Hydrologic Data and Description of a Hydrologic Monitoring Plan for Medicine Lake Volcano, California

By Tiffany Rae Schneider and William D. McFarland

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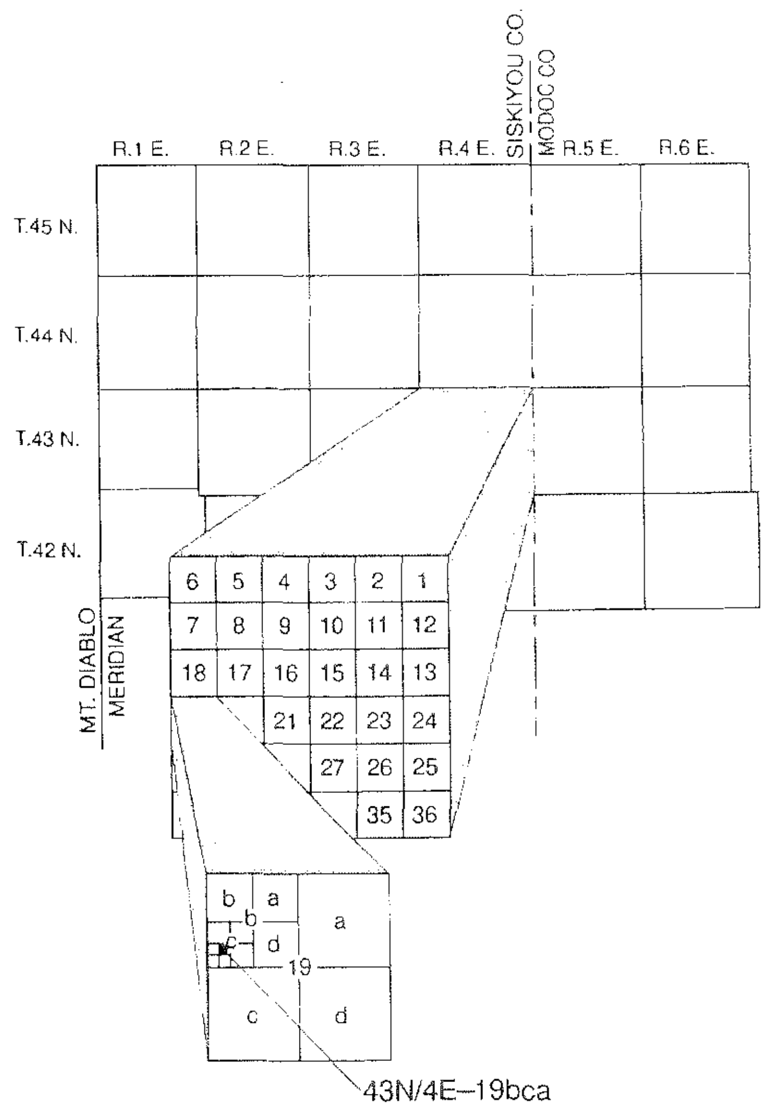
WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based on the rectangular system for subdivision of public land. Each number-letter designation indicates the location of the well with respect to township, range, and section. Well 43N/4E–19bca is a well in T.43 N., R.4 E., sec. 19. Townships in that vicinity are numbered north and east of the Mt. Diablo baseline and meridian (for example, 43N/4E). The letters indicate the location within the section; the first letter (b) identifies the quarter section (160 acres); the second letter (c) identifies the quarter-quarter section (40 acres); and the third letter (a) identifies the quarter-quarter-quarter section (10 acres). Well 19bca is in the northeast quarter of the southwest quarter of the northwest quarter of section 19, township 43 north, range 4 east (see figure below).



CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch	2.54	centimeter
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
	Area	
square mile	2.590	square kilometer
	Volume	
gallon	3.785	liter
gallon	0.003785	cubic meter
	Flow	
cubic foot per second	0.02832	cubic meter per second
gallon per minute	0.06308	liter per second

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8\,(°C) + 32$$

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32)/1.8$$

Electrical conductivity is measured as specific electrical conductance, in units of microsiemens per centimeter at 25°C.

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

A hydrologic reconnaissance of the Medicine Lake Volcano area was done to collect data needed for the design of a hydrologic monitoring plan. The reconnaissance was completed during two field trips made in June and September 1992, during which geothermal and hydrologic features of public interest in the Medicine Lake area were identified. Selected wells, springs, and geothermal features were located and documented, and initial water-level, discharge, temperature, and specific-conductance measurements were made.

Lakes in the study area also were surveyed during the September field trip. Temperature, specific-conductance, dissolved oxygen, and pH data were collected by using a multiparameter probe.

The proposed monitoring plan includes measurement of water levels in wells, discharge from springs, and lake stage, as well as analysis of well-, spring-, and lake-water quality. In determining lake-water quality, data for both stratified and unstratified conditions would be considered. (Data for stratified conditions were collected during the reconnaissance phase of this project, but data for unstratified conditions were not.) In addition, lake stage also would be monitored. A geothermal feature near Medicine Lake is a "hot spot" from which hot gases discharge from two distinct vents. Gas chemistry and temperature would be monitored in one of these vents.

INTRODUCTION

Although the Pacific Northwest is thought to have abundant hydrothermal resources, they remain essentially undeveloped. To encourage responsible resource development, the Bonneville Power Administration (BPA), with guidance from the Northwest Power Planning Council and in cooperation with the U.S. Geological Survey (USGS), is participating in three hydrologic monitoring projects in Oregon. The areas of interest are the Vale, Newberry Volcano, and Alvord Valley Known Geothermal Resources Areas. A fourth hydrologic monitoring study was started in northern California at Medicine Lake Volcano. A goal of the pilot projects is to adequately evaluate environmental and land-use issues. To accomplish this goal, BPA has begun projects to collect baseline environmental data prior to geothermal development.

Medicine Lake Volcano (figs. 1 and 2) is a large shield volcano 30 miles northeast of Mt. Shasta in northern California. Lavas from the volcano cover more than 700 square miles. Medicine Lake Volcano is larger in total volume than Mt. Shasta, which is the largest of the Cascade stratovolcanoes. Medicine Lake Volcano is geologically similar to Newberry Volcano in central Oregon.

The geothermal resources of the Medicine Lake Volcano area are a potential source of power generation. Medicine Lake Volcano has been explored extensively for geothermal resources by Unocal Corporation (Unocal) and most recently by California Energy Company, Inc., and Calpine Power Services Company. The Medicine Lake Volcano monitoring program was started in 1992, at a reconnaissance level, with two field visits to the study area. This report describes data collected during these two field visits and the elements of the monitoring plan for Medicine Lake Volcano.

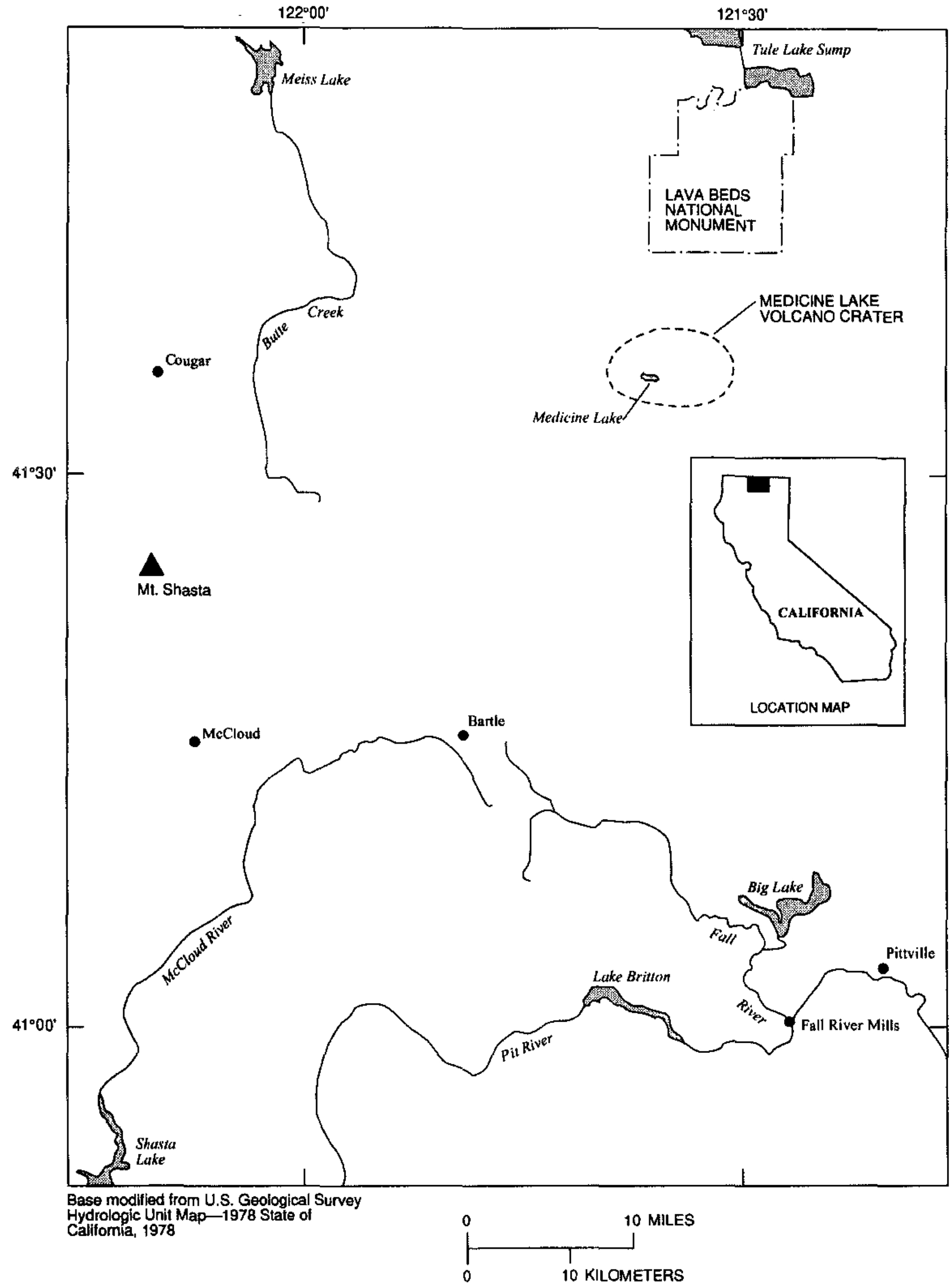

Figure 1. Medicine Lake Volcano-Mt. Shasta area, northern California.

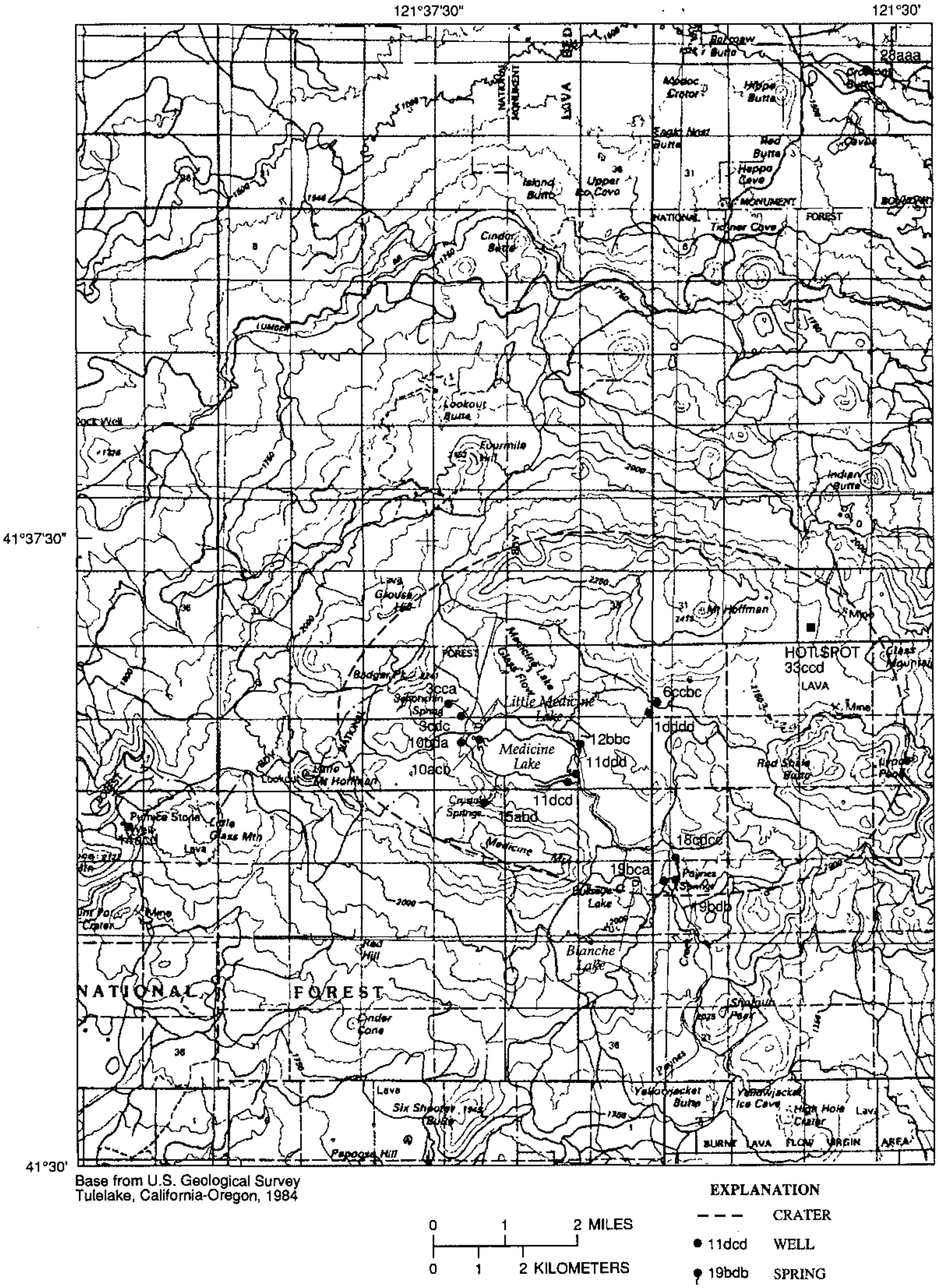

Figure 2. Medicine Lake Volcano study area and location of hydrologic monitoring sites. (See page IV for explanation of well-numbering system.)

Background

The first visit to Medicine Lake Volcano was made June 1–5, 1992. The purpose of the visit was to become familiar with the geography of the area, identify the geothermal and hydrologic features of interest, and to meet with personnel from Unocal. Unocal had been working in the area for more than 10 years and had done preliminary work for designing a hydrologic monitoring project in the Medicine Lake Volcano area.

The second trip to Medicine Lake Volcano was made September 14–18, 1992. On this trip, additional hydrologic and geothermal sites were visited. All wells, springs, and geothermal features were documented, and initial water-level, discharge, temperature, and specific-conductance measurements were made. Permission was obtained from the U.S. Forest Service (USFS) and private landowners to access sites for long-term monitoring. Both the USFS and private landowners were supportive of the monitoring efforts. The water-supply well at Lava Beds National Monument on the northeastern flank of Medicine Lake Volcano is considered an important observation point for the monitoring program. Although this well is low on the flank of the volcano (at 4,570 ft [feet], it is 2,106 ft below the altitude of Medicine Lake) and the water level in the well (3,912-ft altitude) is considerably lower than water levels in wells near Medicine Lake, the well is an indicator of regional flow conditions adjacent to the volcano. USGS personnel visited the National Monument and met with the superintendent.

Purpose and Scope

The purpose of this report is to present hydrologic data that were collected to develop a plan (outlined herein) to monitor hydrologic conditions before, during, and after geothermal development. The report describes current conditions in wells, springs, lakes, and geothermal vents that may or may not be affected by geothermal development activities. All of these features are important to the recreational and environmental uses of the area. The monitoring plan described in this report has not been implemented.

The reconnaissance work of two field trips to Medicine Lake Volcano provided an evaluation of hydrologic conditions at wells, springs, and lakes. These features were located, water levels and discharge were measured, and samples for field water-quality parameters were collected. The scope of the work did not include water-quality analyses.

The study was limited primarily to the local area around Medicine Lake (figs. 1 and 2). Hydrologic features on the flank of the volcano also relate to geothermal development at Medicine Lake Volcano and could be monitored in the future.

DATA-COLLECTION METHODS

Standard USGS field methods were used; these methods are described in the "National Handbook of Recommended Methods for Water-Data Acquisition" (Interagency Advisory Committee on Water Data, 1977).

Location of Hydrologic Features

Wells, springs, and lake survey locations were determined during field visits using both topographic maps and Global Positioning Satellite (GPS) technology. Topographic maps used during the study were 1:24,000 scale with a contour interval of 40 ft. Some wells and springs were already identified on maps, but, when they were not, field personnel noted the location of these features on maps. Topographic contours were then used to estimate land-surface elevations. In addition to the maps, GPS was used to locate positions and was essential to establish accurate locations during lake survey work. Latitudes and longitudes for wells and springs are listed in tables 1 and 2. Locations for lake survey work are shown on figure 3.

Water Levels in Wells

Water-level measurements in wells were generally made during static conditions. Most water-level measurements were made with a steel engineer's tape calibrated to one-hundreth of a foot. Two measurements were made within a few minutes of each other at each measurement site, and the measurements were accepted only if they agreed within one-hundreth of a foot. In most cases, well locations and land-surface elevations were established by using 1:24,000-scale topographic maps published by the USGS.

Table 1. Records of selected wells near Medicine Lake, California

[Well location number: Refer to explanation and diagram of well-numbering system, page IV. Altitude: Altitude of land surface at well, in feet above sea level, estimated from topographic maps. Depth of open interval: Depth, in feet below land surface, of open, perforated, or screened intervals. Well diameter: Nominal inside diameter of well casing at land surface. Test method: A, air lift. gal/min, gallons per minute. Water level: D, water level reported by driller; other water levels measured by U.S. Geological Survey personnel. °C, degrees Celsius. Specific conductance reported in microsiemens per centimeter at 25 degrees Celsius. --, no data]

Well location number	Name/owner	Date drilled	Latitude	Longitude	Altitude (feet)	Depth of well (feet)	Depth of open interval (feet)		Well diameter (inches)
							Top	Bottom	
45N/4E–28aaa	Lava Beds National Monument/ National Parks Service	1939	414303	1213023	4,570	758.	709.	758.	12.0
43N/2E–14acd	Pumice Stone well	--	413410	1214224	6,339	4.7	0.0	4.7	24.0
43N/3E–1dddd	Unocal Water well	--	413532	1213403	6,721	200.	--	--	8.6
43N/3E–10bda	Guard station well/ U.S. Forest Service	--	413509	1213653	6,788	--	--	--	--
43N/3E–11ddd	Old Sawmill well	--	413449	1213512	6,700	13.8	--	--	30.0
43N/3E–11dcd	Bob Tadina	--	413433	1213521	6,760	172.	--	--	--
43N/3E–12bbc	Medicine Lake Campground well/ U.S. Forest Service	10/88	413511	1213503	6,800	220.	180.	220.	8.0
43N/4E–6ccbc	Phillips water well	10/11/81	413533	1213351	6,717	535.	--	--	9.6

Well location number	Well performance				Water level		Temperature (°C)	Specific conductance	Remarks
	Test method	Yield (gal/min)	Drawdown (feet)	Test period (hours)	Feet below datum	Date			
45N/4E–28aaa	--	11.5	0.3	--	674.0D	7/26/62	17.1	189	
					653.0	3/02/66			
					658.0	9/17/92			
43N/2E–14acd	--	--	--	--	3.40	9/16/92	--	--	Dug by hand.
43N/3E–1dddd	A	20.0	--	--	--	--	--	--	
43N/3E–10bda	--	--	--	--	7.42	6/02/92	--	--	No log.
					12.21	9/15/92	--	--	
43N/3E–11ddd	--	--	--	--	6.83	9/16/92	--	--	No log.
43N/3E–11dcd	--	--	--	--	137.08	9/16/92	--	--	Newest well.
43N/3E–12bbc	A	100.	--	4	178.98	9/15/92	--	--	
43N/4E–6ccbc	--	--	--	--	98.08	9/16/92	--	--	

Table 2. Records of selected springs near Medicine Lake, California

[Spring location number: Refer to explanation and diagram of well-numbering system, page IV. Altitude: Altitude of land surface at spring, in feet above sea level, estimated from topographic maps. °C, degrees Celsius. Specific conductance reported in microsiemens per centimeter at 25 degrees Celsius. --, no data. gal/min, gallons per minute]

Spring location number	Spring name	Latitude	Longitude	Altitude (feet)	Date	Temperature (°C)	Specific conductance	Remarks
43N/3E–3cdc	South Schonchin Spring	413526	1213659	6,820	9/15/92	--	--	Dry.
43N/3E–10acb	Private Spring (Latunich)	413504	1213641	6,700	9/15/92	6.6	56.0	Discharge 28.7 gal/min, measurement made approximately 600 feet downstream and approximately 100 feet from lake edge.
43N/3E–15abd	Crystal (Government) Springs	413424	1213634	6,860	6/02/92	2.6	47.3	Discharge 3.4 gal/min.
					9/15/92	2.6	43.0	
43N/4E–19bca	Paynes Spring I	413325	1213341	6,558	9/16/92	12.6	56.0	Discharge 75.4 gal/min, measured 600 feet downstream on west fork of Paynes Creek.
43N/4E–19bdb	Paynes Spring II	413319	1213337	6,471	9/16/92	7.8	--	Discharge 23.3 gal/min, measurement made in small channel about 15 feet from orifice.
43N/4E–18cdcc	Paynes Spring III	413342	1213335	6,678	9/16/92	--	--	Seeps only. No discharge measurement made.

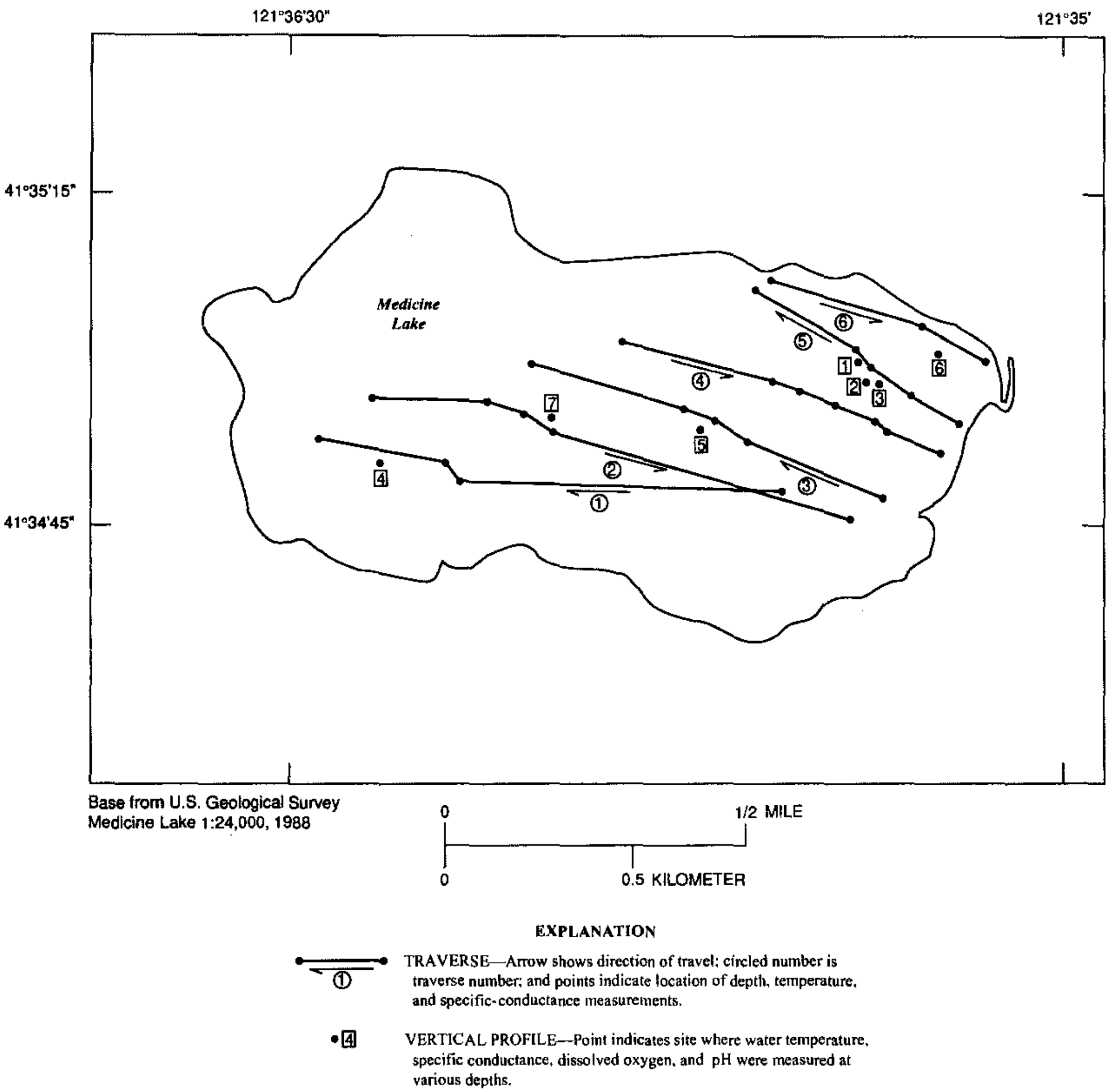

Figure 3. Location of traverses and profiles on Medicine Lake, September 1992.

The water level of the Lava Beds National Monument well was measured by using an air line. In this method, an air line of known length is pressurized with compressed air so that water is forced out of the line; once stabilized, the pressure is measured with an air gage. The measured pressure can be used to calculate the depth of water below land surface. Water-level measurements made with this method are considered accurate to one-tenth of a foot.

Discharge

Discharge from springs was generally measured at a point downstream from the spring orifice where the stream channel was well defined. At sites where the discharge was less than 1 ft^3/s (cubic foot per second), a Parshall flume was used. At one site, spring discharge was measured by using a simple volumetric method where flow into a bucket of known volume was timed with a stopwatch. This method is one of the most accurate for measuring flow when the flow of water is small and can be adequately channeled into a bucket.

Field Water-Quality Data

Temperature data were collected by using a digital thermometer, a combination temperature and specific-conductance probe, or a multiparameter probe. These instruments were calibrated at the beginning of each day. The thermometer was calibrated with a mercury thermometer, and the specific-conductance meter was checked with specific-conductivity standard solutions that bracketed the expected range of specific conductances.

Lake survey work was accomplished using a multiparameter probe. The probe was used in the lakes to collect temperature, specific-conductance, dissolved oxygen, and pH data. The probe cable length was 75 ft, and, as a consequence, some vertical profiles were limited by the length of cable. For some measurements, the temperature and specific-conductance probe was used. The cable length on that probe was 150 ft.

HYDROLOGIC DATA COLLECTION

Many of the data collected during this project were collected in September 1992. Most of the discussion that follows pertains, therefore, to conditions during September, near the end of the water year.

Wells

Selected wells both inside and outside the crater were field-located to measure water levels in the shallow (less than 1,000-ft depth) ground-water system (table 1). These wells are primarily water-supply wells. Some of them are no longer in use; others are currently being used for campgrounds, cabins, and National Monument water supply, and two will likely be used in the future as water-supply wells for geothermal energy production and drilling.

Unused wells include the Pumice Stone well (43N/2E–14acd), the Guard Station well (43N/3E–10bda), and the Old Sawmill well (43N/3E–11ddd). The Unocal and Phillips wells (43N/3E–1dddd and 43N/4E–6ccbc) were drilled to supply water for geothermal operations. The only wells used routinely in the study area are the Lava Beds National Monument well (45N/4E–28aaa) and the Medicine Lake Campground well (43N/3E–12bbc).

Numerous wells have been drilled in and near the Medicine Lake Volcano crater for geothermal exploration. These wells are generally several thousand feet deep and were not visited as part of this study.

Springs

Springs in the vicinity of Medicine Lake are cold-water springs. Six springs were located during this study (table 2). All springs had discharge with the exception of South Schonchin Spring (43N/3E–3cdc), which has apparently been dry for some time, according to USFS personnel. Paynes Spring III (43N/4E–18cdcc) also did not have measurable flow. At one time, South Schonchin Spring supplied drinking water to cabins on the west side of Little Medicine Lake. Paynes Spring III is a swampy area with diffuse seepage that was unmeasurable, but it may have flow during wetter years.

Schonchin Spring (43N/3E–3cca), as identified on the 1:24,000-scale Medicine Lake quadrangle, could not be located as a distinct discharge area and is not listed in table 2. It may be a general area of seepage located approximately where a spring is indicated on the quadrangle (fig. 2).

Crystal Springs (43N/3E–15abd), also called Government Spring, has been developed at the orifice to collect the discharging water, which is piped to the USFS guard station on the west end of Medicine Lake and to cabins west of Little Medicine Lake. The spring has a small (3.4 gal/min [gallons per minute]) discharge but has had relatively constant flow, according to USFS personnel.

Paynes Springs I and II (43N/4E–19bca and 43N/4E–19bdb) constitute the primary discharge of the Paynes Springs area, with discharges of 75.4 and 23.3 ft^3/s, respectively. These springs are used occasionally to provide water for campers and horses.

Lake Surveys

Surveys were made of Medicine, Little Medicine, Blanche, and Bullseye Lakes to determine their approximate maximum depths and to collect data on temperature, specific conductance, dissolved oxygen, and pH. These surveys included vertical profiles to evaluate vertical variations in the water-quality parameters and traverses to evaluate lateral variations in these parameters.

The most complete survey was done on Medicine Lake (fig. 3). Temperature and specific-conductance data collected at shallow depths (approximately 5 ft) during lake traverses had relatively uniform values. Temperature of the lake water at these depths was in the range of 14.1 to 14.5°C (degrees Celsius), and specific-conductance values ranged from 13 to 14 µS/cm (microsiemens per centimeter).

Figures 4–10 show vertical profiles of temperature, specific conductance, dissolved oxygen, and pH from seven sites in Medicine Lake. Profiles 1–3 (figs. 4–6) are from the deepest (greater than 140 ft) part of the lake and show that temperature abruptly decreases at a depth of 40 ft. Between the lake surface and 40 ft, water temperature is about 14.0°C. Below 40 ft, temperatures decrease to between 4.0 and 5.0°C. Profile 1 (fig. 4) shows that the concentration of dissolved oxygen generally remains constant at approximately 8 mg/L (milligrams per liter) to 40 ft, and then increases briefly to 10.5 mg/L before dropping to a minimum of 7 mg/L at 80 ft. Both pH and specific conductance remain relatively constant with depth. In the case of profile 3 (fig. 6), which is to a depth of 110 ft, the specific conductance increases to 19 µS/cm.

Profiles 4–7 (figs. 7–10) were done in shallower (depth less than 100 ft) areas of the lake. Profiles 5 and 6 were to depths of 50 and 65 ft, respectively. In these two profiles, the temperature decreases near the bottom of the profile, and dissolved oxygen concentration increases slightly. Other parameters in profiles 4–7 remain relatively constant.

Little Medicine Lake is a small lake northwest of Medicine Lake that is approximately 500 ft in diameter. The lake has a maximum depth of 25 ft and is greater than 10 ft deep at most locations. The temperature of the lake ranged from 14.5 to 15.5°C and averaged about 15.0°C, dissolved oxygen concentrations ranged from 7.2 mg/L to 8.3 mg/L and averaged 7.6 mg/L, and pH ranged from 7.1 to 7.5 and averaged 7.2.

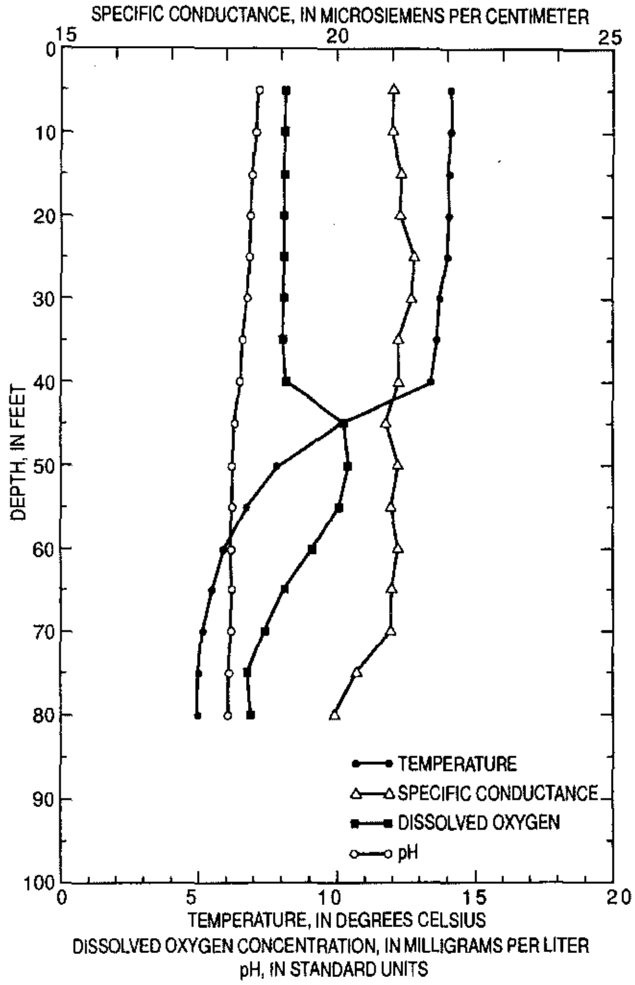

Figure 4. Vertical profile 1 of temperature, specific conductance, dissolved oxygen, and pH in Medicine Lake, September 1992.

Blanche and Bullseye Lakes are approximately 2 miles southeast of Medicine Lake and are approximately 500 ft in diameter. Blanche Lake has a maximum depth of 1.5 ft near the center. Water temperature ranged from 16.9 to 17.9°C, dissolved oxygen concentration ranged from 7.6 to 8.0 mg/L, pH ranged from 5.9 to 6.7, and specific conductance ranged from 14 to 15 µS/cm. Bullseye Lake has a maximum depth of 8.2 ft. Water temperature ranged from 13.6 to 14.6°C, dissolved oxygen concentration ranged from 7.5 to 8.5 mg/L and was generally between 7.5 and 7.6 mg/L, pH ranged from 6.9 to

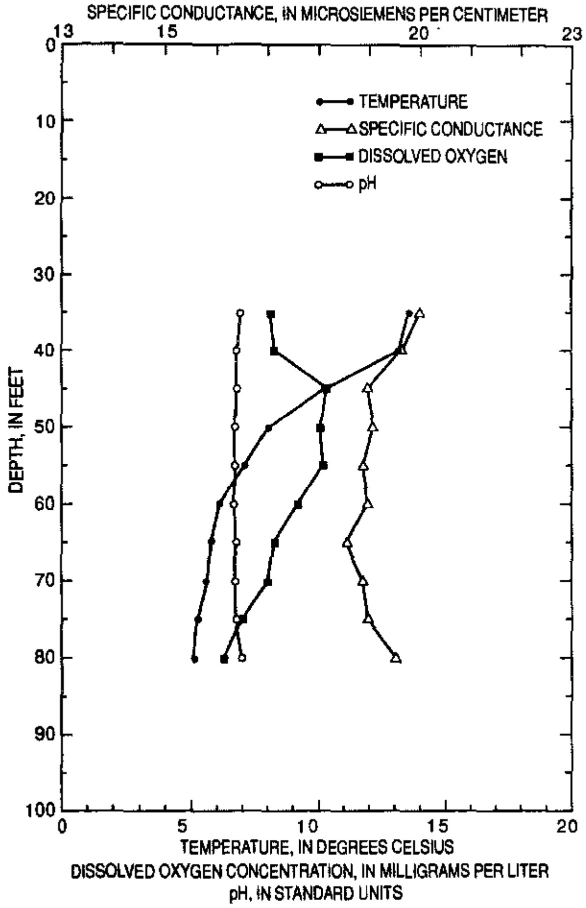

Figure 5. Vertical profile 2 of temperature, specific conductance, dissolved oxygen, and pH in Medicine Lake, September 1992.

7.0, and specific conductance was consistently 15 µS/cm.

MONITORING PLAN

This section describes a proposed monitoring plan that is based on data from the two field trips conducted in 1992. The duration and scope of the proposed monitoring will depend on the duration of the production of geothermal power (excavation/injection of fluids) and the variability in physical and chemical parameters that are monitored. Parameters having the greatest variability will require more frequent measurement, and those with less variability may require less frequent measurement. The scope of the monitoring plan would be evaluated on a yearly basis and will depend on the extent of the geothermal development and the nature of the data collected.

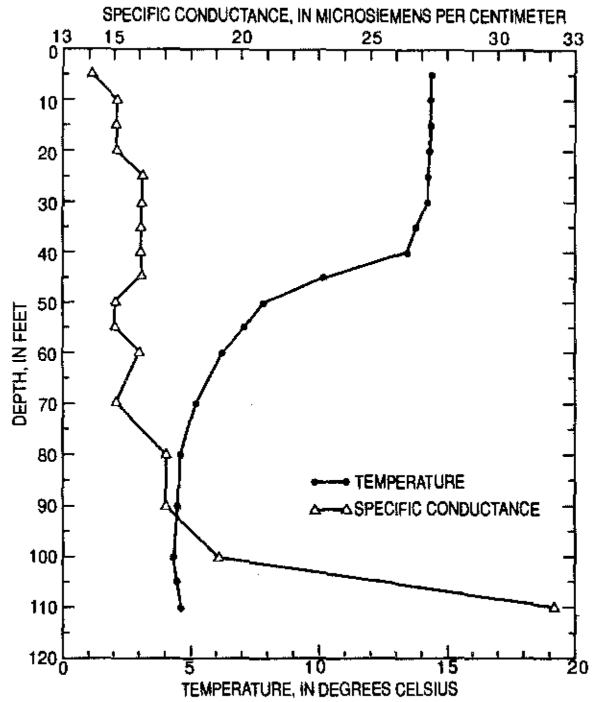

Figure 6. Vertical profile 3 of temperature and specific conductance in Medicine Lake, September 1992.

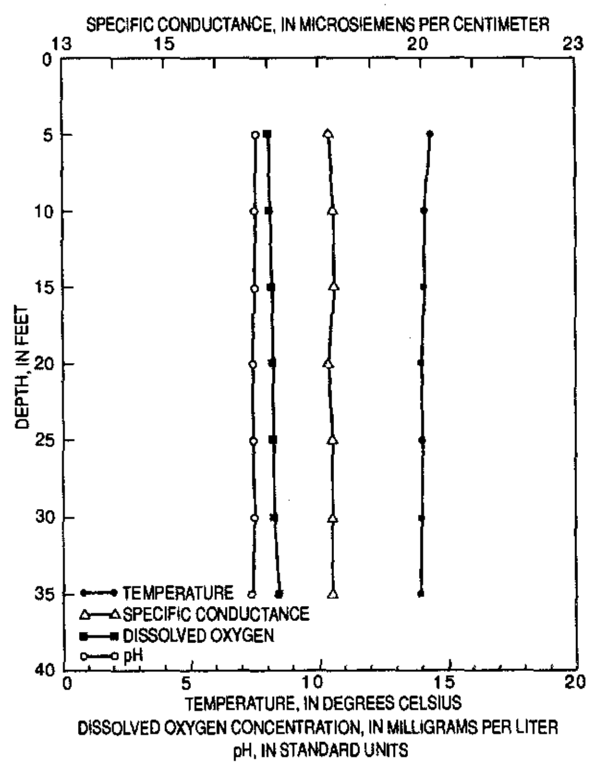

Figure 7. Vertical profile 4 of temperature, specific conductance, dissolved oxygen, and pH in Medicine Lake, September 1992.

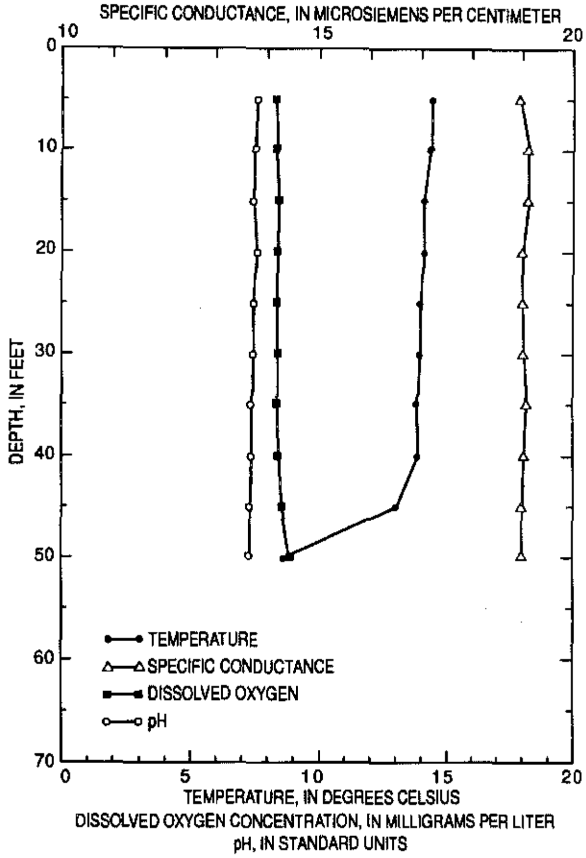

Figure 8. Vertical profile 5 of temperature, specific conductance, dissolved oxygen, and pH in Medicine Lake, September 1992.

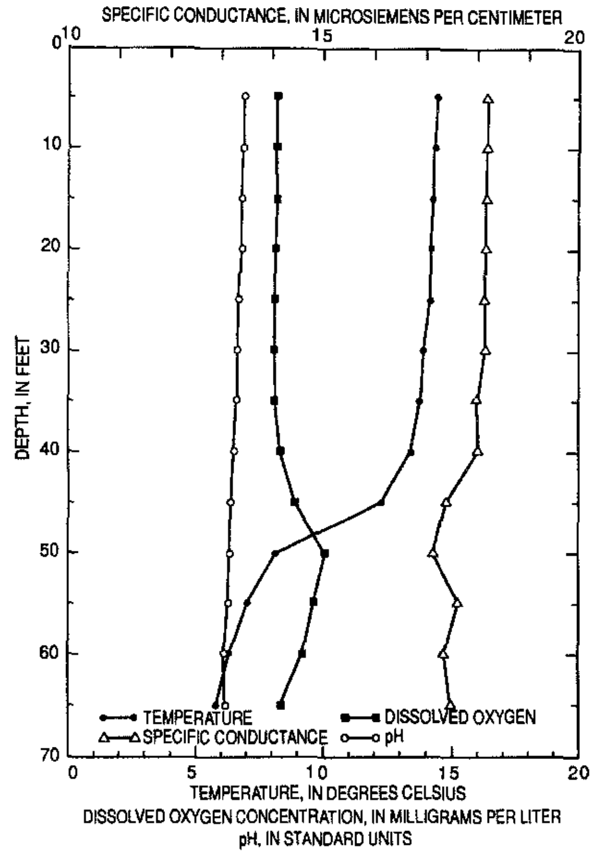

Figure 9. Vertical profile 6 of temperature, specific conductance, dissolved oxygen, and pH in Medicine Lake, September 1992.

Table 3 (on page 13) contains a proposed initial plan for data-collection frequency at selected sites.

As a result of development of access to the Medicine Lake area, the USFS has proposed a water-quality monitoring plan at Medicine Lake (U.S. Forest Service, 1984). This previously developed plan, although designed for a different purpose, would be reviewed and considered in any future monitoring efforts.

Wells, Springs, and Lakes

Medicine Lake Volcano has wells, springs, and lakes within its crater. Medicine Lake Volcano also has one "hot spot," or hot gas vent, near Glass Mountain (44N/4E–33ccd, fig. 2). Most of the land surrounding Medicine Lake is privately owned, although the USFS maintains campgrounds on the northeast shore of the lake. Both the USFS and private citizens rely on cold-water springs and wells in the crater for drinking-water supplies.

Medicine Lake Volcano sites selected for monitoring during the 1992 reconnaissance phase of the monitoring program are listed in tables 1 and 2. The sites include eight wells and six springs; Medicine, Little Medicine, Blanche, and Bullseye Lakes; and a multivent hot spot on the flank of Glass Mountain. In addition, a meteorological station would be established within the crater.

It is uncertain whether extraction of geothermal fluids or injection of cooled geothermal water, which will cause decreased or increased reservoir pressures at depth, respectively, will affect wells, springs, or lakes in the area. Because of the uncertainty, monitoring of these features would be an integral part of the monitoring plan.

Water chemistry from selected wells, springs, and the four lakes would be monitored to detect natural changes in concentrations of various constituents. Gas samples would be collected and analyzed from the hot spot. Wells, springs, and lakes would be sampled twice a year, and gas samples would be taken once a year. Discussions with Unocal, former holder of the

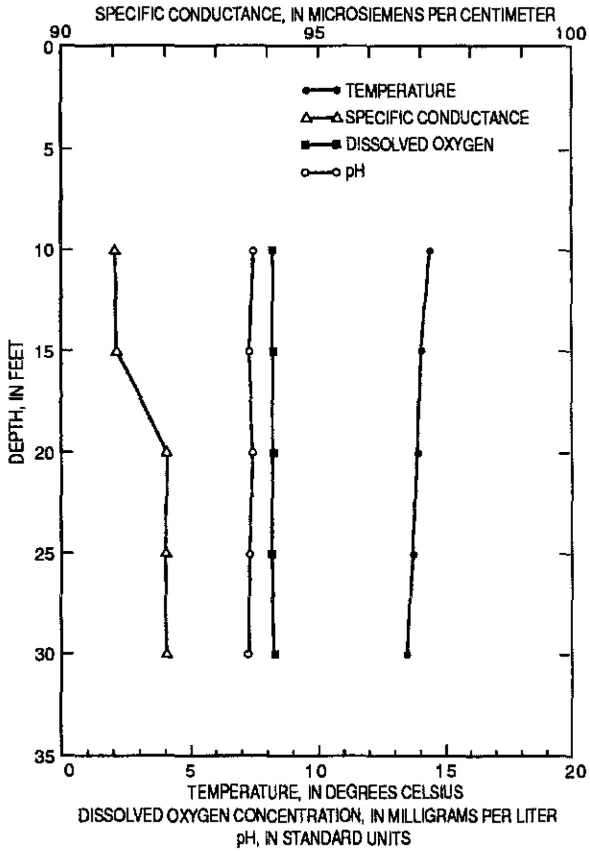

Figure 10. Vertical profile 7 of temperature, specific conductance, dissolved oxygen, and pH in Medicine Lake, September 1992.

rights to the area, indicated that it may also be possible to collect samples from deeper geothermal wells in the future. Constituents for the suggested analyses are listed in the Appendix. The physical parameters, chemical constituents, and isotopes included in this monitoring plan were taken from the U.S. Geological Survey (1977) guidelines for collecting environmental baseline data on Federal geothermal leases.

Water levels would be measured at least twice each year in the eight wells to determine the natural variations within the crater and on the flank of Medicine Lake Volcano. Ground-water temperature and specific conductance could be measured in four wells that are equipped with pumps. These measurements could also be made at least twice each year in conjunction with the water-level measurements. The snowpack depth would be a determining factor on the number of field visits. Access to all measurement sites would be difficult during the winter because roads in the area are closed owing to deep snow, and sites would be buried under several feet of snow.

Discharge measurements on springs would be made at least twice each year. Measurement of discharge during winter probably would not be possible because of deep accumulations of snow.

Little information is available on water quality in Medicine, Little Medicine, Blanche, and Bullseye Lakes. Before a long-term monitoring strategy for the lakes can be devised, their natural chemical variation, both with respect to location and season, must be better defined. This natural variation is important in deciding location and timing of sampling and the types of analyses needed.

A two-stage approach could be used to determine the natural chemical variation of the lakes during both stratified and unstratified conditions. Medicine Lake would be the primary focus of the lake-water-quality sampling because of the relatively large size of the lake. The two-stage approach would include reconnaissance of field parameters such as temperature, specific conductance, pH, and dissolved oxygen along vertical profiles and lateral traverses in the lakes. This reconnaissance could be done shortly after the lakes are clear of ice in the spring, before thermal stratification occurs. Data that were collected in September 1992 could be used to evaluate the lakes during stratified conditions.

Selection of long-term monitoring sites, appropriate sampling frequencies, and chemical constituents to be analyzed would be selected on the basis of the findings from the reconnaissance.

Samples would be collected in areas having anomalously high or low values of one or more of the four field parameters. Some sampling locations would also be selected in areas having normal, or background, values. These samples would be analyzed for nutrients, isotopes, trace elements, and major ion chemistry. Similar analyses would be done once for each of the smaller lakes.

Little information is available on lake stage for any of the four lakes in the crater. A comparison of observations from the 1992 field trips indicates that the stage of Medicine, Blanche, and Bullseye Lakes can vary by several feet. In fact, the drop in lake level between June and September 1992 (approximately 5 ft) for Medicine Lake suggests that water may discharge through the lake bottom. Little Medicine Lake, however, seemed to have a fairly constant stage during the June–September 1992 period. Data would be collected to establish the "typical" range in lake levels.

A continuous recording stage gage would be installed on Medicine Lake—possibly at the boat

Table 3. Proposed measurement and sampling schedule for monitoring in the Medicine Lake Volcano area, California

[--, not applicable or not measured; S, semiannually; *, measurement or collection of water-quality sample; C, continuous; T, three measurements per year; **, gas temperature only; A, annually]

Location	Name of feature	Water level/ stage	Temperature/ conductance	Discharge	Chemical sample
		Wells			
45N/4E–28aaa	Lava Beds National Monument	S	S	--	S
43N/2E–14acd	Pumice Stone well	S	--	--	S
43N/3E–1dddd	Unocal water well	S	S	--	S
43N/3E–10bda	Guard station well	S	--	--	S
43N/3E–11ddd	Old Sawmill well	S	--	--	S
43N/3E–11dcd	Bob Tadina	S	S	--	S
43N/3E–12bbc	Medicine Lake Campground well	S	S	--	S
43N/4E–6ccbc	Phillips water well	S	S	--	S
		Springs			
43N/3E–3cdc	South Schonchin Spring	--	S*	S*	S*
43N/3E–10acb	Private Spring (Latunich)	--	S	S	S
43N/3E–15abd	Crystal (Government) Springs	--	S	S	S
43N/4E–19bca	Paynes Spring I	--	S	S	S
43N/4E–19bdb	Paynes Spring II	--	S	S	S
43N/4E–18cdcc	Paynes Spring III	--	S*	S*	S*
		Lakes			
43N/3E–10/11	Medicine Lake	C	S	--	S
43N/3E–10a	Little Medicine Lake	T	S	--	S
43N/3E–24a	Blanche Lake	T	S	--	S
43N/3E–24a	Bullseye Lake	T	S	--	S
		Hot Spot			
44N/4E–33ccd	Hot spot	--	C**	--	A

ramp on the east end of the lake. Staff gages would be established for Little Medicine, Blanche, and Bullseye Lakes. These staff gages would be read a minimum of three times a year.

Meteorological Station

Climatic conditions within the crater are very different from those at other meteorological stations in the region (Lava Beds National Monument), and climatic trends may also be different. It is important that climatic conditions in the crater be monitored so that trends in other hydrologic parameters (lake stage, ground-water levels, and others) can be interpreted. A meteorological station would be installed to monitor precipitation, temperature, relative humidity, wind speed, and net solar radiation. This station could be located at the site of the existing snow course station and nonrecording precipitation gage near the Guard Station. By selecting this location, data could be directly compared with historic and current snow-measurement data and any existing precipitation data.

Hot Spot Temperature

The hot spot on the northwestern flank of Glass Mountain (44N/4E–33ccd) is the only geothermal feature at the land surface in the Medicine Lake Volcano crater. Gases discharge from two distinct (1–1.5-ft-diameter) vents. A large area (300 by 500 ft) surrounding the vents has no vegetation, and the ground surface is covered with pumice. Field personnel observed that throughout this area, elevated temperatures could be observed just 2 to 3 in. below the ground surface. One of these vents would be monitored with instruments that measure variations in the temperature of the discharging gases. In addition, gas samples would be collected annually to monitor the composition of discharging gases as development/production proceeds.

Monitoring Wells

An important part of the Medicine Lake Volcano monitoring plan would involve monitoring geothermal wells. These wells could be selected from wells that have been used for exploration or new wells might have to be drilled to appropriate depths and at specific locations. In addition, gas samples would be collected annually to monitor the composition of discharging gases as development/production proceeds. The design of this type of monitoring well network is beyond the scope of this project.

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APPENDIX

PHYSICAL PARAMETERS, CHEMICAL CONSITITUENTS, AND ISOTOPES TO BE COLLECTED AT MONITORING SITES

A. Field parameters (measured with a multiparameter probe)

(1) pH, alklinity, temperature, specific conductance

(2) Dissolved oxygen, when feasible (for instance, dissolved oxygen is not meaningful when samples are obtained from wells equipped with air-jet pumps)

B. Major chemistry (dissolved unless otherwise stated) and physical parameters (includes analytical methods and detection limits for laboratory analyses)

(1) Major ions:

Ca, atomic absorption, 0.1 mg/L

Mg, atomic absorption, 0.1 mg/L

Na, atomic absorption, 0.1 mg/L

K, atomic absorption, 0.1 mg/L

HCO_3, titration, 1 mg/L

Cl, ion chromatography, 1 mg/L

SO_4, ion chromatography, 1 mg/L

F, ion chromatography, 10 μg/L

(2) Minor constituents:

SiO_2, colorimetry, molybate blue, 0.1 mg/L

Al, atomic emission, DG plasma, 10 μg/L

Fe, atomic absorption, 10 μg/L

Mn, atomic absorption, 10 μg/L

(3) Nutrients:

total P, colorimetry, 10 μg/L

ortho P, colorimetry, 10 μg/L

$NO_2 + NO_3$, colorimetry, 0.1 mg/L

NH_4, colorimetry, 0.01 mg/L

(4) Dissolved solids:

residue on evaporation, 1 mg/L

(5) Turbidity:

nephelometry, 0.1 NTU

C. Isotopes (dissolved):

(1) oxygen-18/oxygen-16, mass spectrometry, ±0.15 o/oo

(2) deuterium/protium, mass spectrometry, ±1.5 o/oo

D. Trace elements (dissolved):

(1) As, atomic absorption, 1 μg/L

(2) Ag, atomic absorption, graphite furnace, 1 μg/L

(3) B, atomic emission, DC plasma, 10 μg/L

(4) Ba, atomic absorption, 100 μg/L

(5) Cd, atomic absorption, 10 μg/L

(6) Cr, DC plasma, 1 μg/L

(7) Cu, atomic absorption, 10 μg/L

(8) Hg, atomic absorption, flameless, 0.1 μg/L

(9) Li, atomic absorption, 10 μg/L

(10) Mo, atomic absorption, 1 μg/L

(11) Pb, atomic absorption, graphite furnace, 1 μg/L

(12) Se, atomic absorption, 1 μg/L

(13) Sr, atomic absorption, 10 μg/L

(14) Zn, atomic absorption, 10 μg/L

E. Dissolved gases:

(1) CO_2, calibrated from alkalinity titration

(2) H_2S, calculated from total recoverable sulfide; total recoverable sulfide determined by iodometric titrimetry with detection limit of 0.5 mg/L as S

(3) NH_3, calculated from ammonium ion concentration

F. Radon-222 (dissolved):

liquid scintillation, 70 pCi/L

G. Gross radioactivity (dissolved):

gross alpha, residue proc., 0.4 μg/L (U), 0.4 pCi/L (Th-230) gross beta, residue proc., 0.4 pCi/L (Sr-90/Y-90, Cs-137)

H. Vertical profiles:

(1) pH

(2) temperature

(3) specific conductance

(4) dissolved oxygen

I. Continuous monitoring:

specific conductance and temperature

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