Wash.

DESCRIPTIONS OF THE PRINCIPAL SPRINGS

TRAVERTINE-TEXAS SPRINGS AREA

Geologically and hydrologically the springs in the local Travertine-Texas Springs area form one group. Identification of any single discharge point as being a Travertine, Texas, or an undeveloped spring (tables 1, 2) is only a matter of determining which of two water-collecting systems the springs discharge into. In addition to the springs a tunnel at Furnace Creek Inn, a sump, a buried tile, a well, and a newly constructed trench in Furnace Creek Wash also are included as discharge points in the Travertine-Texas Springs area.

Travertine Springs.—Flow from 10 discharge points, identified as Travertine Springs (tables 1, 2), is collected by a system of ditches and shallow trenches and conveyed in a concrete flume to Furnace Creek Wash. The total flow from Travertine Springs that is carried by the concrete flume is measured by a 9-inch Parshall flume for the period of April 29, 1956, through November 29, 1957, and ranged from 1.76 to 1.94 cfs (table 3). All this water is diverted to the main irrigation ditch of the U.S. Borax and Chemical Corp.

To check the total discharge of Travertine Springs the discharge of each of the 10 points (table 1) was measured independently by a weir or estimated by measuring the cross-sectional area of the ditch (pocket tape) and the velocity of the flow (stopwatch). On January 17, 1957, the total flow of the points independently measured or estimated was 1.9 cfs.

To determine whether there was a loss or gain of water in the unlined ditches between the points of uppermost discharge and the collection points in the concrete flume, pairs of weirs were set in two of the ditches of Travertine Springs. Measurements taken between one pair of 18-inch rectangular weirs about a quarter of a mile apart showed a very small difference (table 3). These differences averaged less than 0.05 second-foot. However, the differences measured are more apparent than real, because they are within the limits of error of the measurements and are not considered significant. No measurable difference was observed between a pair of 90° V-notch weirs set approximately 75 feet apart in an area of very dense phreatophyte growth.

Texas Springs.—The Texas Springs of this report include the group of discharge points at 27/1–14N1, 14P1, 14Q1, 23B1 (known as Texas Spring), 23B2, 23B3, 23B4, 23G1, and 23G2. Texas Spring (27/1–23B1) is a horizontal tunnel about 330 feet long dug into the side of the hill where it apparently intersects the water table. The observed discharge is from permeable lenses of gravel and gravel and sand. The tunnel has three vertical air vents and on a small scale is very similar to the kanats drilled by the ancient Persians (Tolman, 1937). The flow from the tunnel from February 9, 1956 ,through November 6, 1957, was measured at 0.5 cfs by an 18-inch rectangular weir (table 3). Measurements reported by the Park Service indicate that the discharge of Texas Spring in 1926 (presumably before construction of the tunnel) was 0.28 cfs, and on January 9, 1941 (after construction of the tunnel), was 0.38 cfs.

Part of the water from Texas Spring is diverted to the Texas Spring campground and the balance is diverted to the irrigation system of the U.S. Borax and Chemical Corp.

Undeveloped springs.—In addition to the 11 developed springs there are 27 undeveloped springs, seeps, and phreatophyte areas (tables 1 and 2) in the Travertine-Texas area (pl. 1). The discharge from each of these points is so small that it is impracticable to attempt to measure the flow from them by direct means. However, the total discharge from these 27 points is estimated at 0.1 cfs.

Evapotranspiration.—In the Travertine-Texas Springs area above the points of measured spring discharge, phreatophytes (predominantly mesquite) arrowweed, desert baccharis, saltgrass, and locally reed grass and a rush) cover approximately 300 acres at about 25 percent volume density. This coverage is equivalent to a growth of 100 percent volume density on an area of about 75 acres. Using an average value of about 5 feet per acre for the annual evapotranspiration for 100 percent volume density for these phreatophytes (T. W. Robinson, oral commun., 1956), a total of about 375 acre-feet for the total annual evapotranspiration is obtained, which is equivalent to a sustained flow of about 0.5 cfs, the value used in table 4.

Sump in Furnace Creek Wash.—The U.S. Borax and Chemical Corp. has bulldozed a large sump (27/1–26B1) in the gravel channel of Furnace Creek Wash. The bottom is several feet below the water table in the wash, and the sump intercepts ground-water underflow beneath the channel of the wash. This flow, collected in a ditch and conveyed into the irrigation distribution system of the Borax Corp. and measured by an 18-inch rectangular weir, ranged from 1.3 to 1.5 cfs for the period April 29, 1956, through November 29, 1957 (table 3). The Park Service (written commun., 1941) indicated that on January 9, 1941, the flow was 0.97 cfs. This difference in discharge is not considered significant, because the 1941 value is an estimate, and the limits of error for the estimate probably are greater than the difference between the 1941 estimate and the later weir measurements.

Buried tile in Furnace Creek Wash.—Park Service records and reported information from the U.S. Borax and Chemical Corp. indicate that a buried tile (27/1–26B2) exists in Furnace Creek Wash about 400 feet downstream from sump 27/1–26B1. Records do not indicate the exact position and depth of the tile, but it is reported that it extends across the channel of Furnace Creek Wash about at the position shown on plate 1. Flow from the tile is conveyed in a 6-inch buried pipe to Furnace Creek Inn and Ranch where it constitutes the domestic supply.

The flow from the buried tile was measured by an 18-inch rectangular weir in a junction box along the 6-inch line about 1,600 feet down Furnace Creek Wash from sump 27/1–26B1. The measured flow ranged from 0.42 to 0.45 cfs for the period February 23, 1956, through October 23, 1957 (table 3). Some of the apparent differences in flow probably are due to different individuals measuring the flow. However, the error or difference is very small and is not significant. The Park Service estimated or measured a flow of 0.275 cfs in 1941, apparently at the same junction box used in 1956–57, and estimated or measured a flow of 0.515 cfs at another junction box about 400 feet downstream from the U.S. Borax and Chemical Corp. sump 27/1–26B1. The site of this junction box was visited during 1956 by the Geological Survey, but the installation had been destroyed. The reasons for the large difference in the values reported by the Park Service are not known. However, because of the uncertainty regarding the physical position and condition of the installation and because parts of the pipelines have been destroyed during infrequent flash floods in Furnace Creek Wash and rebuilt thereafter, it is possible that the Park Service and the Geological Survey did not measure water from the same source, even though some of their measurements apparently were made at the same site. For these reasons it is not believed that the values reported by the Park Service and the Geological Survey are comparable.

Furnace Creek Inn tunnel.—In about 1935 the U.S. Borax and Chemical Corp. constructed a tunnel about 700 feet long north of Furnace Creek Inn, starting on the west side of a hill west of Furnace Creek Wash and extending through the hill to a point near or under the west side of the wash. At the end of the tunnel a concrete bulkhead was constructed and approximately a dozen sand points were driven about 10 feet beyond the end of the tunnel. The combined discharge of these sand points (27/1–22H1) was measured periodically from February 18 through November 6, 1957, and ranged from 0.15 to 0.45 cfs (table 3). This flow is collected in a pipeline and is part of the U.S. Borax and Chemical Corp. irrigation supply.

Wells in Furnace Creek Wash.—Prior to the drilling of the test well the only known well in the area of this study was 27/1–23P1, a 19-foot dug well in Furnace Creek Wash. This well now is unused, but reportedly was pumped at several hundred gallons per minute. Presumably at that time the water level was higher than it was during this investigation. The depth to water below land surface in this well for the period from November 27, 1956, through June 19, 1957, ranged from 15.09 feet to dry at 19 feet (table 1). The Park Service reported that another well existed in Furnace Creek Wash near Furnace Creek Inn. The well reportedly was 16 feet deep, the depth to water was 11½ feet below the land surface, and it was pumped at 157 gpm. Sometime between 1941 and 1948 the well was destroyed.

Park Service trench in Furnace Creek Wash.—During May and June 1957 the Park Service constructed a trench (27/1–26B3) across part of Furnace Creek Wash. This trench lies between well 27/1–23P1 and buried tile 27/1–26B2. The trench intersects the water table, and the flow for the period June 20 through November 6, 1957, measured by a 3-inch Parshall flume, ranged from 0.22 to 0.24 second-foot (table 3). This flow is now temporarily added to the irrigation supply of the U.S. Borax and Chemical Corp.

Unmeasured underflow to Death Valley.—As indicated by the combined flow of the tunnel and sand points 27/1–22H1, sump 27/1–23B1, buried tile 27/1–26B2, and trench 27/1–26B3, the total underflow in Furnace Creek Wash is at least 2.27 second-feet during part of the year. In addition to these measured values, which are included in table 4, there is an additional and unknown quantity of underflow that is not intercepted.

To determine the total underflow in Furnace Creek Wash it would be necessary to determine the elements of the following equation:

$$Q = TId$$

where Q is the ground-water underflow in gallons per day, T is the coefficient of transmissibility of the total thickness of the saturated water-bearing section in gallons per day per foot for each lineal mile, I is the hydraulic gradient of the water surface in feet per mile, and d is the lineal distance, in miles, along a selected water-level contour. To determine all these elements would necessitate several test wells and pumping tests in Furnace Creek Wash, which were beyond the scope of this investigation.

NEVARES SPRINGS AREA

Nevares Springs.—Discharge points 28/1–36G1, 36G2, 36K1, 36M1, and 36M2 comprise Nevares Springs (pl. 1). The main flow is from a group of discharge points on top of a travertine spring mound identified as 28/1–36G1. For the period from November 29, 1956, through January 21, 1957, the flow from 28/1–36G1, measured by a 3-inch Parshall flume, was 0.6 second-foot (tables 1, 3). The flow from discharge point 28/1–36G2, in a wash at the base of the travertine mound, was measured at 0.05 second-foot (table 1). The discharge from 28/1–36K1, about 1,500 feet south of 28/1–36G2, is at a very low rate of seepage and not measurable by direct means.

As a check on the flow from 28/1–36G1, a second 3-inch Parshall flume was set in the unlined ditch about 0.2 mile downstream. This corresponds to point *A* of Robinson (written commun., 1951), and in both 1951 and 1956 the flow was measured at 0.5 second-foot. These measurements (table 3) indicate a small loss of about 0.1 second-foot between the spring and the point 0.2 mile downstream, which probably is due largely to seepage loss. Robinson (written comm., 1951) reported that dye tests were used to determine whether water from Nevares Springs returned underground and reemerged at springs 28/1–36M1 or 36M2, but the tests were inconclusive. However, springs 28/1–36G1, 36M1, and 36M2 are in the same alluvial-filled channel of Cow Creek, so even though loss to ground water from spring 36G1 and reemergence of spring water at 36M1 and 36M2 cannot be proved, there is a strong possibility that the loss and reemergence does occur. Therefore, the total flow of Nevares Springs is estimated at 0.6 cfs, which is the maximum flow measured at the highest altitude of discharge at spring 28/1–36G1.

Cow Spring and other undeveloped springs.—Downgradient from Nevares Springs there are 10 undeveloped springs. Of these, only Cow Spring (27/1–3A1) is named. The flow from Cow Spring on March 5, 1957, was estimated at 0.04 cfs. Spring 28/1–35N1 was estimated to have a discharge of 0.01 cfs, and the combined discharge of the other eight springs was estimated at less than 0.05 cfs. Therefore, the estimated discharge from the 10 undeveloped springs did not exceed 0.1 cfs, and this is also believed to be reemergent water from Nevares Springs.

Salt Springs.—Springs 27/1–3K1 and 3P1 have an estimated combined discharge of about 0.01 cfs. These springs are of little consequence as a source of water, but are of interest because of their high chloride content (table 5), particularly 27/1–3P1, which is described in the following section of the report.

CHEMICAL QUALITY OF GROUND WATER

Analyses of spring and well water in the Furnace Creek Wash area are shown in table 5. The water analyzed is of the sodium bicarbonate sulfate type. (For description of water-type classification, see Piper, Garrett, and others, 1953, p. 26, footnote.) Water from Travertine and Texas Springs contains dissolved solids of about 600 ppm (parts per million). Water from Nevares and Cow Springs ranges from about 600 to 1,400 ppm. Water from the test well contains dissolved solids (sum of determined constituents) of 569 ppm.

TABLE 5.—*Chemical analyses of spring water in the Furnace Creek Wash area*

Constituents are in parts per million. All values are rounded to conform to the standards of the Geological Survey, Quality of Water Branch. Values preceded by the letter *a* were calculated and are approximate.
Source of data: DPH, California Department of Public Health; DWR, California Department of Water Resources; NPS, U.S. National Park Service; USGS, U.S. Geological Survey.

Temperature: The temperature of the water is at the point of collection, in degrees Fahrenheit. For the temperature of the water at the point of discharge, see table 1.
Dissolved solids by evaporation, analytically determined.
Dissolved solids calculated: Arithmetic total of all constituents determined, except for bicarbonate which is divided by 2.03 to obtain the carbonate equivalent.

USGS No.	Date collected	Lab. or Field No.	Source of data	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: By evaporation	Dissolved solids: Calculated	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
27/1-3A1	4-8-55	P631-311	DWR	100	----	----	45	20	146	10	----	345	0	178	37	2.0	1.9	0.61	603	611	*a*195	60	702	8.3
3K1	12-1-56	21083	USGS	----	----	----	----	----	----	----	----	----	----	----	180	3.6	----	11	----	----	46	----	2,360	----
3P1	12-1-56	21084	USGS	73	----	----	----	----	----	----	----	----	----	----	22,200	11	----	327	----	----	214	----	56,800	----
22H1	4-5-57	T369-2171	DWR	91½	26	----	40	22	180	13	----	378	0	208	50	2.5	0	1.6	810	*a*729	*a*190	*a*65	1,140	7.6
23B1	11-27-53	S206-3767	DWR	----	----	----	36	21	160	11	----	310	17	166	54	4.0	0	1.0	634	623	*a*176	*a*65	1,000	8.5
23B1	4-11-56	R1125-3696	DWR	87	----	----	35	18	154	12	----	342	----	156	35	3.7	1.9	.88	607	584	*a*162	65	953	7.8
23B1	4-5-57	T370-2122	DWR	91	25	----	35	20	155	12	----	348	0	160	43	2.0	0	1.0	716	*a*599	*a*170	*a*65	1,010	7.9
23R1, 25D1-2, 26A1-7	4-22-54	4226-2718	DWR	90	----	----	38	20	150	14	----	354	0	165	40	4.0	1.0	.86	593	606	*a*177	*a*63	966	8.1
	4-11-56	R1125-3697	DWR	88	----	----	36	19	159	12	----	351	0	169	37	4.0	3.7	.88	616	613	*a*168	65	968	7.7
25D1	3-25-54	----	USGS	90	43	----	26	22	145	11	0.13	321	----	158	39	3.0	0	0	----	605	*a*155	*a*65	949	8.0
26B1	4-11-56	R1126-3698	DWR	80	----	----	40	20	160	12	----	363	0	179	41	4.0	2.9	1.5	644	639	*a*182	64	1,020	7.5
28/1-34N1	12-1-56	21082	USGS	74	----	----	52	38	253	16	----	455	0	a352	74	4.4	----	1.3	----	*a*1,010	284	64	1,580	7.7
36G1	11-30-53	S194-3764	DWR	----	----	----	38	32	250	15	----	403	10	307	77	4.0	0	1.1	938	932	*a*227	*a*69	1,420	8.2
36G1	11-29-56	4449	DPH	104	----	----	42	22	138	12	----	317	0	173	34	2.9	1.8	1.2	625	583	192	*a*59	----	7.9
36K1	3-3-57	21836	USGS	69	----	----	30	43	408	30	----	575	0	a535	101	2.0	----	1.7	----	*a*1,430	250	75	2,120	7.7
Test well	11-24-58	28599	USGS	97	----	----	32	23	140	11	----	322	0	a157	40	1.0	----	1.0	----	*a*569	176	62	955	8.1

Except for minor variations and except for Salt Springs for which no complete analyses are available, the composition of all the tested ground water is remarkably uniform, even though the concentrations vary somewhat.

A sample of water from the Salt Springs southeast of Park Service Headquarters was partially analyzed. The high of 22,200 ppm of chloride is attributed to the presence of older saline deposits through which the springs find their way to the surface.

The fluoride content of all the water analyzed is higher than the maximum amount allowed by the U.S. Public Health Service (1962, p. 8) for domestic use. However, there is nothing in the chemical analyses that indicates other than a meteoric source of the ground water.

T. W. Robinson (written commun., 1951) writes of Nevares Springs, "The thermal character of the water is indicative of a deep-seated source." By oral communication (1956) Mr. Robinson has indicated that he does not mean to imply a deep-seated source for the water, but rather for the high temperature of the water. Also D. E. White, geologist, Mineral Deposits Branch, U.S. Geological Survey, has examined the chemical analyses in table 5 and has stated that there is nothing in the analyses to indicated that even a very small percentage of the water from the springs in the Furnace Creek Wash area is from a primary or juvenile source.

Water from the test well is low in dissolved solids and is suitable for domestic and irrigation uses. The fluoride content of 1.0 ppm is near the acceptable limit of the U.S. Public Health Service (1962, p. 8) and therefore the water is of better quality for human consumption than that from the Texas and Travertine Springs, which have water with fluoride concentrations that range from 2.0 to 4.0 ppm.

DRILLING AND TESTING ACTIVITIES

In May 1958 the Park Service deepened and extended an existing trench, 27/1–26B3 (pl. 1), across Furnace Creek Wash, and thereby increased the flow from the trench from 0.24 cfs to 0.35 cfs. During the same period several test holes were augered with a truck-mounted power auger to determine the depth to bedrock in the wash. Bedrock was not penetrated in the center of the wash within the 24-foot depth limit of the auger.

Ground-water flow did not occur in the trench in its entire length but was restricted to narrow channels along permeable gravel lenses.

The lack of uniform flow and the difficulty and expense of excavating the alluvium to the bedrock floor indicate that an attempt to measure the total flow in the wash probably is not feasible. During 1959 runoff in Furnace Creek Wash following a cloudburst filled the trench with debris.

During November 1958 a well was drilled for the National Park Service in the SW¼NW¼ sec. 24, T. 27 N., R. 1 E. (pl. 1). This well was drilled to a depth of 250 feet to test the thickness, character,and water-yielding properties of the deposits in the area north of Travertine and east of Texas Springs where the existence of a ground-water body had been postulated. The lithologic log of the well and test-pumping data follow.

Furnace Creek test well of National Park Service

[Altitude about 490 ft. Cable-tool well drilled and gravel packed by Roscoe Moss Drilling Co. in November 1958. 14-in. casing, perforated with hydraulic perforator from 100 to 240 ft. Log by U.S. Geol. Survey]

	Thickness (feet)	*Depth (feet)*
Pleistocene:		
Alluvium:		
Clay, silt, sand, and gravel. The gravel is as much as 1 in. in diameter. Materials are quartzite, marble, and other metamorphic rocks derived from Funeral Range	50	50
Same material, somewhat cemented (harder drilling)	20	70
Same material, finer (clay to gravel ¼ in. in diameter); much easier drilling	45	115
Same material; particles as much as ¾-in. diameter. Fairly easy drilling (5 ft per hr)	10	125
Same material, better sorted; majority of particles in ⅛–¼ in. range. Drilling somewhat harder	30	155
Same material, particles as much as ¾-in. diameter	15	170
Same material; drilling somewhat harder	20	190
Fanglomerate:		
Clay, silt, sand, and gravel; trace of calcite "onyx" cementing material	20	210
Same material, gravel somewhat finer (⅛–¼ in. range) larger proportion of rounded particles; calcite cement	5	215
Gravel, as above; abundance of calcite "onyx" cementing material. Harder drilling	15	230
Pliocene and Pleistocene(?):		
Lacustrine deposits:		
Gravel, somewhat finer (⅛–¼ in. range); larger proportion of rounded particles; less "onyx." Abundant clay (brown). Easier drilling	15	245
Abundant clay; gravel as above, mostly cavings	5	250

The well was developed by surging and pumping on November 20, 1958, and the water level allowed to recover for a period of 8½ hours before test pumping was begun on November 21. Pumping was resumed at a rate of about 390 gpm with a resulting drawdown of 102 feet after a period of 72 hours. A summary of the drawdown and the subsequent recovery is given in the following table.

Date	Time (hour)	Pumping rate [1] (gpm)	Water level [2] (feet)	Drawdown (feet)	Specific capacity [3]
1958					
Nov. 20	7:50 a.m.	0	74.51		
21	7:30	0	74.61		
24	8:00	393	177	102	3.9
	8:25	351	172	97	3.6
	8:55	357	166	91	3.9
	9:10	320	142	67	4.8
	10:00	320	142	67	4.8
	10:05	250	121	46	5.4
	11:00	257	115	40	6.4
	11:15	205	101	26	7.9
	11:50	205	100	25	8.2
	12:10 p.m.	140	90	15	9.3
	12:25	140	90	15	9.3
	12:34:00	Pump off			
	12:34:30		82		
	12:34:40		77		
	12:34:40		76.90		
	12:34:50		75		
24	12:38:00 p.m.		75.88		
	12:40:00		75.64		
	12:50:00		75.56		
	1:05:00		75.52		
	3:15		75.38		
25	9:35 a.m.		75.10		
1959					
Nov. 8			75.18		
1962					
Dec. 28			75.20		
1964					
Jan. 17			75.38		

[1] Pumping rates were measured with a pipe orifice using calibrations made by Purdue University for Layne and Bowler, Inc.

[2] Water-level measurements in whole feet were made by air line. Measurements in tenths and hundredths of a foot were made by steel tape and are below land-surface datum; the distance between the measuring point and land-surface datum has been subtracted from the measured water level. For taped measurements the measuring point is bottom of hole in casing which is 1.32 ft above land-surface datum and 0.68 ft below top of casing.

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

A water-level recorder installed on Texas Spring showed no change in the spring flow during the period of developing and pumping of the test well. Measurements at other discharge points in the Furnace Creek area showed no change during the test. However, this test is not conclusive and cannot be considered to demonstrate that pumping the test well has no effect on the discharge of the Texas and Travertine Springs.

Actually the log of the test well suggests that the physical situation is best described by the third hypothesis (p. Y21 and fig. 4). Accordingly, under the nearly natural conditions now existing in the Furnace Creek Wash area the hydraulic system that supports the discharge of the Texas and Travertine Springs is in a state of dynamic balance or equilibrium. The long-term average natural discharge of the Texas and Travertine Springs is equal to the long-term average recharge. Also, the water table or piezometric surface above the springs and in hydraulic continuity with the springs and the test well is in a more or less fixed position—a feature that indicates virtually no long-term change of ground water in storage. Pumping from the Furnace Creek test well will be a new and additional discharge superimposed on the natural system. Pumping of water from the well will cause a drawdown of the water table in the vicinity of the well, and thus upset the natural dynamic balance or equilibrium. Before a new equilibrium can be established, water levels must fall throughout the aquifer to an extent sufficient to reduce the natural discharge or increase the recharge by an amount equal to the amount pumped by the well. Until this new equilibrium is established, ground water will be withdrawn from storage.

The hydraulic system of the Furnace Creek Wash area is such that pumping the test well probably will induce virtually no additional recharge. Therefore, any pumping of the test well must ultimately result in a decreased discharge of the Texas and Travertine Springs. However, it may take many months of pumping before this effect can be demonstrated, and perhaps years of pumping before the effect is appreciable.

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