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Additional reference for Region 6 303d recommendations — Owens River watershed.

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Eccles--SOURCES OF ARSENIC IN STREAMS TRIBUTARY TO LAKE CROWLEY, CALIFORNIA

SOURCES OF ARSENIC IN STREAMS TRIBUTARY TO LAKE CROWLEY CALIFORNIA

March 3 1849

U.S. GEOLOGICAL SURVEY

Water–Resources Investigations 76–36

PREPARED IN COOPERATION WITH THE CITY OF
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16. Abstracts

Water from hot springs in Long Valley is the largest source of arsenic entering Lake Crowley which supplies more than 50 percent of the water entering the Los Angeles-Owens River aqueduct. Seepage-salinity surveys were used to locate and evaluate the major, arsenic-contributing sources. About 60 percent of the arsenic discharged to Lake Crowley is from spring orifices submerged in the channel of Hot Creek at Hot Creek Gorge. Some hot spring water contains in excess of 1,000 micrograms per litre of arsenic. It blends with water flowing in the creek and is diluted to about 200 micrograms per litre. The source of arsenic to the hot springs is attributed to the geothermal activity underlying Long Valley, which is described as a collapsed caldera.

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UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

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CONVERSION FACTORS

Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric*
acres	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometres)
ft (feet)	3.048×10^{-1}	m (metres)
ft^3/s (cubic feet per second)	2.832×10	l/s (litres per second)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic metres per second)
in (inches)	2.540×10	mm (millimetres)
mi (miles)	1.609	km (kilometres)
mi^2 (square miles)	2.590	km^2 (square kilometres)
tons	9.072×10^{-1}	t (metric tons or tonnes)
ton/yr (tons, short, per year)	9.072×10^{-1}	t/yr (metric tons or tonnes per year)

SOURCES OF ARSENIC IN STREAMS TRIBUTARY TO LAKE CROWLEY, CALIFORNIA

By Lawrence A. Eccles

ABSTRACT

Lake Crowley is the largest single source of water for the city of Los Angeles. More than 50 percent of the water entering the Los Angeles-Owens River aqueduct flows through Lake Crowley. Arsenic enters Lake Crowley primarily from hot springs in Long Valley.

Sixty percent of the arsenic discharged to Lake Crowley is from hot springs in Hot Creek Gorge. The hot-spring water containing about 1,000 micrograms per litre of arsenic blends with the water flowing in the creek and is usually diluted to a concentration of about 200 micrograms per litre; additional dilution occurs downstream.

About 75 percent of the arsenic in Hot Creek is discharged from only two springs. The remaining sources of arsenic in the gorge are poorly defined seepage and flow from numerous small springs.

Other sources of arsenic in Long Valley are from either high volume and low-arsenic concentration springs, such as the springs at Hot Creek Fish Hatchery, or high-concentration and low-volume springs, such as those found in the vicinity of the Alkali lakes. These other sources individually are small in comparison with the source in Hot Creek Gorge. It seems unlikely that arsenic from these sources could cause the arsenic concentration in Lake Crowley to exceed the Environmental Protection Agency's recommended criterion (limit) for a public water supply.

PROBLEM

Many hot springs and other surface manifestations of geothermal activity occur in Long Valley, Calif. (fig. 1). Water from these hot springs has a high concentration of arsenic and other dissolved minerals and blends with surface water that flows into manmade Lake Crowley and subsequently into the Los Angeles city water supply by way of the Los Angeles-Owens River aqueduct. The hot-spring water is the major source of arsenic to Lake Crowley and thence to the aqueduct which supplies 80 percent of the water for the city of Los Angeles (Los Angeles Department of Water and Power, written commun., 1975). The dilution of the high-arsenic water with other native water ultimately reduces the arsenic concentration to an average of 30 micrograms per litre at aqueduct-distribution points (Los Angeles Department of Water and Power, written commun., 1972). This concentration is below the recommended criterion of 0.1 milligram (100 micrograms) per litre for a public water supply (Environmental Protection Agency, 1972, p. 56); however, during extended periods of low surface runoff or greatly increased arsenic discharge from the hot springs, the arsenic concentration might approach the recommended criterion. Consequently, the arsenic sources in Long Valley have been a matter of continuing concern to the city of Los Angeles for at least 25 years.

This report, prepared in cooperation with the city of Los Angeles, Department of Water and Power (LADWP), discusses the location, magnitude, and characteristics of the arsenic sources in Long Valley. Should measures to control the arsenic concentration in Lake Crowley be required, this information would be necessary.

Purpose and Scope

The purpose of this investigation was to determine the location, magnitude, and characteristics of the hot springs that serve as the source of high-arsenic water discharging to Lake Crowley.

The scope of the investigation encompassed:

1. A collection and compilation of data, reports, and literature.

2. A general reconnaissance which included an inventory of arsenic sources in the area, requiring collection and analysis of about 50 water samples from 13 sources.

3. A detailed investigation of Hot Creek, the most significant contributor of arsenic. This required seepage-salinity surveys six times during the year and about 30 discharge measurements and water samples.

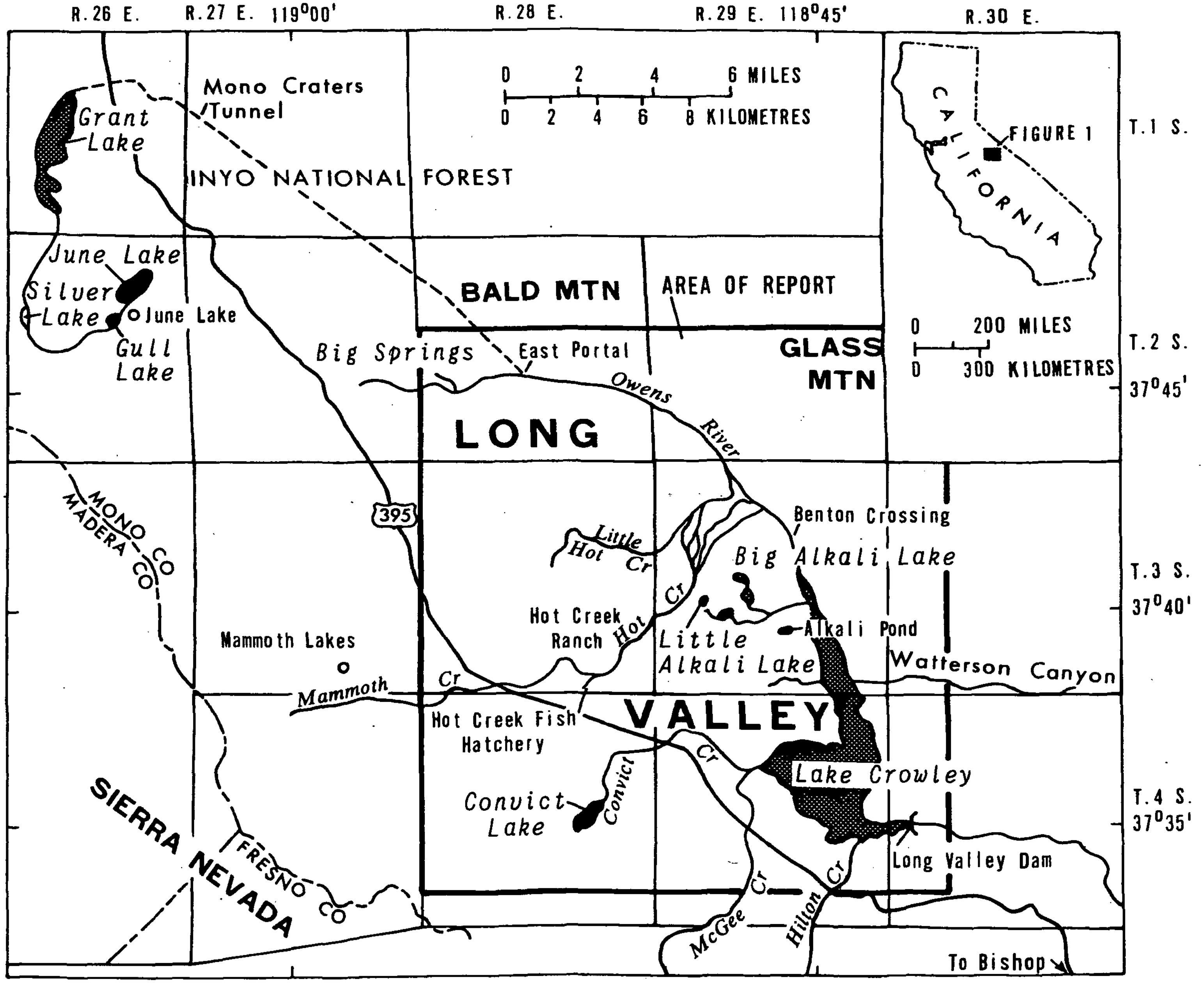
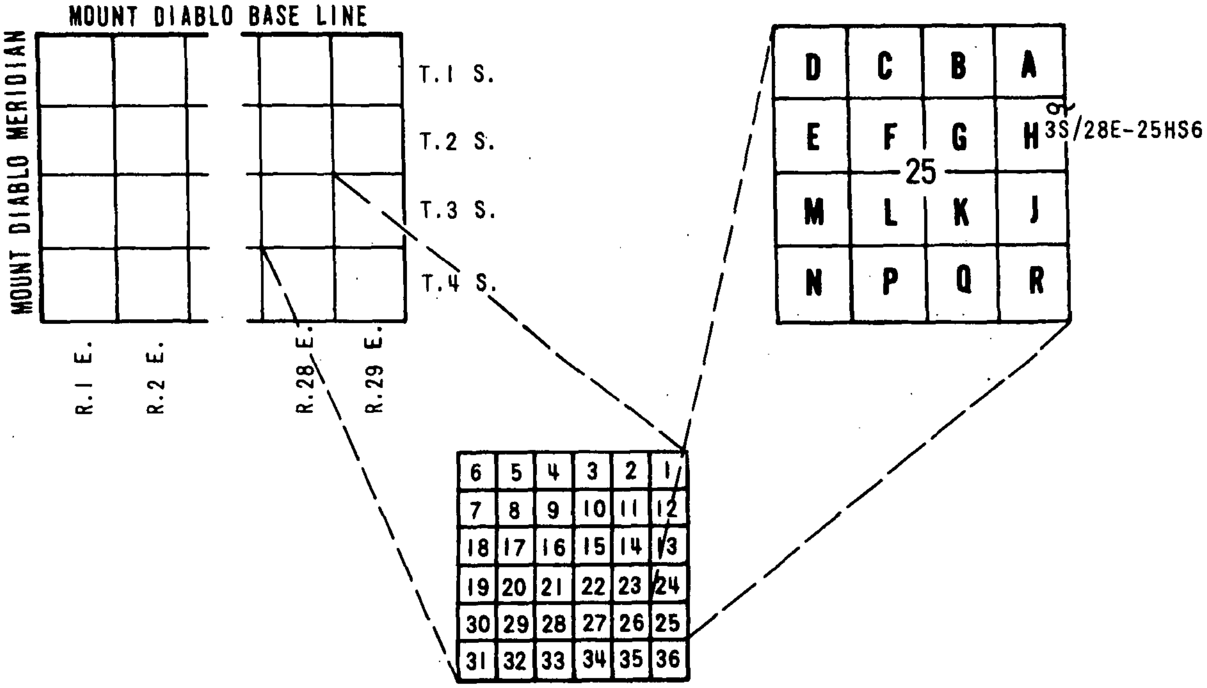


FIGURE 1.--Index map.

Spring- and Well-Numbering System

Springs and wells in the California State well-numbering system are assigned numbers according to their location in the rectangular system for the subdivision of public land. For example, in the spring number 3S/28E-25HS6, the number preceding the hyphen indicates township and range (T. 3 S., R. 28 E.); the number between the hyphen and the first letter designates the section within the township (sec. 25); the letter following this number designates the 40-acre (16-ha) subdivision within the section as shown in the accompanying diagram; the second letter S indicates that it is a spring; and the final digit is the serial designation of the spring.



Springs and wells identified in this report but not shown on maps herein are shown in the well- and spring-data report by Lewis (1974). Lewis included data on 129 springs and 83 wells in Long Valley.

Classification of Springs

Springs defined as thermal in this report follow the criteria used in Lewis' (1974, p. 7) report. The criteria used by Lewis are as follows:

"Strictly defined, any spring (or well) water whose average temperature is noticeably above the mean annual temperature of the air at the same locality may be classed as thermal (Waring, 1915, p. 4). Among European springs that are developed commercially, only those whose temperature is higher than about 20°C (Celsius) are classified as thermal. In the United States, only those springs are called thermal whose temperature is 15°F (Fahrenheit) (8.4°C) above the mean annual temperature of the air at their localities. In areas where the mean annual air temperature is low, some springs that do not freeze in winter because of their natural protective conditions are considered to be thermal; in tropical areas some springs that are only a few degrees warmer than the temperature of the air may be considered thermal.

"In the Long Valley area the average annual temperature is about 45°F (7.2°C). By United States standards, then, and for the purpose of this report, any spring having a temperature of 45° + 15°F or 60°F (15.6°C) may be classified as thermal."

Springs defined as warm are those having temperatures higher than 12° and less than 15.6°C. Cold springs are those with temperatures of 12°C or less.

GEOHYDROLOGIC SETTING

Surface-Water Drainage

The Long Valley drainage area encompasses about 370 mi^2 (960 km^2). The average annual precipitation ranges from less than 10 in (250 mm) at the east end of the valley (altitude less than 7,000 ft or 2,130 m) to more than 50 in (1,270 mm) along parts of the Sierra crest and mountain passes (Werner and others, 1967). Most precipitation occurs as snow from the Pacific winter storms, and most of the runoff takes place during the spring and early summer.

The important sources of surface water in the valley are: The Owens River, upstream from the confluence with Hot Creek, which drains almost the entire northwestern part of the valley; Hot Creek and its tributary Mammoth Creek; and Convict, McGee, and Hilton Creeks, which drain the eastern slopes of the Sierra Nevada. The large springs at the Hot Creek Fish Hatchery and the springs in Hot Creek Gorge discharge considerable flow into Hot Creek. About 10 percent of the water entering Lake Crowley is from other sources, mainly flow from ephemeral streams and washes in the area and from spring discharge near the lake which includes runoff from the Alkali Lakes (Werner and others, 1967).

The surface-water collection network for the aqueduct system in this area includes not only Long Valley but also water from the Mono Basin which is stored in June, Gull, Silver, and Grant Lakes (fig. 1). Water from the outlet of Grant Lake is routed from that basin to Long Valley through Mono Craters Tunnel. The flow through the tunnel represents the largest single inlet to Lake Crowley. More than 50 percent of the water entering the Los Angeles-Owens River aqueduct flows through Lake Crowley.

Geology

The occurrence of hot springs in Long Valley is attributed to volcanic activity. Long Valley is a collapsed caldera bounded by the Sierra Nevada to the south and west, Glass Mountain to the north, and the Benton Range (not shown), a low mountainous area to the east (fig. 2). The caldera collapsed following the flow of the Bishop Tuff (Bailey and others, 1973).

The caldera is filled with as much as 18,000 ft (5,500 m) (Pakiser, 1961, p. 253) of interbedded alluvial, glacial, and volcanic materials, which are mantled in the central part by poorly permeable lacustrine and volcanic deposits. Lake Crowley occupies the approximate site of the Pleistocene Long Valley Lake (Mayo, 1934) which covered about 100 mi^2 (260 km^2). The exposed alluvial and glacial deposits on the edges of the caldera provide a means for precipitation and for runoff from the slopes to infiltrate into the surficial ground-water system which is associated with a deeper hot-water geothermal system (R. E. Lewis, oral commun., 1972).

For this report the geology is generalized in figure 2.

Ground Water and Springs

There are three distinct subsurface hydrologic systems in Long Valley: A shallow, unconfined ground-water system; a shallow, confined ground-water system; and a deeper geothermal system (R. E. Lewis, oral commun., 1972).

The depth to water in the shallow, unconfined ground-water system ranges from about 2 to 45 ft (0.6 to 13.7 m) below the land surface. Although some recharge to this system is from infiltration of local precipitation, infiltration of runoff from the Sierra Nevada accounts for most of the recharge. The quality of this water is good until it mixes locally with water discharged from the geothermal system.

Little is known about the shallow, confined ground-water system. It was briefly investigated by R. E. Lewis (oral commun., 1973). Local confinement of the shallow ground water was found to occur in the vicinity of Lake Crowley and near the Owens River, above the lake. No high concentrations of arsenic were found in any of the test wells drilled during Lewis' investigation.

Most of the available information on the deeper system is from commercial exploration for geothermal energy. Several wells were drilled near Casa Diablo Hot Springs. The wells ranged in depth from 630 to 1,063 ft (192 to 324 m). Maximum temperature observed during testing of the wells was 181°C (McNitt, 1963, p. 29). High concentrations of arsenic, boron, fluoride, and dissolved solids in the effluent from the wells during testing forced cessation of geothermal-energy exploration and development at that time.

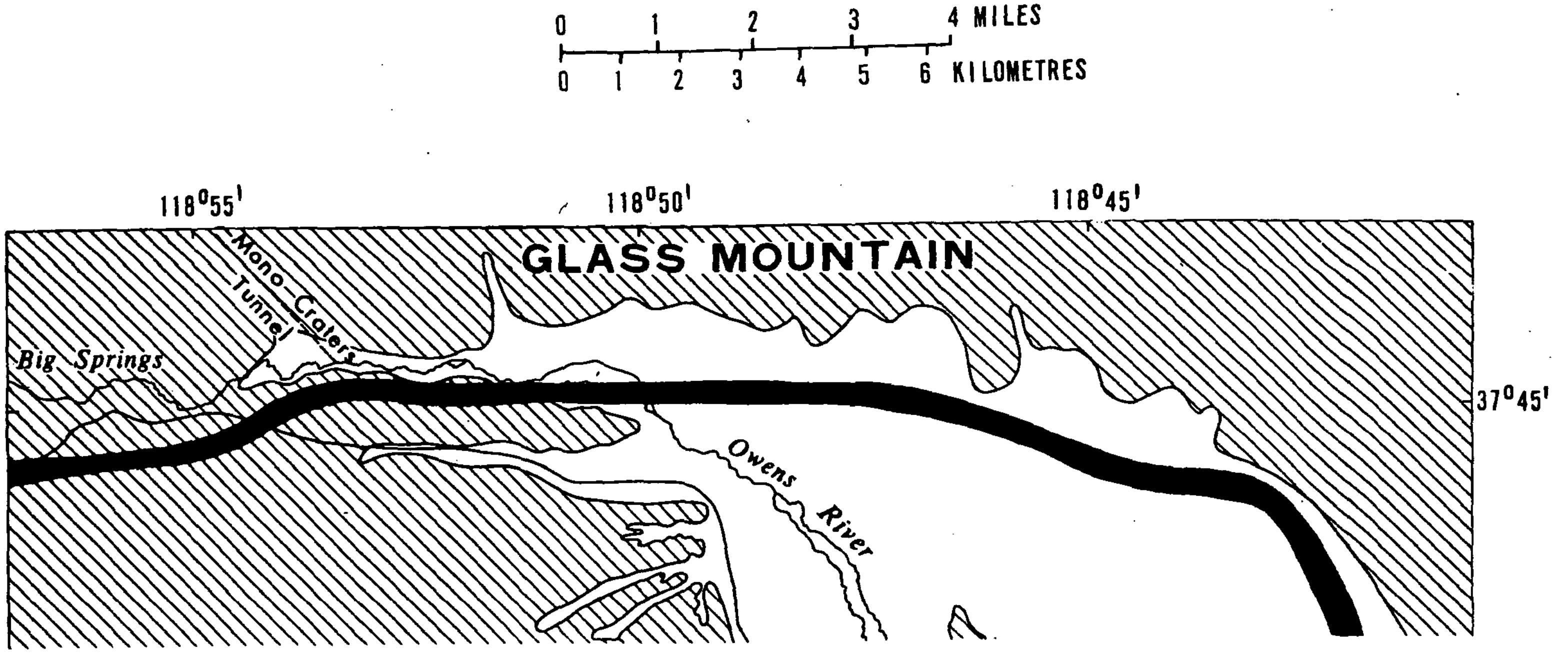
The visible thermal activity is within a zone encompassing Hot Creek, Little Hot Creek, Casa Diablo Hot Springs, Whitmore Hot Springs, and the Alkali Lakes (fig. 2). Most of the thermal springs, fumaroles, and zones of thermally altered rock are along faults or the projected strike of faults (Cleveland, 1962, p. 15). Numerous springs discharge water from the geothermal system that is mixed with water from the shallow ground-water systems. The temperature of the springs varies depending upon the degree of mixing with the shallow ground water.

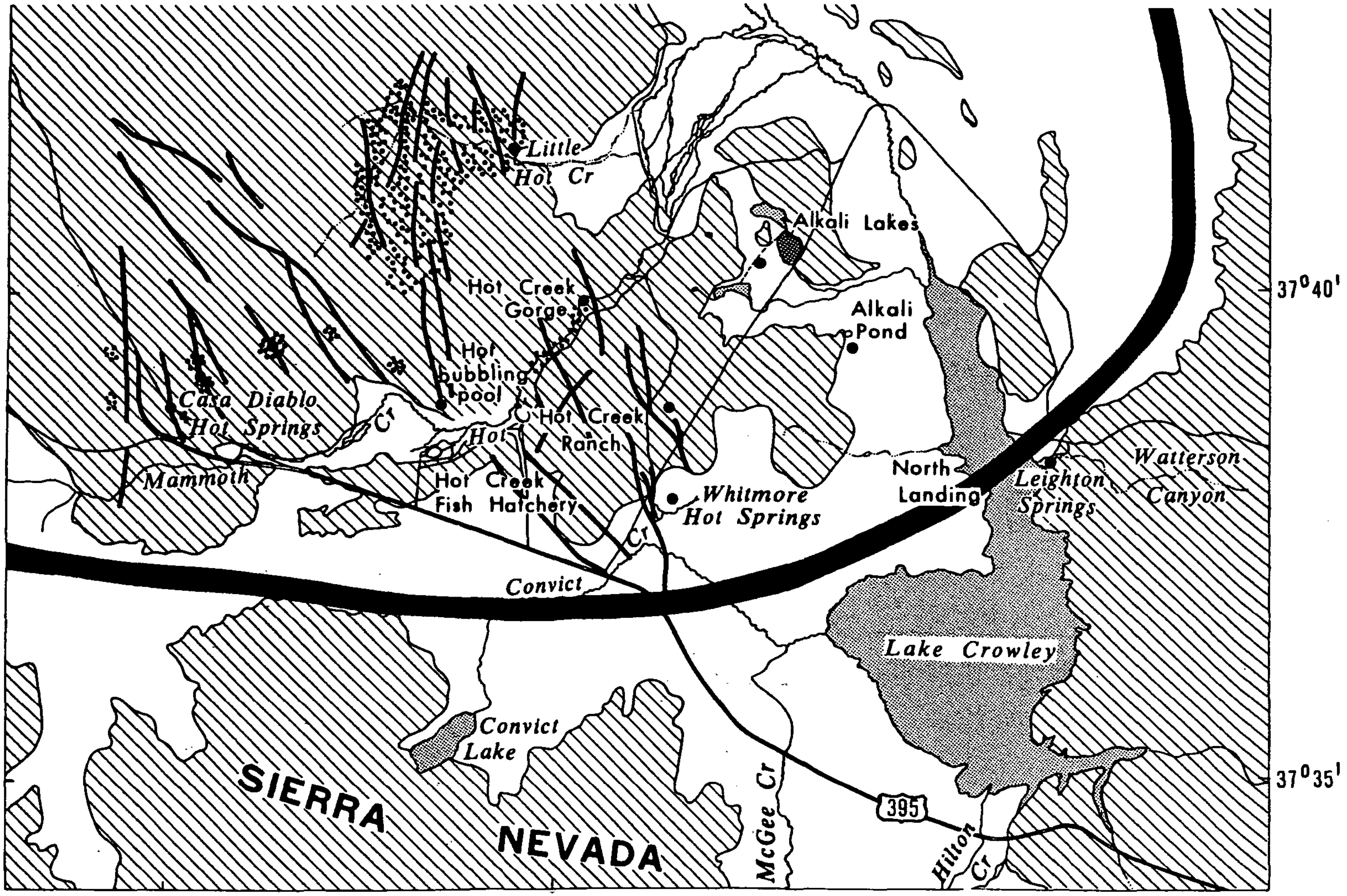
The hot springs in Hot Creek Gorge are controlled by faulting and are well inside the inferred caldera boundary. The springs here are the hottest of the thermal springs in Long Valley. The slightly thermal Chance Spring, the Hot Creek Fish Hatchery springs, and the Hot Creek Ranch springs (fig. 3) are fed primarily by shallow ground water emerging from beneath the impermeable basalt outcrops. The quality of this water is variable, depending on the degree of mixing of the geothermal water with the shallow ground water. Although these springs are not shown to be controlled by faulting, the springs influenced most by geothermal water seem to be those along the projected strike of faults.

The thermal springs near the Alkali Lakes and Alkali Pond are attributed to upwelling shallow ground water mixed with the deeper geothermal water (R. E. Lewis, oral commun., 1972).

EXPLANATION

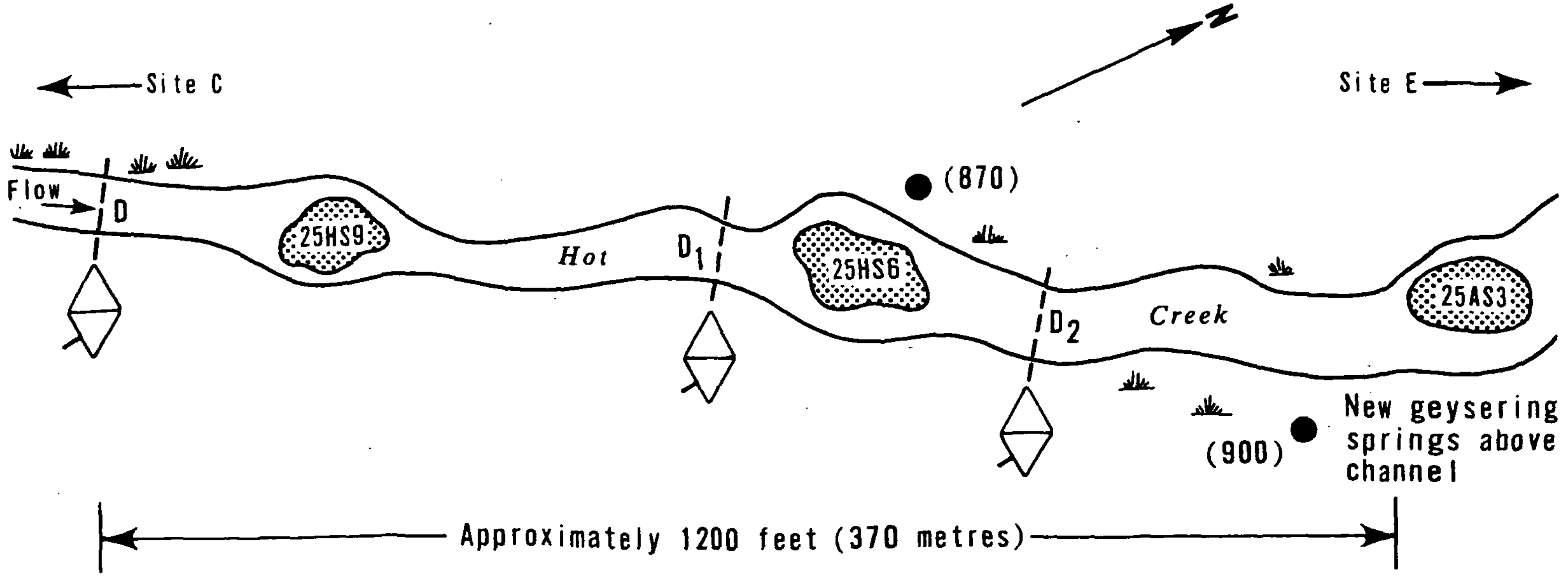
- ☐ PERMEABLE ROCKS CONSISTING OF ALLUVIUM AND UNDIFFERENTIATED GLACIAL DEPOSITS
- ▨ ROCKS OF LOW PERMEABILITY CONSISTING OF BASALT, RHYOLITE, TUFF, ANDESITE, GRANITE, METAMORPHIC ROCK, AND LACUSTRINE DEPOSITS
- ■ CALDERA BOUNDARY INFERRED FROM GRAVITY DATA
- — CONTACT BETWEEN PERMEABLE ROCKS AND ROCKS OF LOW PERMEABILITY
- ━ FAULT
- ● AREA OF THERMAL SPRING(S) OR FUMAROLE(S)
- ⁘ ZONE OF THERMALLY ALTERED ROCK
- ▩ LAKE OR PONDED WATER





Geology modified from Rinehart and Ross (1964)

FIGURE 2.--Generalized geology and principal zones of thermal activity.



(Many small springs, seeps, and fumaroles not shown)

D

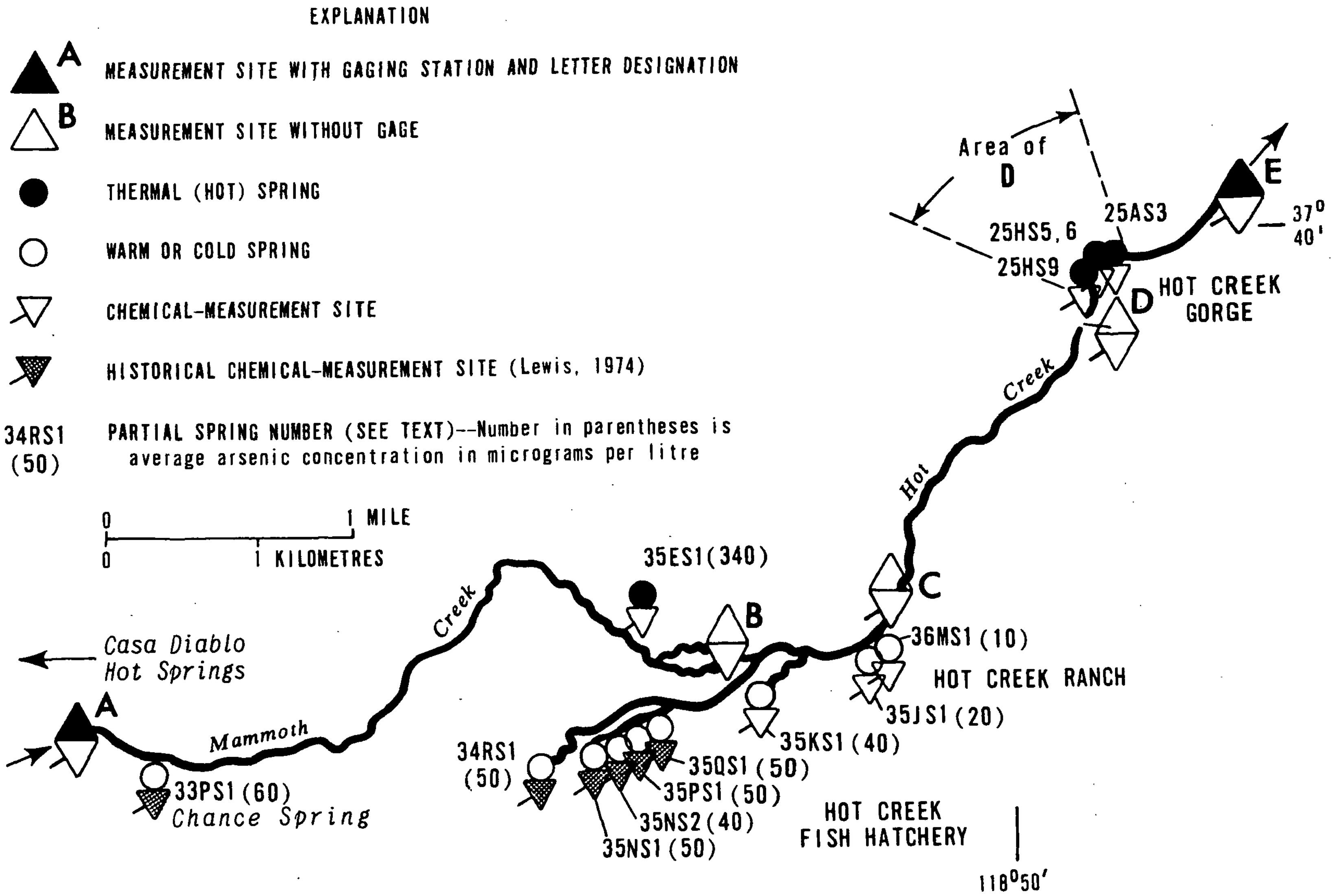


FIGURE 3.--Sampling sites and selected springs along reach of Mammoth and Hot Creeks showing average arsenic concentrations.

Chemical Characteristics of Geothermal Waters

According to Willey, O'Neal, and Rapp (1974), the geothermal water is either a sodium bicarbonate or a sodium chloride bicarbonate type. It is characterized in Long Valley by: High concentrations of dissolved solids--mainly sodium, bicarbonate, chloride, boron, and arsenic; a relatively low concentration of magnesium compared to other native water; and high concentrations of a host of trace elements. Table 1 lists the average arsenic concentration in water from the larger thermal springs. The chemical behavior of antimony is quite similar to that of arsenic, and they are usually found together. A brief reconnaissance revealed that antimony occurs in association with high arsenic concentrations at several sampling locations (table 2). The toxicity level of antimony is probably the same as arsenic, but no standards have been set (California Water Resources Control Board, 1963, p. 139).

SAMPLING-SITE SELECTION

The sources of arsenic are discussed in two categories: (1) Those from the Owens River system above Lake Crowley to which the Mono Craters Tunnel and Hot Creek are tributary, and (2) those miscellaneous sources near Lake Crowley not associated with the Owens River. The latter includes springs in the Alkali Lakes, Alkali Pond, and North Landing areas; discharge from Whitmore Hot Springs and Leighton Springs; and discharge from the Convict Creek and McGee Creek drainages (figs. 4 and 5).

According to Werner, Mukai, and Schiffman (1967) Hot Creek is the main source of arsenic in Long Valley and the largest sources of arsenic in Hot Creek are the hot springs in Hot Creek Gorge. Arsenic in high concentrations is not evident in sources tributary to the Owens River above its confluence with the Mono Craters Tunnel or tributary to the Owens River between Benton Crossing and Lake Crowley. Therefore, virtually all the arsenic discharged into Lake Crowley from the Owens River could be measured at Benton Crossing. The investigation of the Owens River system consisted of (1) an accounting of arsenic between the stream gage on the Owens River below the east portal of the tunnel and Benton Crossing and (2) the subsequent delineation of the sources in the tributary Hot Creek.

The sampling sites in Hot Creek were designed to measure the different spring-discharge areas (fig. 3): (1) Chance Spring along the lower reach of Mammoth Creek, (2) the Hot Creek Fish Hatchery springs at the headwaters of Hot Creek and the cold springs at Hot Creek Ranch; and (3) the hot springs in Hot Creek Gorge. Hot Creek was not sampled downstream from site E because of the absence of noticeable spring discharge between that point and the Owens River. The sites chosen were based on previous water-quality data, geologic studies, and a brief reconnaissance (Werner and others, 1967; Rinehart and Ross, 1964; Lewis, 1974; and LADWP, written commun., 1972).

TABLE 1.--*Average arsenic concentration of selected springs in Long Valley*

[Compiled from previous and current analyses. See Lewis (1974) for exact location of springs]

Springs	Arsenic (micrograms per litre)
Hot Creek	
Lower Mammoth Creek	
3S/28E-33PS1 (Chance Spring)	60
3S/28E-35ES1 (Hot Bubbling Pool)	340
Hot Creek Fish Hatchery Springs	
3S/28E-34RS3	50
3S/28E-35KS1	40
3S/28E-35NS1	50
3S/28E-35NS2	40
3S/28E-35QS1	50
Hot Creek Ranch	
3S/28E-35JS1	20
3S/28E-36MS1	10
Hot Creek Gorge	
3S/28E-25AS1	1,100
3S/28E-25HS5	1,000
3S/28E-25HS6	880
New geysering springs (not numbered) in Hot Creek Gorge (fig. 3)	900
Little Hot Creek (composite sample)	
3S/28E-13ES1-4	600
Headwaters of Owens River near Big Springs	
2S/27E-25AS1	20
2S/28E-20RS1	50
Alkali Lakes area	
3S/29E-17RS1, 4	350
3S/29E-20NS1	460
3S/29E-21LS1	370
3S/29E-21PS1	370
3S/29E-29CS1, 2	500
3S/29E-29DS1	530
3S/29E-29FS1	680
Alkali Pond area (composite sample)	
3S/29E-27ES1-5, FS1, 2, GS1, 2	400
North Landing	
3S/29E-34KS1	360
Whitmore Hot Springs (composite sample)	
4S/29E-6HS1-4	300
Leighton Springs	
3S/29E-36QS1, 2	130
4S/29E-1BS1	70

TABLE 2.--*Selected antimony data*[1]

[Concentrations in micrograms per litre. Refer to fig. 5 for sampling locations]

Sample location	Date	Arsenic	Antimony	Remarks
Mammoth Creek at Highway 395	10-17-72	4	0.2	Surface runoff little affected by geothermal water.
Hot Creek at Gorge	10-17-72	230	19	Surface runoff influenced by large hot spring discharges.
Runoff from Big Alkali Lake	10-19-72	380	18	Discharge of upwelling ground water influenced by deeper geothermal water and subject to evaporation.
Composite of hot springs 3S/28E-13ES1-4	10-18-72	540	50	Sampled at point below confluence of discharge from these springs (Little Hot Creek sampling point).

[1] Samples analyzed by U.S. Geological Survey Neutron Activation Analysis Laboratory, Denver, Colo., except for arsenic in sample from 3S/28E-13ES1-4 analyzed by Los Angeles Department of Water and Power.

Sampling sites for the miscellaneous sources near Lake Crowley and Little Hot Creek were at springs or at points of confluence of discharge from several springs.

The schedule of sampling and results are shown in table 9.

METHODS

The seeps and springs in Hot Creek could not be measured individually. Therefore, a method referred to here as a seepage-salinity survey was used to determine the volume and chemical composition of water gained or lost in several individual reaches of the creek.

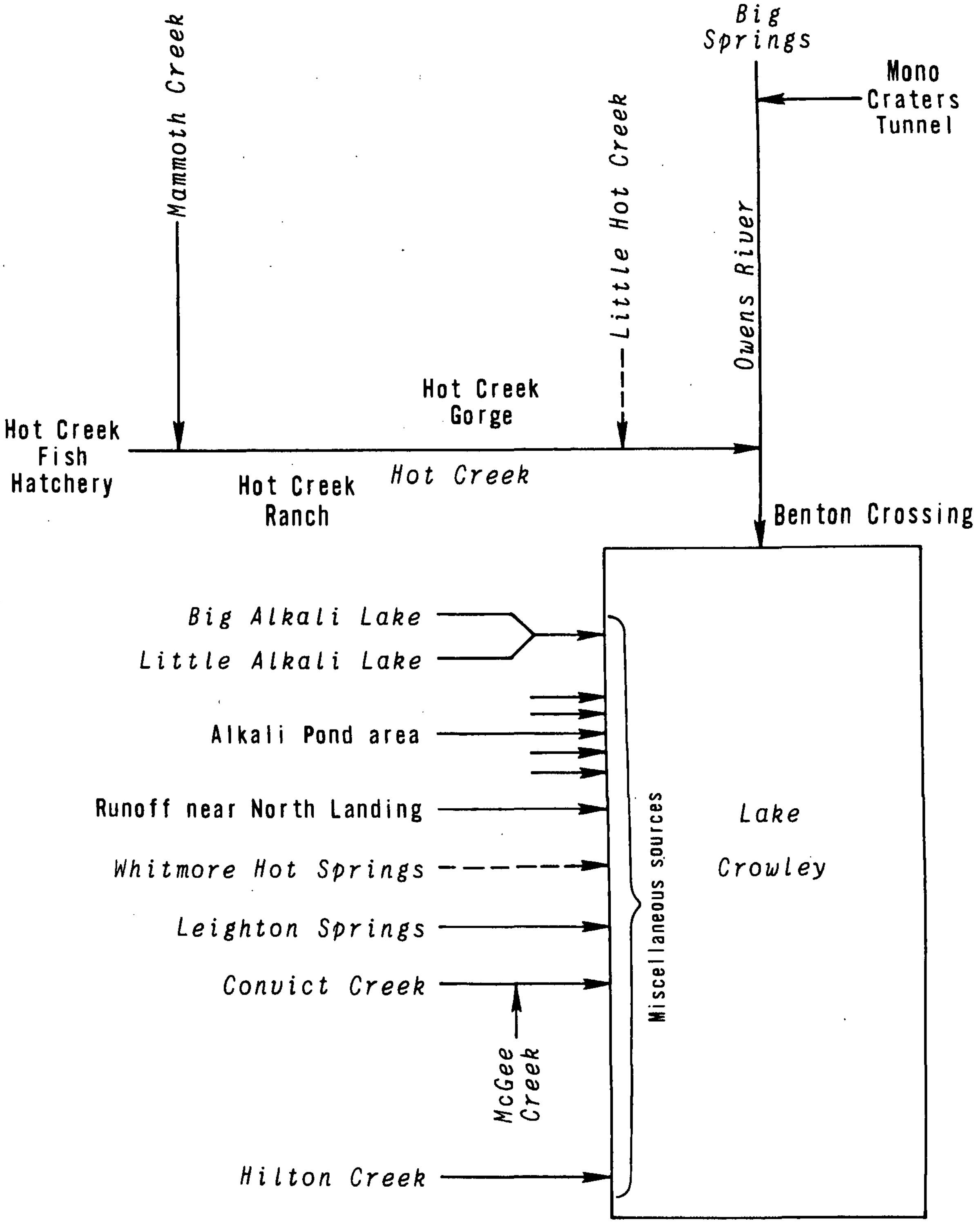
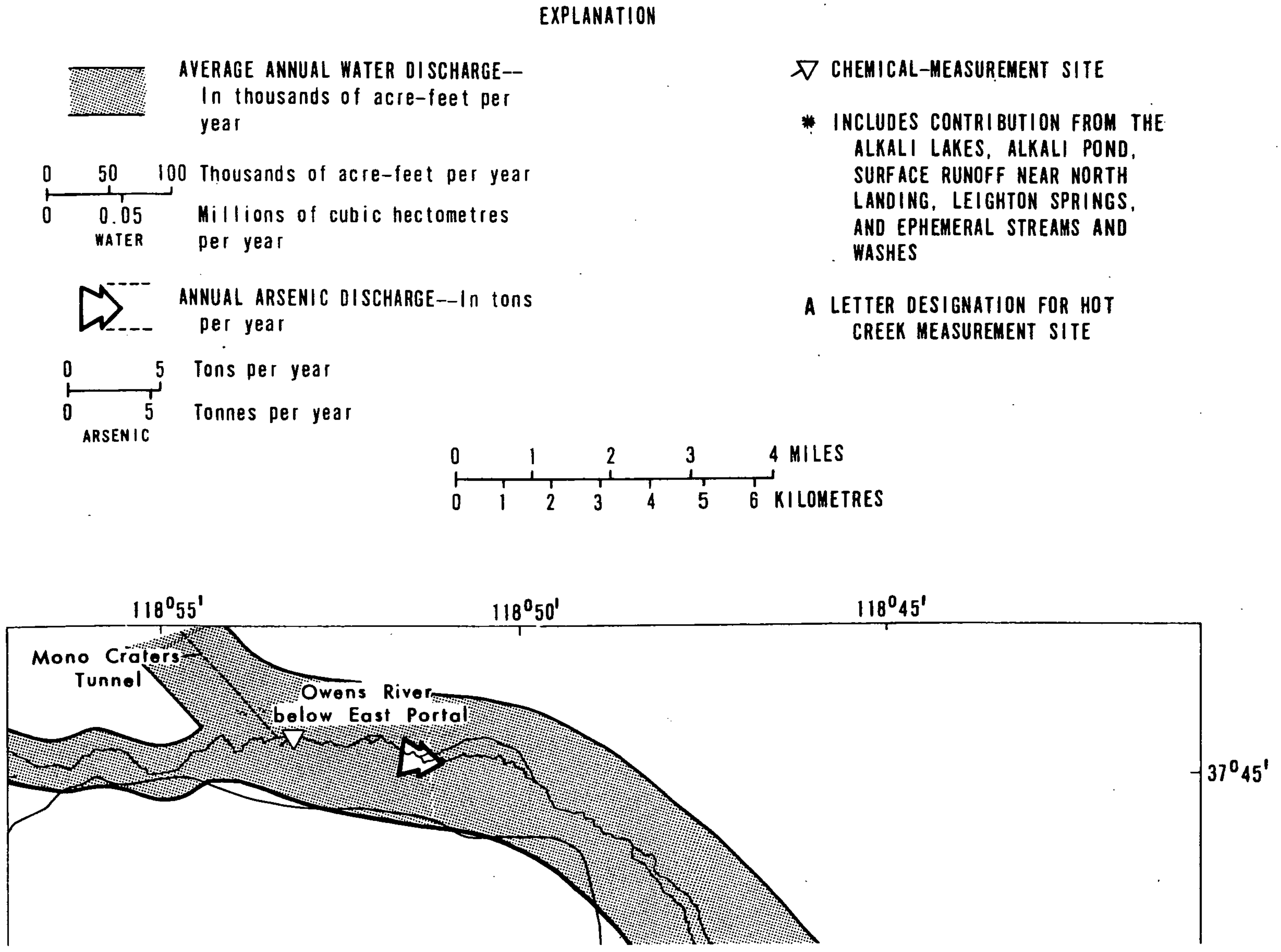


FIGURE 4.--Schematic of arsenic inventory.



EXPLANATION

▨ AVERAGE ANNUAL WATER DISCHARGE--In thousands of acre-feet per year

0 50 100 Thousands of acre-feet per year
0 0.05 Millions of cubic hectometres per year
WATER

ANNUAL ARSENIC DISCHARGE--In tons per year

0 5 Tons per year
0 5 Tonnes per year
ARSENIC

▽ CHEMICAL-MEASUREMENT SITE

* INCLUDES CONTRIBUTION FROM THE ALKALI LAKES, ALKALI POND, SURFACE RUNOFF NEAR NORTH LANDING, LEIGHTON SPRINGS, AND EPHEMERAL STREAMS AND WASHES

A LETTER DESIGNATION FOR HOT CREEK MEASUREMENT SITE

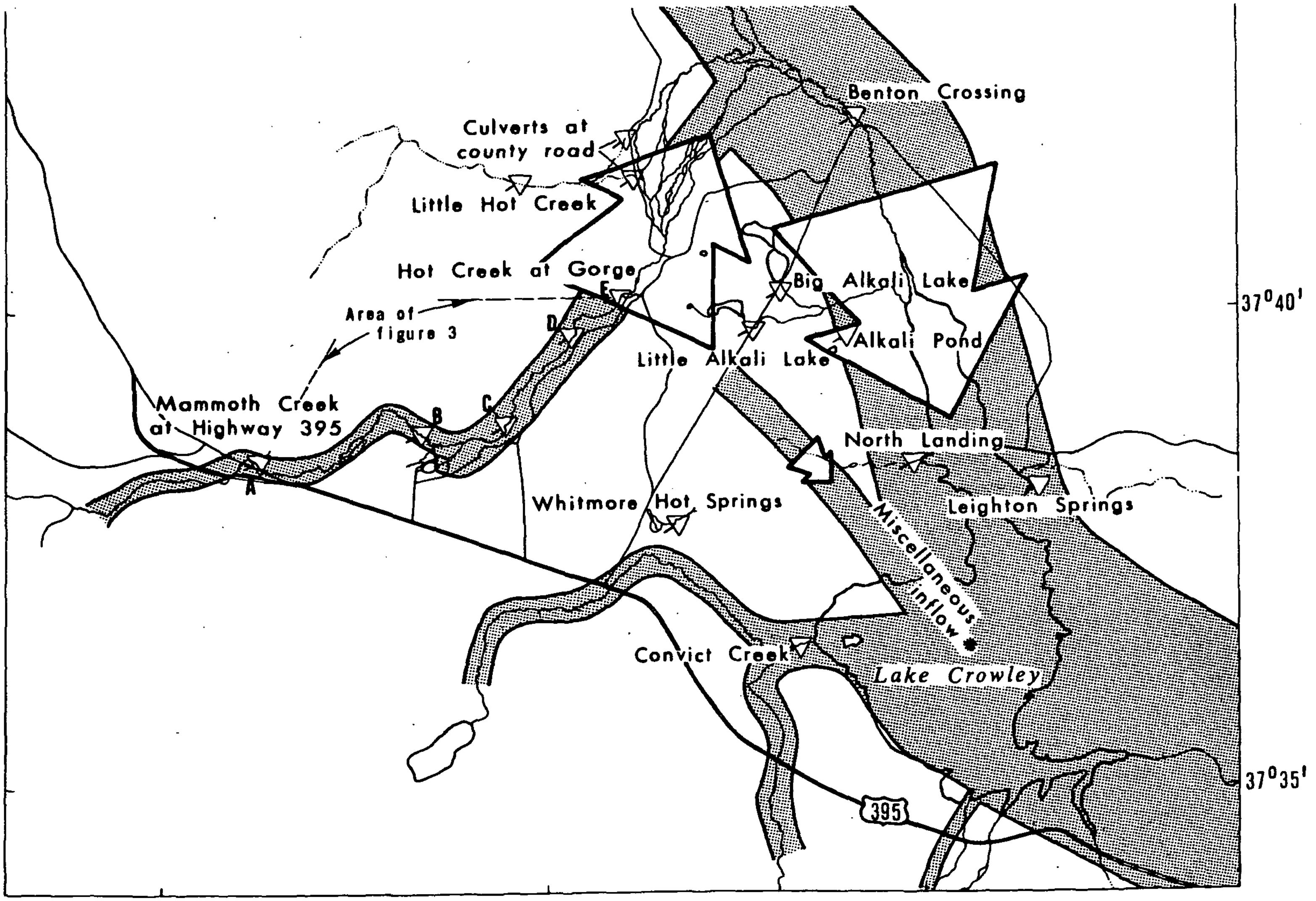


FIGURE 5.--Sampling-site locations and inventory of water and arsenic discharge.

In using the method, flow and concentration data taken at selected points on the creek account for the flow of water and chemical constituents passing each sampling site. An increase in flow from one point to the next indicates a seepage gain in the reach, and a decrease in flow represents a seepage loss. The concentration of a given chemical constituent in the water gained or lost between the two points is the change in mass flow of the given constituent divided by the change in water flow between the two points. The method is described in the following equations. For a reach of a stream between upstream point x and downstream point y, the flow gain or loss, Q, between the points is:

$$\Delta Q_{xy} = Q_y - Q_x$$

(in volume/unit time).

The gain or loss in mass, m, of chemical constituent i is:

$$\Delta m_i = Q_y c_{iy} - Q_x c_{ix}$$

(in mass/unit time).

where c is the concentration of the constituent at the sampling site.

The concentration C of constituent i in the water gained or lost in the reaches is:

$$C_i = \Delta m_i / \Delta Q_{xy}$$

(in mass/unit volume).

A computer program to handle the calculations was devised by Leonard and Morgan (1970) and was used in this study.

Two definite requirements in the use of the seepage-salinity survey are: (1) Streamflow must be stable during the period that the survey is being made, and (2) the water samples taken at the measuring sites must be representative of the total flow at that site. The continuous records from the stream-gaging stations verified that the flow remained constant during the sampling periods. Errors arising from nonrepresentative water samples were minimized by using equal-transit-rate sampling techniques (Guy and Norman, 1970) for collecting the samples from poorly mixed reaches of the stream. Almost all water samples were filtered at the time of collection; therefore, values are for dissolved constituents. A comparison of several filtered and unfiltered water samples taken at the Hot Creek at Gorge sampling site showed little or no difference in arsenic values. Arsenic transported to Lake Crowley on sediment (bedload plus suspended) was beyond the scope of this investigation.

The miscellaneous sources having no drainage into Lake Crowley by way of the Owens River and Little Hot Creek were evaluated by taking individual water samples and discharge measurements at springs or at points of confluence of discharge from several springs in the local area.

Most of the chemical analyses of the water samples were done by the LADWP laboratory. Other samples were analyzed by the U.S. Geological Survey Central Laboratory at Salt Lake City, Utah. Selected samples for arsenic and antimony were analyzed by the U.S. Geological Survey Neutron Activation Analysis Laboratory at Denver, Colo. A few samples were split upon collection and sent to all three laboratories for comparison of analyses.

The LADWP and U.S. Geological Survey Central Laboratory used the silver diethyldithiocarbamate method described in Techniques of Water-Resources Investigation of the U.S. Geological Survey (Brown and others, 1970) for the analysis of arsenic. Neutron activation analysis, a provisional method for antimony and arsenic analysis, was used by the Denver laboratory.

Samples for arsenic required no special handling or treatment. The samples for antimony were placed in special sample containers in the field which required volumetric measurements and special handling.

RESULTS

Arsenic Sources in the Owens River Drainage above Lake Crowley

Hot Creek

The sources of arsenic discharged into Hot Creek were determined by a seepage-salinity survey between the stream gage on Mammoth Creek at U.S. Highway 395 (site A, fig. 3) and the gage at the downstream end of Hot Creek Gorge (site E).

The first sampling survey on October 17, 1972, was the major reconnaissance of arsenic sources. Subsequent sampling visits were intended to verify the results of the first visit. Therefore, in discussion, major emphasis and values presented will refer to the October 17 survey. The contribution to Hot Creek from Little Hot Creek was determined by direct measurement and is discussed later in this section.

On August 24, 1973, several new hot springs appeared in Hot Creek Gorge. These new springs would be expected to constitute additional sources of arsenic, and the surveys of September 5 and 25, 1973, were intended to check this. These springs appeared just after an earthquake occurred nearby; the two events are probably related.

The results of all chemical analyses and flow measurements are presented in table 9. Results of the seepage-salinity survey of October 17 are presented in table 3.

TABLE 3.--*Seepage-salinity survey of Hot Creek, October 17, 1972. Estimated concentrations and chemical discharge of selected constituents gained or lost in each reach*

[Number above line is concentration in milligrams per litre except arsenic which is in micrograms per litre; number below line is rate of chemical discharge in tons per year]

Reach (see fig. 3 for sampling-point locations)	Net gain or loss in discharge (ft^3/s)	Calcium	Magnesium	Sodium	Chloride	Arsenic
A → B	1.1	$\frac{15}{17}$	$\frac{7.3}{8.0}$	$\frac{51}{56}$	$\frac{33}{36}$	$\frac{90}{.1}$
B → C	29	$\frac{11}{320}$	$\frac{6.2}{180}$	$\frac{20}{570}$	$\frac{3.4}{100}$	$\frac{45}{1.3}$
C → D	-5	$\frac{(1)}{-54}$	$\frac{(1)}{-19}$	$\frac{(1)}{42}$	$\frac{(1)}{49}$	$\frac{(1)}{-.3}$
D → D_1	4	$\frac{11}{43}$	$\frac{1.5}{6.0}$	$\frac{220}{850}$	$\frac{130}{500}$	$\frac{610}{2.4}$
D_1 → D_2	7	$\frac{17}{120}$	$\frac{1.3}{9.0}$	$\frac{274}{1,900}$	$\frac{160}{1,100}$	$\frac{860}{5.9}$
D_2 → E	5	$\frac{12}{59}$	$\frac{3.9}{19}$	$\frac{130}{640}$	$\frac{91}{450}$	$\frac{24}{.12}$

[1] Concentration of chemical constituents in net gain or loss is not presented for this reach because simultaneous gain and loss of constituents takes place--that is, a low-flow high-concentration spring occurred together with a point or points of seepage loss. Concentration values generated by calculation would represent neither loss nor gain.

Of the total gain in arsenic between sites A and E, 1 to 2 percent is contributed from reach A→B. The concentration of arsenic in the inflow between sites A and B was calculated to be 90 μg/l (micrograms per litre), table 3. This concentration is slightly higher than the average for the analyses of Chance Spring (3S/28E-33PS1) previously sampled in that area; it indicates little or no inflow of water containing high concentrations of arsenic like that found in nearby spring 3S/28E-35ES1 (table 1).

The largest contributors of water and arsenic between points B and C were the springs at Hot Creek Fish Hatchery and Hot Creek Ranch, which yield 75 percent of the water and 14 percent of the arsenic that is gained in the creek between sites A and E. The concentration of arsenic in the net gain in reach B→C was calculated to be 45 µg/l, or about the average arsenic concentration of the water from the hatchery springs (tables 1 and 3). Because the results indicated that the sources between sites A and C contained relatively low arsenic concentrations, they were grouped together and referred to as upstream sources in subsequent surveys.

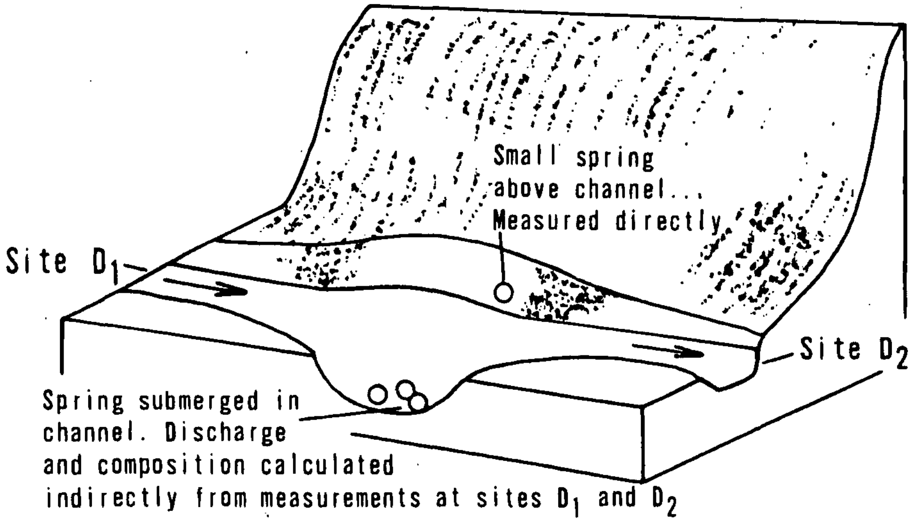
In reach C→D there is a net loss of flow. For this reason the net gain of arsenic from sources in Hot Creek Gorge was evaluated by measurements made at sites C and E. Magnesium, calcium, and arsenic were lost while sodium and chloride were gained, but the concentrations of all constituents except chloride remained nearly unchanged between sites C and D. The mechanism of appearance and disappearance of these chemical constituents entering and leaving the stream was not determined.

The reach D→E, which encompasses the large hot springs in Hot Creek Gorge, is the most important source of arsenic. In order to describe the seepage activity in greater detail, the reach was subdivided into three shorter reaches as shown in figure 3. Generally, the high sodium, chloride, and arsenic concentrations, together with the low magnesium concentrations in the net gain for the reach D→E, suggest that the water is a blend of the type found in springs 3S/28E-25HS5 and 25HS6 (table 9) and water lost in reach C→D.

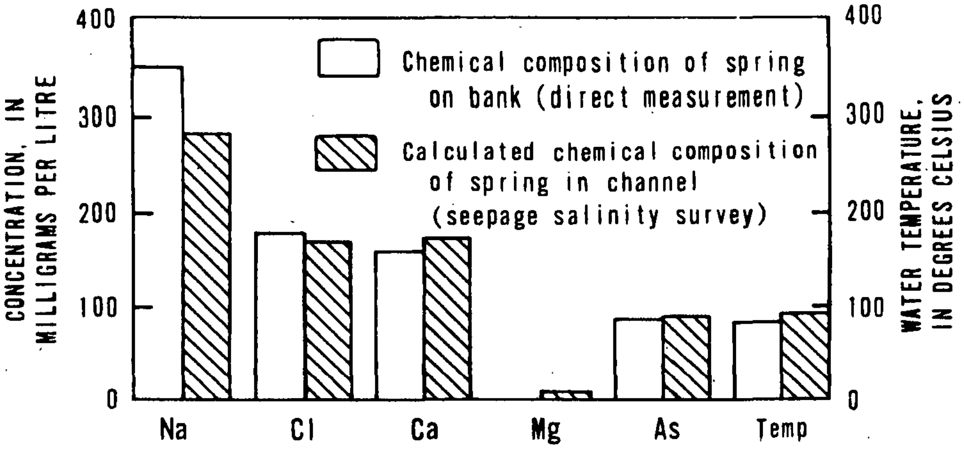
The seepage gain for the reach D→D_1 that encompasses spring 3S/28E-25HS9 is the second largest source of arsenic inflow to Hot Creek. A water-temperature, cross-section profile taken at site D_1 indicated that the hot-water inflow is mostly along the right bank in this reach. The sodium, chloride, and arsenic concentrations increase substantially, and the magnesium concentration decreases. The chemical composition of the water gained in the reach suggests that it is a mixture of water from hot spring 3S/28E-25HS9 with composition represented by that in spring 3S/28E-25HS6 and other native water such as found at site C. Thus, the water lost in reach C→D may be reappearing, in part, in this reach.

The same mechanism, but to a much lesser degree, may occur in reach D_1→D_2. The composition of the net gain resembles a mixture of water almost exclusively like that sampled from spring 3S/28E-25HS6 (table 9) and water like that found at site C. Thus, some of the water lost in reach C→D may be reappearing here also.

The inflow to the reach D_1→D_2 encompassing the spring 3S/28E-25HS6 comes almost entirely from several orifices in the bottom of a pool in the creek channel. The calculated temperature and chemical composition of the increase in flow from this reach closely resembled the measured temperature and chemical composition of the hot-spring water sampled directly from an orifice on the nearby bank, which is probably part of this same spring complex (fig. 6).



A.--Schematic illustration of spring complex 3S/28E-25HS6.



B.--Calculated versus directly measured concentration of selected chemical constituents and water temperature from spring complex 3S/28E-25HS6. Calcium, magnesium, and arsenic scale expanded by 10, 10, and 100 respectively for comparative purposes.

FIGURE 6.--A. Block diagram of spring complex 3S/28E-25HS6 and B. Composition of selected constituents in spring complex 3S/28E-25HS6.

Reach $D_2 \rightarrow E$ gains flow from both diffuse seepage and some small springs. The composition of this water, however, is not the same type as that found in the two reaches upstream. In particular, sources containing high concentrations of arsenic seem to be lacking in this reach.

Although most of the seepage gain into the creek in the gorge is contributed by spring complexes 3S/28E-25HS6 and 3S/28E-25HS9, some seepage seems to be continuous through the entire gorge. The springs in Hot Creek Gorge contribute about 85 percent of the arsenic from about 25 percent of the flow gained in Hot Creek between sites A and E. Data from the survey of October 17, 1972, for the reach C to E show a net gain in the rate of arsenic discharge of 8.1 ton/yr (7.3 t/yr) and a net gain in water discharge of 11 ft^3/s (0.3 m^3/s) (table 4).

For the six surveys of Hot Creek (table 4) the average net gain in discharge between Hot Creek Ranch and the gage at the end of the gorge was about 9 ft^3/s (0.3 m^3/s) producing 9 tons (8.2 t) of arsenic per year. The net gain in flow between sites C and E had a concentration of arsenic calculated to be about 1,100 µg/l, which is slightly higher than that found in the hot springs in the gorge that were sampled directly. Spring complex 3S/28E-25HS6 is the largest single source of arsenic in Long Valley and produces more than half the arsenic in Hot Creek. Spring complex 3S/28E-25HS9 is the second largest source producing less than half as much as 3S/28E-25HS6. The remaining source of arsenic in the gorge is indefinable seepage and flow from numerous small springs. The arsenic discharge from the gorge accounts for more than 60 percent of the arsenic received by Lake Crowley.

During the night of August 24, 1973, several new hot springs appeared in Hot Creek Gorge. They were above the right bank and below spring 3S/28E-25HS6 (fig. 3). The two largest springs geysered 10-13 ft (3-4 m) high at first, but the geysering subsided to 3-7 ft (1-2 m) in periodic bursts by late September (R. A. Bailey, written commun., 1973). By December the activity of the new springs subsided further, but the activity of some others increased. New fumaroles formed at the bottom of the gorge and some geysering occurred from springs along the left bank. The temperatures of the geysering springs were at boiling point (about 93°C at this altitude). The arsenic concentration measured in some of these new springs was 900 µg/l, about the same as concentrations at spring 3S/28E-25HS6 sampled a year earlier (table 9).

Data from seepage-salinity surveys of September 5 and September 25, 1973 (tables 4 and 5), indicate that the emergence of these new springs did not cause an overall change in the arsenic discharged from Hot Creek.

TABLE 4.--*Estimated concentrations and chemical discharge of selected constituents gained between sites C and E*

[Number above line is concentration in milligrams per litre except arsenic and boron which are in micrograms per litre; number below line is rate of chemical discharge in tons per year]

Date	Discharge (ft^3/s)	Calcium	Magnesium[1]	Sodium	Potassium	Sulfate	Chloride	Fluoride	Arsenic	Boron
Oct. 17, 1972	11	15 170	1.4 15	320 3,400	21 230	83 900	200 2,100	7.8 84	750 8.1	9,100 98
Jan. 17, 1973	8	16 130	2.4 -19	410 3,200	24 190	100 810	220 1,700	9.3 74	1,000 7.9	12,000 94
Mar. 21, 1973	7	12 83	2.6 -18	470 3,200	25 170	110 760	250 1,700	11 78	1,300 9.1	11,000 74
Apr. 17, 1973	9	14 120	2.1 19	420 3,700	24 210	97 860	240 2,100	8.6 76	1,100 10	9,700 86
Sept. 5, 1973	10	14 140	.2 2	350 3,500	22 210	90 1,100	200 1,900	--	920 9.1	9,300 92
Sept. 25, 1973	8	24 200	4.2 -33	410 3,300	27 220	110 860	230 1,900	12 92	1,300 10.1	14,000 110

[1] Computed loss of magnesium attributed to channel losses between sites C and D.

TABLE 5.--*Seepage-salinity survey of Hot Creek, September 25, 1973. Estimated concentrations and chemical discharge of selected constituents gained in each reach*

[Number above line is concentration in milligrams per litre except arsenic which is in micrograms per litre; number below line is rate of chemical discharge in tons per year]

Reach (see fig. 3 for sampling point locations)	Net gain or loss in discharge (ft^3/s)	Calcium	Magnesium	Sodium	Chloride	Arsenic
A → C	38	10 390	6.7 250	17 620	4.6 170	23 0.9
C → D	-8	(1) -79	(1) -46	(1) -29	(1) -16	(1) .24
D → D_1	8	16 130	.4 3	110 850	60 470	400 3.1
D_1 → D_2	5	22 110	.6 -3	420 2,100	240 1,200	1,300 6.2
D_2 → E	3	12 35	4.4 13	120 370	72 210	210 .6

[1] Concentration of chemical constituents in net gain or loss is not presented for this reach because simultaneous gain and loss of constituents takes place--that is, a low-flow high-concentration spring occurred together with a point or points of seepage loss. Concentration values generated by calculation would represent neither loss nor gain.

Little Hot Creek

The hot springs (3S/28E-13ES1-4) of Little Hot Creek are along faults (table 6 and fig. 2). The chemical composition of this water is similar to the composition of the hot springs in Hot Creek Gorge, but the arsenic concentration and the water temperature are considerably lower. Flow from these hot spring openings converges into a single channel and normally is the only water in the creek. During the investigation, the composite discharge of these springs was measured and sampled three times. The arsenic and water discharges were nearly constant during the investigation.

TABLE 6.--*Concentration and discharge of selected constituents in Little Hot Creek*

[Sodium, chloride, and arsenic: Number above line is concentration in milligrams per litre except arsenic which is in micrograms per litre; number below line is rate of chemical discharge in tons per year]

Date	Sodium	Chloride	Arsenic	Specific conductance (micromhos at 25°C)	Flow (ft^3/s)	Estimated annual discharge (acre-ft/yr)
FLOW FROM UPPER CREEK (COMPOSITE OF SPRINGS 3S/28E-13ES1-4); LITTLE HOT CREEK SAMPLING SITE, FIGURE 5						
Oct. 19, 1972	420 160	220 84	540 0.2	2,100	0.38	280
Jan. 12, 1973	440 180	200 84	600 0.3	2,100	.43	310
Sept. 26, 1973	380 140	200 76	610 0.2	2,000	.38	280
FLOW THROUGH CULVERTS AT COUNTY ROAD SAMPLING SITE, FIGURE 5						
Oct. 18, 1972	780 120	390 58	710 0.1	3,500	.15	110

Downstream from the Little Hot Creek sampling site (fig. 5) the channel widens and the flow almost disappears. A small quantity of water is backed up behind the culverts at the county road. No more than 0.15 ft^3/s (4.2 l/s) was observed flowing through the culverts during the investigation, but appreciable flow could occur during runoff of local precipitation.

The subsurface discharge is computed to be between 15 and 60 acre-ft (0.02 and 0.07 hm^3) per year, far less than the average spring discharge of 290 acre-ft (0.36 hm^3) per year minus the flow at the culverts. Evaporation and evapotranspiration could account for the loss of flow (R. E. Lewis, oral commun., 1973).

The arsenic concentration in a shallow ground-water sample from a nearby observation well was only 79 μg/l, much lower than that in the springs. The accumulation of salt residue along the creek channel and the high salinity of the water backed up behind the culverts indicate extensive evaporation (table 6). During periods of high flow in Little Hot Creek, some salt residue would be dissolved and transported to Hot Creek, but the associated additional runoff to Lake Crowley would dilute this solution. These hot springs would not make any significant contribution of arsenic to Hot Creek and consequently to Lake Crowley, even during extended dry periods which are of most concern. This is supported indirectly by a survey of the Owens River described in the following section.

Owens River

The reach of the Owens River between the gage below the east portal of the Mono Craters Tunnel and Benton Crossing was surveyed for gain in chemical discharge (fig. 5). Hot Creek is the only significant tributary to this reach. The net gain and concentration of the chemical constituents discharged to this reach showed that no significant quantity of arsenic was contributed to Lake Crowley from this reach of the Owens River other than that from Hot Creek (table 7).

TABLE 7.--*Estimate of net gain in Owens River between East Portal and Benton Crossing compared to the discharge from Hot Creek*

[Number above line is concentration in milligrams per litre except arsenic which is in micrograms per litre; number below line is rate of chemical discharge in tons per year]

Stream	Date	Flow (ft^3/s)	Calcium	Magnesium	Sodium	Chloride	Arsenic
Net gain in Owens River	9-26-73	45	$\frac{15}{620}$	$\frac{4.9}{180}$	$\frac{78}{3,400}$	$\frac{39}{1,700}$	$\frac{200}{9.1}$
Hot Creek at Gorge	9-25-73	[1]57	$\frac{12}{660}$	$\frac{4.4}{220}$	$\frac{70}{3,900}$	$\frac{36}{2,000}$	$\frac{200}{11.2}$

[1] Flow into and out of Hot Creek remained the same on 9-25-73 and 9-26-73; therefore, Hot Creek was not resampled on 9-26-73. The data indicate some seepage loss in either lower Hot Creek or the reach of the Owens River that was examined.

The sources of arsenic upstream from the gage below the east portal are both the flow from the tunnel and the springs at the headwaters of the Owens River. The arsenic concentration is about 10 μg/l; however, considering the large water discharge from these sources, which accounts for about half the water entering Lake Crowley, the contribution of arsenic is quite large. The estimate for the rate of arsenic discharge from these sources, based on long-term records of water samples and discharge data from the LADWP, is 2 ton/yr (1.8 t/yr).

Miscellaneous Sources

Alkali Lakes and Alkali Pond

The springs near Big and Little Alkali Lakes and Alkali Pond are similar in chemical composition to those in Hot Creek Gorge except that they are cooler and have less than half the arsenic concentration (tables 8 and 9). Almost all the spring discharge in the Alkali Lakes area drains into either Big Alkali Lake or Little Alkali Lake by two discrete lake outflow channels through culverts at the county road. The contributions from the sources in the Alkali Lakes area were measured at the culverts (fig. 5). There is no common drainage to Lake Crowley for the springs at Alkali Pond.

Water samples from the springs feeding Big Alkali Lake and of the outflow from the lake were taken during January 1973. The arsenic concentration of the springs and of the outflow was about the same, which indicated little evaporation during the winter months or loss of arsenic resulting from chemical precipitation. Evaporation and loss of arsenic by chemical precipitation is indicated by the chemical analyses of springs and runoff for Little Alkali Lake (table 8). Water in Big Alkali Lake is subject to dilution from overflow of Hot Creek during periods of high runoff. This situation was not observed during the study period, but during a previous event about 1 ft^3/s (28 l/s) was measured flowing from Hot Creek into Big Alkali Lake. Flow from the lakes was not constant during the investigation, and an accurate estimate of the arsenic discharge cannot be made without an intensive monitoring program. The combined discharge from the lakes did not exceed 2.5 ft^3/s (71 l/s) when sampled. Estimates based on available data indicate that the rate of arsenic discharge is about 1 ton/yr (0.9 t/yr) from the Alkali Lakes and about 0.4 ton/yr (0.36 t/yr) from the springs in the Alkali Pond area. Overflow of Hot Creek during periods of high surface runoff and the subsequent flushing of Big Alkali Lake would cause a sudden input of arsenic into Lake Crowley. This would probably be of little consequence because the increased volume of water required to cause this would, in turn, reduce the arsenic concentration.

TABLE 8.--*Selected constituents from springs and runoff for Big and Little Alkali Lakes and from springs at Alkali Pond*

[Concentrations in milligrams per litre except arsenic and boron in micrograms per litre, and specific conductance in micromhos per centimetre at 25°C. Samples collected by U.S. Geological Survey and analyzed by Los Angeles Department of Water and Power]

Date	Calcium	Magnesium	Sodium	Potassium	Sulfate	Chloride	Fluoride	Specific conductance	Arsenic	Boron
SPRINGS AT BIG ALKALI LAKE 3S/29E-21LS1, PS1 (IN ORDER)										
Jan. 12, 1973	25	0.5	380	32	68	150	5.0	1,800	370	6,500
Jan. 12, 1973	25	.5	380	32	69	150	5.2	1,800	360	6,200
RUNOFF FROM BIG ALKALI LAKE										
Oct. 19, 1972	22	0	380	35	66	170	5.4	1,900	110	6,000
Jan. 12, 1973	--	--	--	--	--	--	--	--	350	--
Sept. 27, 1973	24	.2	350	30	66	160	5.1	1,850	410	6,200
SPRINGS AT LITTLE ALKALI LAKE 3S/29E-20NS1, 29CS1 (IN ORDER)										
Jul. 26, 1973	24	.1	440	19	81	200	5.4	1,940	460	8,800
Jul. 26, 1973	35	.7	390	23	73	190	6.0	1,840	490	8,900
RUNOFF FROM LITTLE ALKALI LAKE										
Oct. 19, 1972	11	1	790	68	130	380	11	3,600	520	12,000
Sept. 27, 1973	9.6	2	850	76	130	380	12	3,800	680	13,000
AVERAGE OF SPRINGS AT ALKALI POND 3S/29E-27ES1-5, FS1, 2, GS1, 2 (NO COMMON DRAINAGE FOR THESE SPRINGS)										
Jan. 15, 1973	24	.7	390	31	65	160	5.5	1,880	400	7,500

North Landing

The surface runoff from several springs in the local drainage area near North Landing (fig. 5) is an insignificant source of arsenic. Some water is ponded about a mile (1.6 km) from the lake. The high salinity of the water indicates extensive evaporation. The arsenic discharge from this area is estimated to be no more than 0.3 ton/yr (0.27 t/yr). This source was measured twice, once during relatively high flow and once during extremely low flow. The 0.3 ton/yr (0.27 t/yr) is based on the high-flow figure. The low-flow estimate is less than 0.1 ton/yr (0.09 t/yr).

Whitmore Hot Springs

The arsenic discharge from Whitmore Hot Springs was considered to be an insignificant source. A measurement was made just below the confluence of the runoff from the springs. The arsenic concentration was 300 μg/l and the discharge was 0.9 ft^3/s (25 l/s), which gives a rate of arsenic discharge of 0.3 to 0.4 ton/yr (0.27 to 0.36 t/yr). The runoff from these springs flows toward Lake Crowley but disappears about half a mile (0.8 km) below our measuring point (fig. 5). The runoff enters the shallow ground-water system and is eventually discharged to Lake Crowley. Data are insufficient to estimate underflow into Lake Crowley from these springs, but the underflow is probably minor because of the low hydraulic conductivity of the sediments in this area.

Two wells were sampled east of Whitmore Hot Springs. One well, 1 mi (1.6 km) east of the springs, had an arsenic concentration of 430 μg/l; the other well, 2 mi (3.2 km) east, had 130 μg/l. The ground-water gradient toward the lake suggests that some arsenic may discharge into the lake from this area.

Leighton Springs

Leighton Springs (fig. 5) and some seepage on the east side of Lake Crowley near the mouth of Watterson Canyon are insignificant arsenic sources. These springs are classified as thermal (21°C) with a discharge of 2.5 ft^3/s (71 l/s) and with a low arsenic concentration (70 μg/l). Lake Crowley receives an arsenic discharge of less than 0.2 ton/yr (0.18 t/yr) from this source.

Convict, McGee, and Hilton Creeks

Convict and McGee Creeks are perennial streams with an average annual discharge of more than 37,000 acre-ft (46 hm^3)(fig. 1). Convict Creek, to which McGee Creek is tributary, was investigated for arsenic discharge to Lake Crowley. Although these creeks discharge 0.3 to 0.4 ton/yr (0.27 to 0.36 t/yr) of arsenic to the lake, they serve to dilute the arsenic concentration in the lake because the arsenic concentration of the creek water is only 10 μg/l. Convict Creek was investigated because of its proximity to Whitmore Hot Springs. Samples were collected from Convict Creek at three sites: The first just below Convict Lake, the second above its confluence with McGee Creek, and the third above Lake Crowley. Several small springs along its banks were also sampled. No arsenic concentrations above 10 μg/l were found in Convict Creek or in the springs sampled; consequently, no significant arsenic was discharged from McGee Creek. Previous water samples from Hilton Creek, collected from a point not far from Lake Crowley, contained almost no arsenic.

SUMMARY

About 60 percent of the arsenic discharged to Lake Crowley is derived from the hot springs in Hot Creek Gorge, most of which comes from springs submerged in the creek channel. This flow of high-arsenic water from the springs [10 ft^3/s (0.28 m^3/s)] is associated with a much larger flow of low-arsenic water in the creek. The resultant arsenic concentration in Hot Creek is usually 200 μg/l. The arsenic from Hot Creek is diluted to less than 100 μg/l when mixed with flow in the Owens River just upstream from Benton Crossing.

Other sources of arsenic discharging to Lake Crowley are small individually in comparison with the source in Hot Creek Gorge.

Based on the 1975 rate of arsenic discharge from the sources in Long Valley, it is unlikely that the arsenic concentration in Lake Crowley will exceed the Environmental Protection Agency's (1972) recommended criterion (limit) for public water supplies.

If the sources in Hot Creek Gorge are to be specifically monitored, it would be advisable to install a stream gage in the vicinity of Hot Creek Ranch in order to isolate the sources in the gorge from the sources upstream.

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TABLE 9.--*Chemical*

[Results in milligrams per litre except for arsenic and boron which are in
were filtered at time of collection; therefore, all results are for
A through E. Refer to figure 5 for other sampling locations except for most
Department of Water and Power except for September 5, 1973, which was

Sampling location or spring number	Date	Discharge	Silica	Calcium	Magnesium	Sodium	Potassium	Alkalinity as $CaCO_3$
A	10-17-72	8.0	14	9.2	3.4	6.6	1.3	51
	1-16-73	5.6	22	11	4.1	8.4	1.7	60
	9-25-73	11	14	8.8	2.7	4.9	.9	45
B	10-17-72	9.1	20	10	3.9	12	2.1	58
	1-16-73	6.5	26	11	4.6	12	2.4	62
C	10-17-72	38	38	11	5.8	18	3.4	81
	1-17-73	35	44	11	6.8	20	3.9	88
	3-21-73	36	43	12	6.6	19	3.6	90
	4-17-73	53	40	14	7.6	27	3.7	100
	9- 5-73	47	42	14	5.9	17	3.8	80
	9-25-73	49	37	10	5.8	14	3.1	78
D	10-17-72	33	37	11	6.1	22	3.8	85
	1-17-73	29	44	12	6.1	23	4.0	92
	3-21-73	33	44	12	6.3	21	3.5	92
	9- 5-73	45	43	11	6.1	20	4.0	80
	9-25-73	41	38	10	5.8	16	3.2	80
D_1	10-17-72	37	42	11	5.6	43	4.5	110
	9-25-73	49	42	11	4.9	31	4.2	96
D_2	10-17-72	44	50	12	4.9	81	3.3	150
	9-25-73	54	50	12	4.4	67	6.3	140
E	10-17-72	49	50	12	4.8	86	7.4	160
	1-17-73	43	60	12	5.1	92	7.7	170
	3-21-73	43	58	12	5.1	92	7.1	170
	4-17-73	62	50	14	6.8	84	6.6	170
	9- 5-73	57	57	14	4.9	76	6.9	140
	9-25-73	57	51	12	4.4	70	6.5	140

analyses of water

micrograms per litre. Discharge is in cubic feet per second. All samples
dissolved constituents. Refer to figure 3 for location of Hot Creek samples
springs located in Lewis (1974). Laboratory analyses by the Los Angeles
analyzed by the U.S. Geological Survey, Salt Lake City Laboratory]

Sulfate	Chloride	Fluoride	Nitrate	Dissolved solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Water temperature °C	Arsenic	Boron
7.0	0.7	<0.1	<0.1	69	37	110	8.2	5.0	10	50
8.6	.7	.1	2.2	--	44	132	8.0	.5	10	10
4.9	<.1	.1	--	58	33	92	8.1	5.0	<10	90
9.5	4.6	.1	<.1	91	41	145	8.1	6.0	20	210
7.4	6.1	.1	1.3	147	45	158	7.9	1.0	30	190
12	3.9	.2	<.1	126	52	200	8.5	12.0	40	210
11	7.3	.2	2.2	--	56	212	7.8	8.0	30	220
12	4.6	.3	.9	137	57	218	8.0	10.5	30	310
14	13	.3	.5	--	65	270	7.7	--	20	340
9.2	4.1	--	.1	147	59	182	7.7	13.0	34	210
9.0	3.6	.2	.4	112	50	178	7.8	10.0	20	200
12	6.0	.3	<.1	132	52	210	8.5	13.5	37	260
12	6.1	.3	4.4	--	55	230	8.6	11.0	50	320
12	5.3	.3	.9	139	56	220	8.9	11.0	30	330
10	5.5	.2	.1	149	53	187	8.3	15.0	39	220
9.0	3.9	.3	.3	115	50	183	8.4	11.5	30	270
16	19	.8	<.1	195	51	310	8.5	16.5	100	820
14	13	.7	.3	164	48	260	8.8	18.0	90	580
25	42	2.0	<.1	315	49	500	8.6	27.5	220	1,800
18	34	1.6	.3	264	48	420	7.3	26.0	200	1,300
28	47	1.9	<.1	340	50	540	8.7	30.0	200	2,200
28	46	1.9	7.5	469	52	550	7.7	28.5	210	2,400
28	45	2.1	.6	347	52	550	8.0	28.0	240	2,000
26	46	1.5	.1	--	64	530	7.6	--	180	1,700
23	38	1.5	.1	309	55	445	7.6	29.0	190	1,800
23	36	1.8	.3	283	48	450	7.7	29.0	200	2,200

TABLE 9.--*Chemical*

Sampling location or spring number	Date	Discharge	Silica	Calcium	Magnesium	Sodium	Potassium	Alkalinity as $CaCO_3$
Benton Crossing	9-26-73	217	--	10	4.1	24	2.8	78
Big Alkali Lake	10-19-72	.4	170	22	0	380	35	690
	1-12-73	2.1	--	--	--	--	--	--
	9-27-73	.3	--	24	.2	350	30	700
Convict Creek	3-20-73	2.7	16	33	.7	6.0	1.4	88
Culverts at County Road (composite)	10-18-72	.2	62	2.4	.5	780	50	1,030
Little Alkali Lake	10-19-72	.3	78	11	1.0	790	68	1,220
	1-12-73	.4	100	31	1.4	500	42	830
	9-27-73	.8	95	9.6	2.0	850	76	1,410
Little Hot Creek	10-19-72	.4	74	21	1.0	420	28	620
	1-12-73	.4	79	22	.5	440	27	630
	9-26-73	.4	88	22	<.1	380	24	620
North Landing	10-19-72	.8	66	8.0	2.0	1,200	94	1,600
	1-15-73	<.1	92	16	4.9	1,200	90	1,800
Owens River below East Portal	9-26-73	172	---	8.8	3.9	10	1.7	56
Undesignated (new geysering springs above channel, fig. 3)	9-25-73	--	130	2.4	<.1	340	20	480
3S/28E-25HS5	9-25-73	--	130	2.0	<.1	320	18	440
3S/28E-25HS6 (orifice on bank, fig. 6A)	10-17-72	--	120	16	0	340	19	450
3S/29E-18B1 (observation well near Culverts at County Road)	10- 2-73	--	43	8.0	2.5	360	16	670

analyses of water--Continued

Sulfate	Chloride	Fluoride	Nitrate	Dissolved solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Water temperature °C	Arsenic	Boron
11	11	0.6	<0.1	132	42	210	8.1	--	50	470
66	170	5.4	<.1	1,200	56	1,900	8.6	30.0	110	6,000
--	--	--	--	--	--	--	--	13.5	350	--
66	160	5.1	.2	1,160	61	1,850	8.2	26.0	410	6,200
14	1.8	.1	.5	129	86	204	7.9	6.0	<10	160
200	390	17	.4	2,210	8	3,500	9.3	12.5	710	13,000
130	380	11	.4	2,270	32	3,600	9.1	7.5	520	12,000
84	210	6.5	3.1	2,010	84	2,300	8.3	7.5	270	8,600
130	380	12	4.4	2,390	32	3,800	8.8	5.0	680	13,000
100	220	9.8	<.1	1,320	56	2,100	8.8	53.5	540	6,000
100	200	7.2	.9	1,350	58	2,100	8.3	52.0	600	9,100
100	200	8.8	.2	1,260	54	2,000	8.2	57.0	610	8,100
240	710	16	6.2	3,470	28	5,500	9.0	8.0	530	19,000
170	540	15	3.1	4,330	60	5,200	8.8	0	400	21,000
11	3.6	.2	<.1	83	38	132	7.1	--	10	210
100	220	11	.2	1,130	6	1,800	8.7	93.0	900	9,100
91	200	9.1	.8	1,010	5	1,600	8.9	93.0	860	8,000
89	180	7.8	.9	1,010	40	1,600	7.2	86.0	870	6,000
16	79	5.5	<.1	940	30	1,360	8.9	16.5	79	5,300

TABLE 9.--*Chemical*

Sampling location or spring number	Date	Discharge	Silica	Calcium	Magnesium	Sodium	Potassium	Alkalinity as $CaCO_3$
Springs near Big Alkali Lake 3S/29E-21LS1	1-12-73	0.1	170	25	0.5	380	32	660
3S/29E-21PS1	1-12-73	.1	170	25	.5	380	32	660
Springs near Alkali Pond 3S/29E-27ES2-5 (composite)	1-15-73	.2	140	24	.7	390	31	650
3S/29E-27FS2	1-15-73	.1	--	--	--	--	--	--
Seepage at mouth of Watterson Canyon 3S/29E-36QS1	1-15-73	--	--	--	--	--	--	--
Leighton Springs 4S/29E-1BS1	1-15-73	2.4	5.8	11	.2	60	3.9	120
Whitmore Hot Springs 4S/29E-6HS1-4	1-15-73	.9	65	20	1.5	120	8.1	200

analyses of water--Continued

Sulfate	Chloride	Fluoride	Nitrate	Dissolved solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Water temperature °C	Arsenic	Boron
68	150	5.0	2.6	1,640	64	1,800	8.0	50.0	370	6,500
69	150	5.2	1.3	1,630	64	1,800	7.9	50.0	360	6,200
65	160	5.5	<.1	1,630	64	1,880	7.6	38.5	400	7,500
--	--	--	--	--	--	--	--	34.0	370	--
--	--	--	--	--	--	--	--	28.0	70	--
19	14	1.5	4.9	269	28	340	8.3	21.0	70	300
38	61	2.8	<.1	575	56	700	8.0	--	300	3,800