A WATER-RESOURCES APPRAISAL OF THE MOUNT SHASTA AREA IN NORTHERN CALIFORNIA, 1985

By *J.C. Blodgett, K.R. Poeschel,* and *J.L. Thornton*

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4239

Sacramento, California
1988

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, *Secretary*

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

For additional information
write to:

District Chief
U.S. Geological Survey
Federal Building, Room W-2234
2800 Cottage Way
Sacramento, CA 95825

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CONVERSION FACTORS

For readers who may prefer to use International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acre-ft (acre-feet)	1,233	cubic meters
feet	0.3048	meters
ft^2 (square feet)	0.09294	square meters
ft^3 (cubic feet)	0.02832	cubic meters
ft^3/s (cubic feet per second)	0.02832	cubic meters per second
$(ft^3/s)/mi$ (cubic feet per second per mile)	0.017601	cubic meters per second per kilometer
$(ft^3/s)/mi^2$ (cubic feet per second per square mile)	0.01093	cubic meters per second per square kilometer
gal/min (gallons per minute)	0.003785	cubic meters per minute
inches	25.40	millimeters
miles	1.609	kilometers
mi^2 (square miles)	2.590	square kilometers

Water Year: A water year is a 12-month period, October 1 through September 30, designated by the calendar year in which it ends. In this report, years are water years unless otherwise noted.

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD 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 water-resources appraisal of the Mount Shasta area in northern California was completed to document present hydrologic characteristics so that comparisons could be made of possible future changes due to land use or volcanic activity. Data collected during this study include glacial areas and volumes, streamflow, sediment concentrations, temperature, and water chemistry of the ground water and springs.

The lower flanks of Mount Shasta consist of broad, smooth aprons of pyroclastic-flow, debris-flow, and fluvial deposits. Incised channels on upper parts of the mountain tend to terminate on the flanks. Only four streams--Mud, Whitney, Squaw Valley, and Ash Creeks--have sufficient streamflow to reach downstream main channels or to travel more than about 6 miles from the summit.

The difference in low flows of the various streams is attributed to variations in glacial melt, storage of ground water in the materials that compose the mountain and the alluvial fans, and the rain-shadow effect of the mountain on precipitation. Annual precipitation in the vicinity of McCloud, southeast of the summit, is about 53 inches, whereas on the northwest side, it is about 18 inches.

Although Mount Shasta is an old volcano, lava flows and other volcanic activity have occurred within the last 10,000 years. The most recent of Mount Shasta's summit vents is Hotlum Cone, which may have erupted as recently as 200 years ago.

Many springs issue from fracture joints in lava and lava tubes around the mountain; the main ground-water movement is generally away from the slopes of Mount Shasta. Where ground-water data were available, the direction of movement is in a downslope direction from areas of recharge near Black Butte and Mount Shasta to areas of discharge near Weed and Mount Shasta (city).

There are three large springs with the same name on the flanks of Mount Shasta: Big Springs near Grenada (yield about 36 cubic feet per second), Big Springs near Mount Shasta (city) (yield about 20 cubic feet per second), and Big Springs near McCloud (yield about 600 cubic feet per second). Springs serve as the main source of water for the communities of Mount Shasta (city), McCloud, Dunsmuir, and Weed.

Ground-water levels fluctuate seasonally from less than 1 to 27 feet with some water-level variation attributed to low storage coefficients. The quality of all ground water from wells located on the flanks of Mount Shasta meets U.S. Environmental Protection Agency standards for drinking water.

Glaciers on Mount Shasta--the largest being Hotlum No. 1 and Whitney--generally lie above an altitude of 9,000 feet. The total volume of all glaciers on Mount Shasta is about 4.7×10^9 cubic feet.

Streamflow in the vicinity of Mount Shasta is affected by snowfield and glacial melt, precipitation from winter frontal-type storms, and ground water released at springs. Most streams on the flanks of the mountain that result from snowfield or glacial melt are ephemeral and do not travel far from the mountain before percolating into the channel bed on alluvial fans. Those streams affected by snowfield and glacial melt show diurnal effects caused by temperature changes. Peak flows for these streams generally occur between 1800 and 2400 hours at the 3,400-foot altitude.

INTRODUCTION

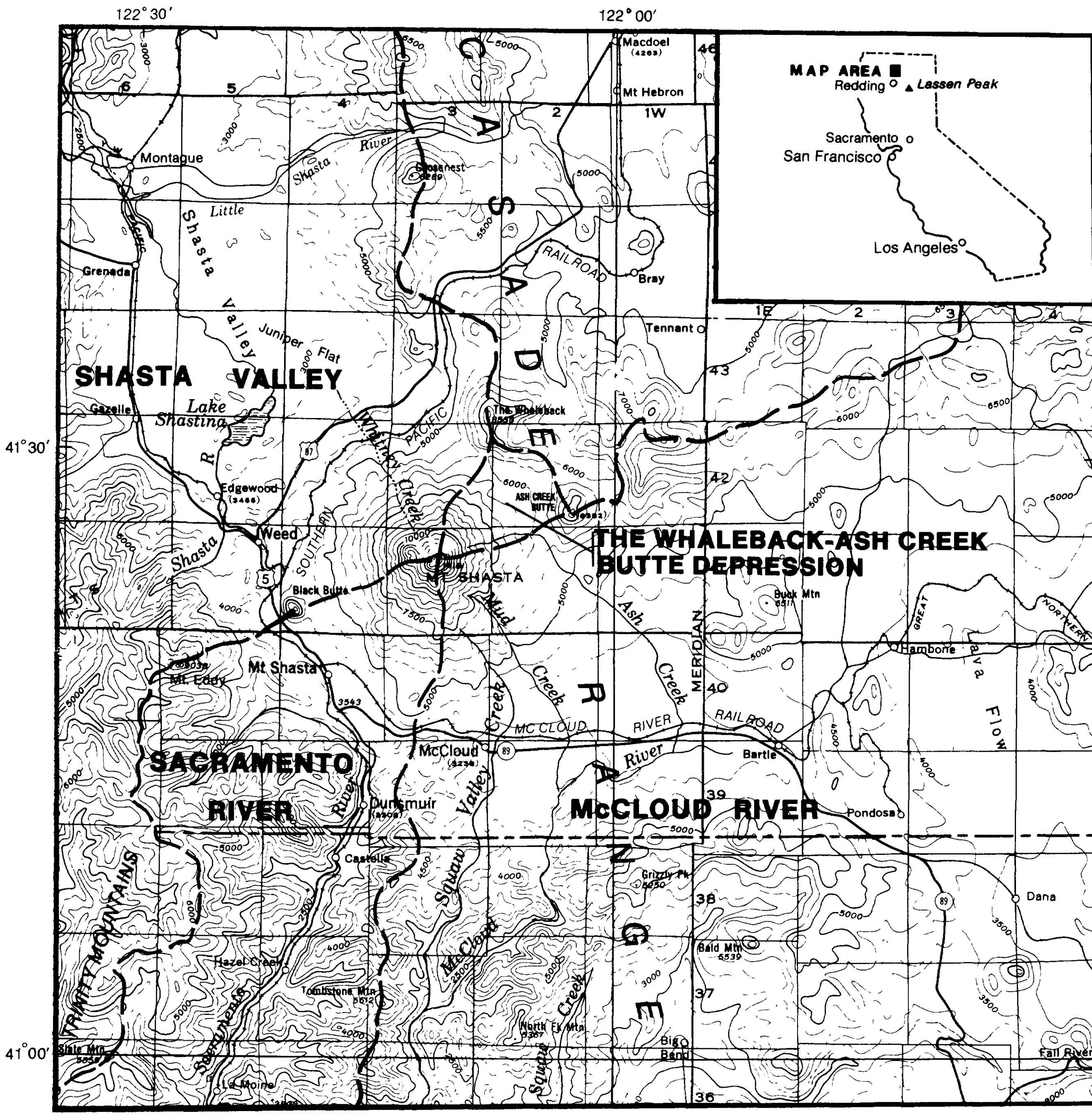
Background

Mount Shasta in northern California (fig. 1) is one of the largest and highest stratovolcanoes of the Cascade Range, which extends from Washington through Oregon and into northern California. Crandell and Mullineaux (1975) reported that six major volcanoes in the Cascade Range (table 1) have been active within historical times (the last 150 years); there has been an average of one eruption every 100 years.

Volcanic eruptions include one or more of the following products: Lava flows (molten magma), tephra (airborne ash and rock debris), pyroclastic flows (hot rocks and super heated air), and debris flows. A summary of the various products caused by activity of the 13 major volcanoes in the Cascade Range is shown in table 1. Mount Shasta is one of four volcanoes from which all four volcanic-related products have resulted from eruptions in the last 12,000 years.

An additional significant activity in historical time on Mount Shasta is the occurrence of debris flows not associated with volcanic eruptions; these debris flows are attributed to glacial melt and other climatic phenomena. In this century, major debris flows have occurred in all four drainage basins of Mount Shasta. These debris flows blocked highways and railroads and resulted in construction of dams and diversion structures to prevent the inundation of roads, railroads, or lumber mills (Carlson and others, 1978; Hill and Egenhoff, 1976).

Within the last century, the increased use of the lands surrounding Mount Shasta for recreation, permanent and seasonal residences, roads, railroads, and reservoir developments has increased the potential for loss of life and property when the next eruption or debris flow occurs. Because the occurrence and magnitude of these events are difficult to predict, development patterns need to be carefully considered in areas of potential hazard.



Base from U.S. Geological Survey 1:500,000, 1961

0 10 20 MILES

0 10 20 KILOMETERS

CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

FIGURE 1. Location of Mount Shasta and hydrologic areas. (Dashed lines indicate approximate boundaries of hydrologic areas.)

TABLE 1. -- Recent activity of some major volcanoes in the Cascade Range

[X indicates activity; -- indicates no activity; ? indicates activity questionable. Adapted from Crandell and Mullineaux, 1975]

	Washington					Oregon					California		
	Mount Baker	Glacier Peak	Mount Rainier	Mount St. Helens	Mount Adams	Mount Hood	Mount Jefferson	Three Sisters	Mount Mazama (Crater Lake)	Newberry Volcano (Newberry Crater)	Mount Shasta	Glass Mountain area	Lassen Peak-Chaos Crags area
Active in historical time (last 150 years)--	X	X	X	X	--	X	--	--	--	--	?	?	X
Known products of eruptions (last 12,000 years):													
Lava flows-------------	X	--	X	X	X	X	X	X	X	X	X	X	X
Tephra (airborne ash and rock debris)-----	X	X	X	X	--	?	--	X	X	X	X	X	X
Pyroclastic flows------	--	X	X	X	--	--	--	--	X	--	X	--	X
Debris flows-----------	X	X	X	X	X	X	--	--	--	--	X	--	X
Known product of noneruptive activity in historical time:													
Debris flows-----------	--	--	X	--	--	X	--	--	--	X[1]	X	--	--

[1]From Osterkamp and others (1985).

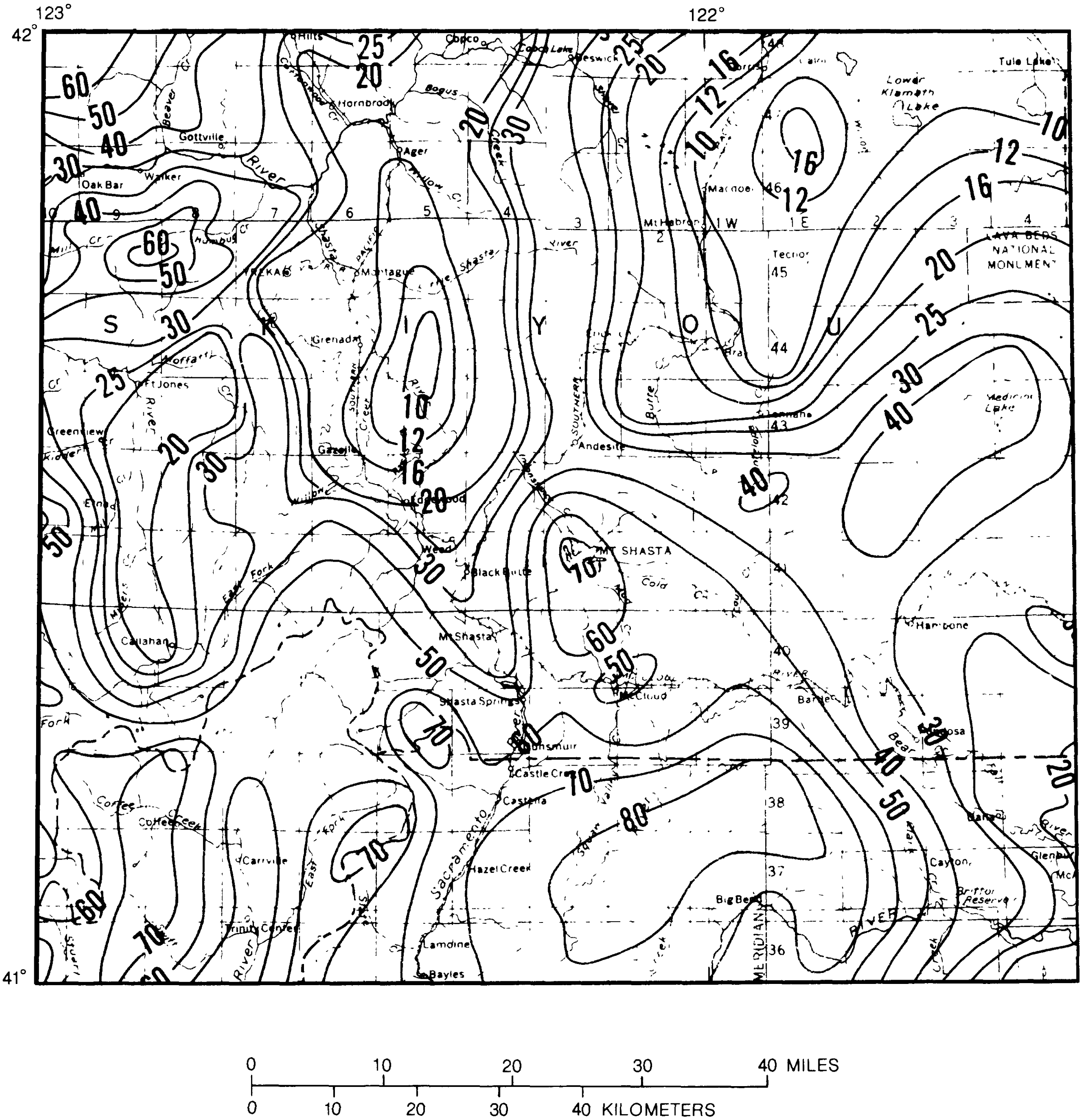
Purpose and Scope

The purpose of this study was to collect hydrologic information in the vicinity of Mount Shasta that could be used to assess the consequences of future debris flows and volcanic eruptions on the water resources of the area. As such, a reconnaissance level data-collection network was designed and implemented to collect water-quality data for ground water and springs, and discharge and quality data for streams in the Mount Shasta area. On the basis of these data (Poeschel and others, 1986), this report presents a discussion of the occurrence and movement of ground water and an analysis of the glaciers and streamflow that drain the slopes of the mountain in the four hydrologic areas around Mount Shasta.

GENERAL FEATURES OF STUDY AREA

Climate

The climate in the Mount Shasta area reflects its extreme topographic relief. The effect of the mountain ranges on precipitation patterns is indicated by the change in precipitation related to orographic uplift in a south-to-north as well as a west-to-east direction. The climate, expressed in general terms, includes warm summer days, cool nights, and mild winters. Temperatures range from 85 °F (Fahrenheit) in summer to 25 °F in winter. Mean annual precipitation at Redding (fig. 1) at the base of the Sacramento River canyon is about 39 inches, and at Mount Shasta (city), near the upstream end, is about 38 inches with an average snowfall depth of 96 inches. The rain-shadow effect of Mount Shasta to the north and west, reflecting the counterclockwise rotation movement of storms moving west to east from the Pacific, is indicated by the dry conditions and sparse vegetation in most parts of Shasta Valley. The variation in precipitation caused by the rain shadow is indicated by the mean annual precipitation at the National Weather Service climatic stations at McCloud (altitude 3,254 feet) of about 53 inches and at Weed (altitude 3,466 feet) of about 27 inches (fig. 2). At the climatic station at Yreka in Shasta Valley (altitude 2,625 feet), the mean annual precipitation is about 18 inches (fig. 2).



EXPLANATION

—40— LINE OF EQUAL MEAN ANNUAL PRECIPITATION -- Interval variable, in inches

FIGURE 2. Mean annual precipitation for 1911-60 in Mount Shasta area. (Modified from Rantz, 1969.)

Geography of Hydrologic Areas

Mount Shasta, one of the most prominent volcanoes of the Cascade Range with an altitude of 14,162 feet, is located about 38 miles south of the California-Oregon State line, between Shasta Valley to the north and the canyon of the Sacramento River to the south (fig. 1). Although the Trinity Mountains rise to over 9,000 feet at Mount Eddy to the southwest and the Cascade Range rises to 5,700 feet to the north and east, the altitude of most of the surrounding area is less than 4,000 feet.

Surrounding Mount Shasta are four major hydrologic areas: Sacramento River, McCloud River, The Whaleback-Ash Creek Butte Depression, and Shasta Valley (fig. 1).

Streams that originate on Mount Shasta enter three main river systems: The Shasta River to the northwest, the Sacramento River to the southwest, and the McCloud River to the east, southeast, and south (fig. 1). Creeks draining the northeast flank of Mount Shasta flow into a closed depression in which fans of debris from Mount Shasta abut the pre-Mount Shasta lava cones of The Whaleback and Ash Creek Butte. Many streams draining Mount Shasta are intermittent and flow into the volcanic debris on the flanks and base of the volcano. Only four streams--Mud, Whitney, Squaw Valley, and Ash Creeks (fig. 1)--have sufficient streamflow to reach downstream main channels or to travel more than about 6 miles from the summit.

The lower flanks of Mount Shasta consist mostly of a broad, smooth apron of fans of porous pyroclastic-flow, debris-flow, and fluvial deposits as seen in the vicinity of Diller Canyon (fig. 3). These fans are composed of the products of fluvial activity and successive eruptions. Valleys that head at many other volcanoes in the Cascade Range are deep erosional clefts in which products of eruptions are concentrated and carried many tens of miles. At Mount Shasta, however, flow phenomena caused by streamflow or debris flow spread out over broad areas on the lower flanks of the volcano. As a result, these flows travel shorter distances than those confined to narrow valleys; however, their paths and areas of inundation are unpredictable.

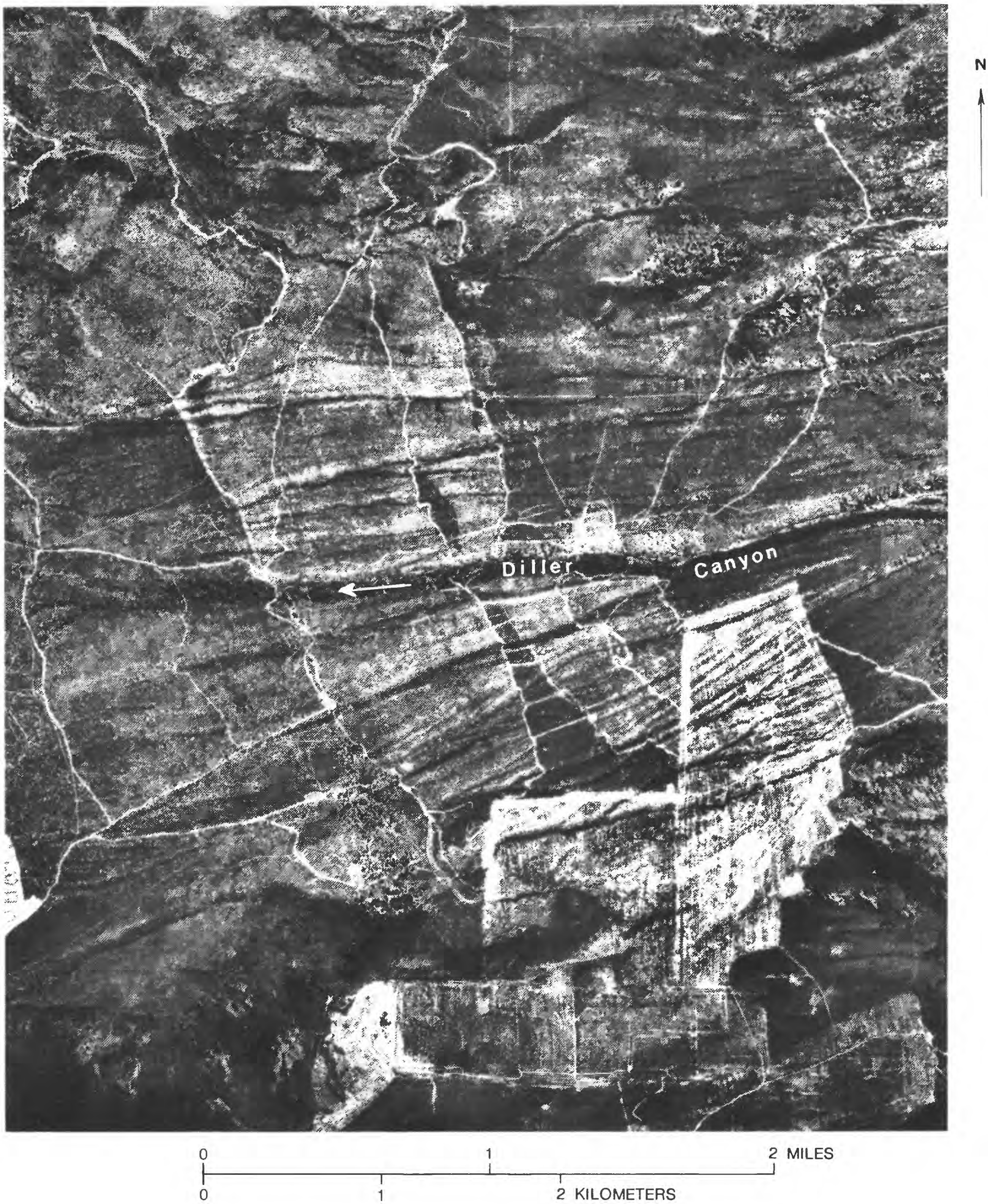


FIGURE 3. Diller Canyon in T. 41 N., R. 4 W. showing downstream dissipation of incised channels on flanks of Mount Shasta. (Photographed July 23, 1981.)

Sacramento River

The area southwest of Mount Shasta designated in this report as the Sacramento River hydrologic area includes the Trinity Mountains and the headwaters of the Sacramento River (fig. 1). The summit of the topographic saddle between the Sacramento and the Shasta River basins, located between Mount Shasta (city) and Weed, is about 4,000 feet in altitude. The principal communities are Mount Shasta (city) and Dunsmuir, with populations of 2,880 and 2,190, respectively. The average annual precipitation at Mount Shasta (city) is 37.5 inches. Native forests consist of dense stands of pine and fir species on the eastern and southern parts of the area, whereas a mixture of various pines, juniper, and manzanita is found in the northern and western sectors. A more detailed description of the woody vegetation typical of the mountain slopes is provided by Hupp and others (1987).

The principal highways in the area are Interstate Highway 5 and State Highway 89 (fig. 1). The Southern Pacific Transportation Co.'s main railroad line between Redding and Weed is located in the Sacramento River canyon, and the McCloud River Railroad runs between Mount Shasta (city) and McCloud. A small airport (Mott Field) is located near Mount Shasta (city).

In the vicinity of Mount Shasta (city), a number of tributaries such as Scott Camp and Wagon Creeks (pl. 1) enter the Sacramento River. The original mouths of these and other tributaries have been inundated by Lake Siskiyou. This lake, with a maximum capacity of 26,100 acre-ft, was formed by Box Canyon Dam in 1968. It should be noted that much of the flow of Wagon Creek in the 3-mile reach upstream from Lake Siskiyou (pl. 1) is augmented by flows from springs on the slopes of Mount Shasta. No perennial streams originating near the summit of Mount Shasta enter the Sacramento River in the vicinity of Mount Shasta (city). The lack of surface-water runoff from Mount Shasta to the Sacramento River in this area is attributed to the absence of glaciers on the south side of the mountain and to the porous nature of the pyroclastic and alluvial material on the flanks. Although Cascade Gulch, Avalanche Gulch, and Diller Canyon originate near the summits of Mount Shasta or Shastina (pl. 1), none of these channels are well defined on the lower flanks of the mountain (fig. 3); they tend to dissipate near an altitude of 4,000 feet. Because of the absence of defined channels, any future debris flow may tend to disperse laterally on the alluvial fan near the downstream terminus of the channel.

Downstream from Mount Shasta (city), the Sacramento River is confined to a narrow deep canyon that terminates near Shasta Lake, altitude 1,065 feet, 35 miles downstream from Mount Shasta (city). The city of Dunsmuir, 10 miles downstream from Mount Shasta (city) in the canyon at an altitude of 2,300 feet, occupies both banks of the Sacramento River. Parts of Dunsmuir are subject to inundation during periods of flooding when streamflow exceeds about 9,000 ft^3/s, a discharge that has an average recurrence interval of 6 years.

McCloud River

The area on the southeast flank of Mount Shasta is designated in this report as the McCloud River hydrologic area (fig. 1). The channels of Squaw Valley, Mud, and Ash Creeks (fig. 1) are located on the east and southeast flanks of Mount Shasta, at an altitude of about 3,200 feet. The principal city in the basin is McCloud (fig. 1), a lumbering and recreation center located on the flanks of Mount Shasta. The major highway in the area is east-west State Highway 89 from Mount Shasta (city) to Lassen Peak (fig. 1). The McCloud River Railroad provides transportation of lumber products from McCloud and other points east to the Southern Pacific railroad at Mount Shasta (city). A small private airport is located about 1 mile northeast of McCloud. The average annual precipitation at McCloud is 52.8 inches.

Native vegetation consists of dense stands of pine, fir, and cedar. Most areas of Squaw Valley, Mud, and Ash Creeks are covered by extensive layers of fine-grained sand of pyroclastic origin (tephra) and debris flows that overlie basalts deposited during the Pleistocene Epoch. Most of this material is highly permeable.

Squaw Valley, Mud, and Ash Creeks, the major streams in this area, are perennial. Konwakiton Glacier forms the headwater of Mud Creek, and Wintun Glacier forms the headwater of Ash Creek (pl. 1). Squaw Valley Creek receives flow from several springs located both upstream and downstream from McCloud. The headwater of Squaw Valley Creek is located between Red Fir and Sargents Ridges (pl. 1) on Mount Shasta near an altitude of 9,600 feet with snowmelt the primary source of water.

Mud Creek has a long history of debris-flow activity (Hill and Egenhoff, 1976). Following several debris-flow and hyperconcentrated flow events during 1924-26, the McCloud Lumber Co. constructed a concrete wing dam to divert Mud Creek flows to the Elk Creek drainage to the east. The dam was destroyed during the next debris flow. The existing Mud Creek Dam (sec. 5, T. 40 N., R. 2 W., pl. 1) was constructed in 1934 by the Civilian Conservation Corps. Constructed along with this dam was a desilting box and a 5.5-mile-long diversion ditch to Pilgrim Creek. The dam structure proved inadequate for higher than normal flows, and today, although it is still in place, the forebay is full of sediment.

Flows in Mud Creek are diverted to Tusalusa Creek by a channel located approximately 1 mile south of State Highway 89 (pl. 1) to prevent the normally high sediment discharge of Mud Creek from entering the McCloud River upstream from Wyntoon. These flows are then diverted to Huckleberry Creek, which empties into the McCloud River about 4 miles downstream from the mouth of Mud Creek, which is upstream from McCloud Dam (located 9 miles south of McCloud outside the study area), and about 0.5 mile downstream from Wyntoon (pl. 1).

The terminus of Squaw Valley and Mud Creeks is the McCloud River southeast of McCloud. Near the mouth of Mud Creek, a number of springs, including Big Springs (pl. 1), supplement the flow of the river. The terminus of Ash Creek is in Ash Creek Sink located in sec. 22, T. 40 N., R. 1 W., about 3 miles upstream from State Highway 89 crossing (pl. 1). The Ash Creek channel at the highway is small, and flow is intermittent at the crossing.

The flow of the McCloud River downstream from Wyntoon has been regulated by McCloud Dam (fig. 1) since November 1965. The reservoir (normal maximum contents, 35,234 acre-ft) is about 9 miles southeast of McCloud between the mouths of Mud and Squaw Valley Creeks. During the flood of January 15, 1974, the maximum reservoir contents of record, 35,967 acre-ft, caused spillway overflow. During a debris flow or high concentration of sediment flow on Mud Creek in the summer of 1977, some of this flow entered the reservoir via Huckleberry Creek, causing a silt plume and concern about the water quality of the reservoir (Darrel Ranken, Forest Hydrologist, U.S. Forest Service, written commun., 1977).

The Whaleback-Ash Creek Butte Depression

The area in the northeast quadrant of Mount Shasta is designated in this report as The Whaleback-Ash Creek Butte Depression (fig. 1). The depression is a plateau located between Mount Shasta, The Whaleback, and Ash Creek Butte, with an altitude of about 5,900 feet. Both The Whaleback and Ash Creek Butte, with summits at about the 8,400-foot altitude, are pre-Shasta lava cones (Miller, 1980).

No climatic data are available for this area; snowfields normally do not melt sufficiently to permit traffic on the roads until late May or June. There are no municipalities or railroads in this area, and all roads are jeep trails and primary- or secondary-type Forest Service roads used for logging and tourism. There are no established campgrounds in the area. The main road is the historic Military Pass Road that connects U.S. Highway 97 near Andesite and State Highway 89 near McCloud (pl. 1). Forests in the area are composed of pine, fir, and cedar on the eastern side, with a transition to lodgepole, yellow pine, juniper, and sagebrush in drier areas on the western side near Shasta Valley (Hupp and others, 1987).

A major lava flow, known as the Military Pass flow, originated near the Hotlum Cone (summit of Mount Shasta) and traveled down the mountain between Gravel and Inconstance Creeks (pl. 1). This lava flow, which is highly fractured and blocky, occurred about 9,700 years ago (Miller, 1980) and is about 5.6 miles long. The three main streams in the area--Brewer, Gravel, and Inconstance Creeks--originate from Hotlum Glaciers Nos. 1 and 2 (pl. 1) and from snowfields near the summit of Mount Shasta, and flows are intermittent. The drainage of lower Brewer Creek may cross the divide between Mount Shasta and Ash Creek Butte and, during extreme high flows, may enter Ash Creek. The terminus of Gravel and Inconstance Creeks, which flows only during the summer months, is in highly porous debris fans and a depression between Ash Creek Butte and The Whaleback. Farther to the north, and across the divide between Ash Creek Butte and The Whaleback, several springs at an altitude of about 5,000 feet augment the flows of Butte and Pomeroy Creeks, which eventually join and flow into Butte Valley near Macdoel (not shown on pl. 1). Much of the debris in the depression area consists of highly permeable tephra. Streamflows decrease in a downstream direction, as reported by Poeschel and others (1986).

Shasta Valley

Shasta Valley, to the northwest of Mount Shasta, is designated in this report as the Shasta Valley hydrologic area and is a nearly oval montane basin about 30 miles long (fig. 1). The average annual precipitation in the valley is about 18 inches. Weed, a lumbering and mill town with a population of approximately 2,800, is the principal city in this area. On the upper slopes of the mountain, the native vegetation is composed of pine, especially in areas not logged. Most of Shasta Valley north of the mountain (fig. 1) is covered by juniper, sagebrush, and manzanita, with a transition to a mixture of pine and manzanita above about 3,500 feet (Hupp and others, 1987).

Major transportation routes that traverse the area include Interstate Highway 5, U.S. Highway 97, and the Southern Pacific railroad (fig. 1). The railroad line branches at Weed, with one route continuing northwest and the other route northeast. Three airports are located in the area--one near Weed, the Montague Airport west of Montague, and the Siskiyou County Airport north of Montague.

The western part of Shasta Valley is overlain by Quaternary alluvium (Mack, 1959). The flat eastern half of the valley is occupied mostly by an extensive flow of basaltic lava known as Holocene Plutos Cave Basalt that erupted from the flanks of Mount Shasta (Mack, 1959). A prominent feature near the eastern part of the valley is the Lava Park lava flow (pl. 1 and fig. 4), 4 miles long and 6,000 feet wide, which flowed from a vent on the flank of Shastina about 9,000 years before present (BP) (Miller, 1980). At the eastern edge of the valley, sediment derived from the Whitney and Bolam basins (pl. 1) is being deposited on the lower flank of Mount Shasta as a broad fan. The major drainages in Shasta Valley (fig. 1) are the Shasta River (which heads in the Trinity Mountains near Mount Eddy) and the Little Shasta River and Willow Creek, which are west of the study area. The floor of Shasta Valley, with an area of about 250 mi^2, contributes little runoff to the Shasta River because of local depressions and the porous nature of the soils and basalt.

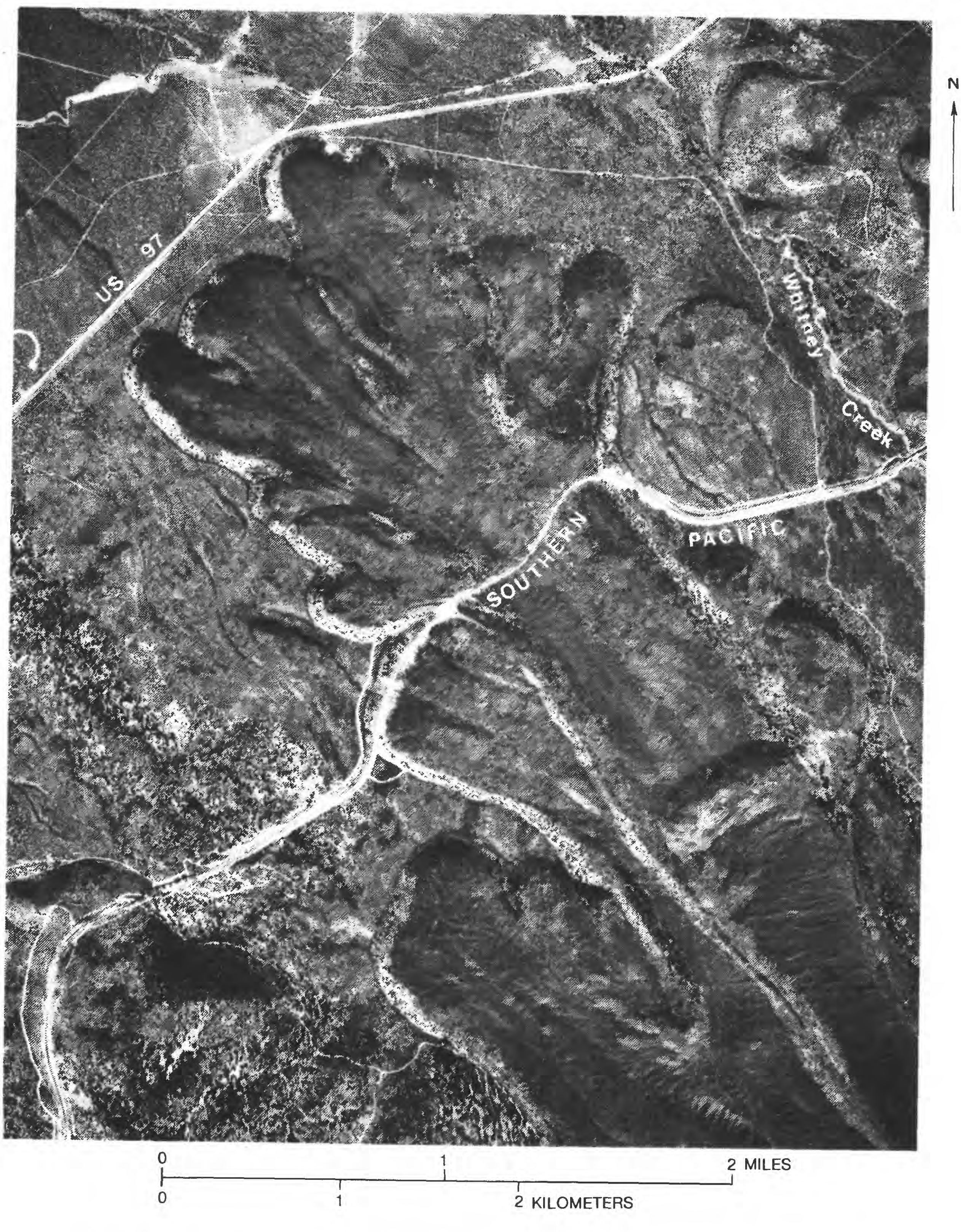


FIGURE 4. Terminus of Lava Park lava flow near Whitney Creek, in T. 42 N., R. 4 W. (Photographed July 23, 1981.)

Three streams on the east side of the valley originate from Mount Shasta or Shastina (pl. 1). Bolam Creek heads at Bolam Glacier, Whitney Creek heads at Whitney Glacier at an altitude of about 10,000 feet, and Graham Creek originates from the snowfields on Mount Shastina and flows along the east side of the Lava Park lava flow. Streamflow for all three streams is intermittent and shows large diurnal fluctuations; it generally occurs during periods of intense rainfall, or when the glaciers or snowfields are melting during summer months. A characteristic of Whitney Creek is the high concentration of sediment during periods of flow (Poeschel and others, 1986).

Sometime prior to 1935, a diversion and flume were constructed (sec. 18, T. 42 N., R. 3 W., about 1.5 miles upstream from the mouth of Bolam Creek) to convey water from Bolam Creek to the hamlet of Bolam built along the Southern Pacific railroad (pl. 1). A settling basin was constructed near the point of diversion to reduce the sediment discharge of the diverted water. Foundations of houses and the trees used to landscape this small community were still visible in 1984. The exact purpose of the flume is unknown, but it may have been used to supply domestic water to the hamlet or to transport logs to the railroad when the area was logged.

About 1,000 feet downstream from the U.S. Highway 97 crossing, all the flow of Whitney Creek was diverted on the left bank by a canal constructed in 1962 and abandoned in 1976. The canal crosses the northwest slope of Mount Shasta to an area near Lake Shastina (formerly Dwinnell Reservoir) (fig. 1). Lake Shastina on the Shasta River, constructed in 1928 about 4 miles from Edgewood (fig. 1), is a multipurpose reservoir with a maximum capacity of 50,000 acre-ft. The diverted flow was intended for agricultural irrigation and livestock water (Sams, 1981). The canal operation was discontinued in 1976 when the irrigated land was sold to developers for subdivision. The former diversion structure was closed with an earthfill dam 11 feet high. Only during large floods exceeding about 8,000 ft^3/s or debris flows on Whitney Creek will the dam be overtopped and flows enter the diversion channel, which may then inundate areas near Lake Shastina. Some residences located along Whitney Creek approximately 3 miles downstream from the U.S. Highway 97 crossing in Juniper Flat (fig. 1) are subject to inundation or impact by flowing water or debris flows (Osterkamp and others, 1985), as the channel location is continually shifting laterally. The channel alignment is unstable, and the alluvial fan is about 3 miles wide.

Streams entering Shasta Valley generally decrease in discharge with distance from the mountain. These streams do not maintain a flow across the lava and alluvium to the Shasta River because of the porous nature of these deposits.

Volcanic Activity

Volcanic activity has played the dominant role in the geologic development of the Mount Shasta area. Before the growth of the Cascade volcanoes, pyroclastic and lava flows were emitted during early Tertiary time from a north-south trending series of cones and fissures located near the present-day Cascade chain. These early flows, termed volcanic rocks of the Western Cascades (Mack, 1959), can be seen west of the Cascade volcanic chain from Mount Shasta north to Mount Hood in northern Oregon.

The volcanic products of the present Cascade volcanoes have been termed volcanic rocks of the High Cascades (Mack, 1959). On Mount Shasta, these volcanic rocks exist as pronounced outcrops of basalt, andesite, or dacite, and as pyroclastic or debris-flow deposits.

Mount Shasta has evolved for over 100,000 years, mostly by explosive eruptions from four main vents (Christiansen and others, 1977, p. 8-20). The earliest vent, located south of the present summit and east of upper Sargents Ridge (pl. 1), erupted lavas and pyroclastics over 100,000 years ago. Basalt and andesite flows that form the southern slopes of Mount Shasta (pl. 1) were erupted from this Sargents Ridge Cone (Christiansen and others, 1977, p. 8-20).

The second vent is located just southwest of the present summit near Red Banks (pl. 1). This vent was responsible for extensive debris flow and pyroclastic flow deposits on the eastern slopes of Mount Shasta and for a few small outcroppings of andesitic lava flows near the summit and on the northern flanks of the mountain (Christiansen and others, 1977, p. 8-20).

The third Mount Shasta vent forms Shastina (pl. 1), the distinct cone on Shasta's western slope. This cone has evolved since the Pleistocene glaciation during Holocene time (the last 10,000 years). Most products of vent formation have been dated at approximately 9,400 years old by Carbon-14 techniques (Christiansen and others, 1977, p. 8-20). Shastina-aged volcanic products include a fan of pyroclastic material extending from Shastina's summit westward down Diller Canyon to the town of Weed, the extensive lava-flow field called Lava Park on Shasta's northwest slope, and the Black Butte plug-dome complex (pl. 1). Black Butte is a symmetrical, talus-covered peak consisting of overlapping dacite domes, surrounded by pyroclastic deposits that are believed to have been erupted in conjunction with dome building (Miller, 1978).

The fourth and most recent of Shasta's vents is the present summit, Hotlum Cone. Lava flows from this cone may have been erupted as recently as 200 years ago (Christiansen and others, 1977, p. 8-20). A dome fills the crater at the summit, which still has active fumeroles and acid hot springs.

Glaciers and Snowfields

Glacier-covered volcanoes pose special hazards associated with the presence of snow and ice, which are a primary source of water and debris that cause debris flows. The May 1980 eruption of Mount St. Helens in Washington caused the removal of 70 percent of glacier ice on the volcano by melting, by displacement as fragmented blocks, or by being blasted away (Brugman and Meier, 1981, p. 743-756). Pyroclastic flows melted and eroded the snowpack and glaciers, causing subsequent debris flows on several channels that drain the flanks of the mountain. The sudden and forceful eruptions on Mount St. Helens indicated the potential hazards associated with volcanoes of the Cascade Range. Brugman and Meier (1981, p. 743-756) suggest that many of the characteristics of glaciers on Mount St. Helens that were altered or destroyed during the 1980 eruptions could be common to other volcanoes in the Cascade Range that also have highly permeable deposits underlying the ice cover.

The size of glaciers on Mount Shasta (fig. 5), in terms of area, thickness, volume, and terminus altitude, was determined by surveys during the summer of 1981. The absence of glaciers in the southwest quadrant is attributed to excessive ablation rates during summer months. In general, the lower terminus of the snowfields and glaciers are at an altitude of 10,000 feet (table 2), and the total volume of all glaciers is the smallest of the major glaciered volcanos in the Cascade Range. A summary of the size of glaciers on Mount Shasta and comparative data for glaciers on Mount St. Helens prior to the eruption in 1980 (Driedger and Kennard, 1984) is given in table 2. These data suggest that there are ample glaciers and snowfields on Mount Shasta that could melt or erode during an eruption creating debris-flow hazards. On Mount Shasta, the largest glaciers in terms of volume are Hotlum No. 1 and Whitney (table 2); Hotlum No. 1 heads in a basin in a sparsely populated area. The other large glacier, Whitney, contributes flows to Whitney Creek which passes through Juniper Flats of Shasta Valley, where a part of the basin is being developed as a residential area. Large debris flows on Whitney Creek also could cause hazardous conditions at the Southern Pacific railroad or U.S. Highway 97 crossings (fig. 1).

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

Volcanic Rocks of the Western Cascades (Eocene to Miocene)

Volcanic rocks of the Western Cascades (formerly referred to as Western Cascades Series by Williams, 1949) are exposed southwest of the study area on the north and south sides of the Sacramento River in Box Canyon (pl. 1), where they consist of a dense, hard, fine-grained, gray andesite with joint spaces ranging from a few tenths of an inch to as much as 3 feet (Bertoldi, 1973). Basalt lava flows, probably of the same age, are exposed in the cut banks of the McCloud River at the Lower Falls Recreation Area, where they display vesicles and columnar jointing. During the well inventory, only one well (40N/4W-28R2, fig. 6) was found in the volcanic rocks of this area. Data indicating yields from wells in the volcanic rocks of the Western Cascades in the study area are generally unavailable. Some parts of these flows may have developed localized fractures due to buckling of the flow crust when underlying lavas were still fluid. Rubble surfaces, which developed when the crust hardened and crumbled with continued movement of underlying fluid lavas, may have been covered by succeeding flows, causing an interbasalt rubble zone to form between successive flows.

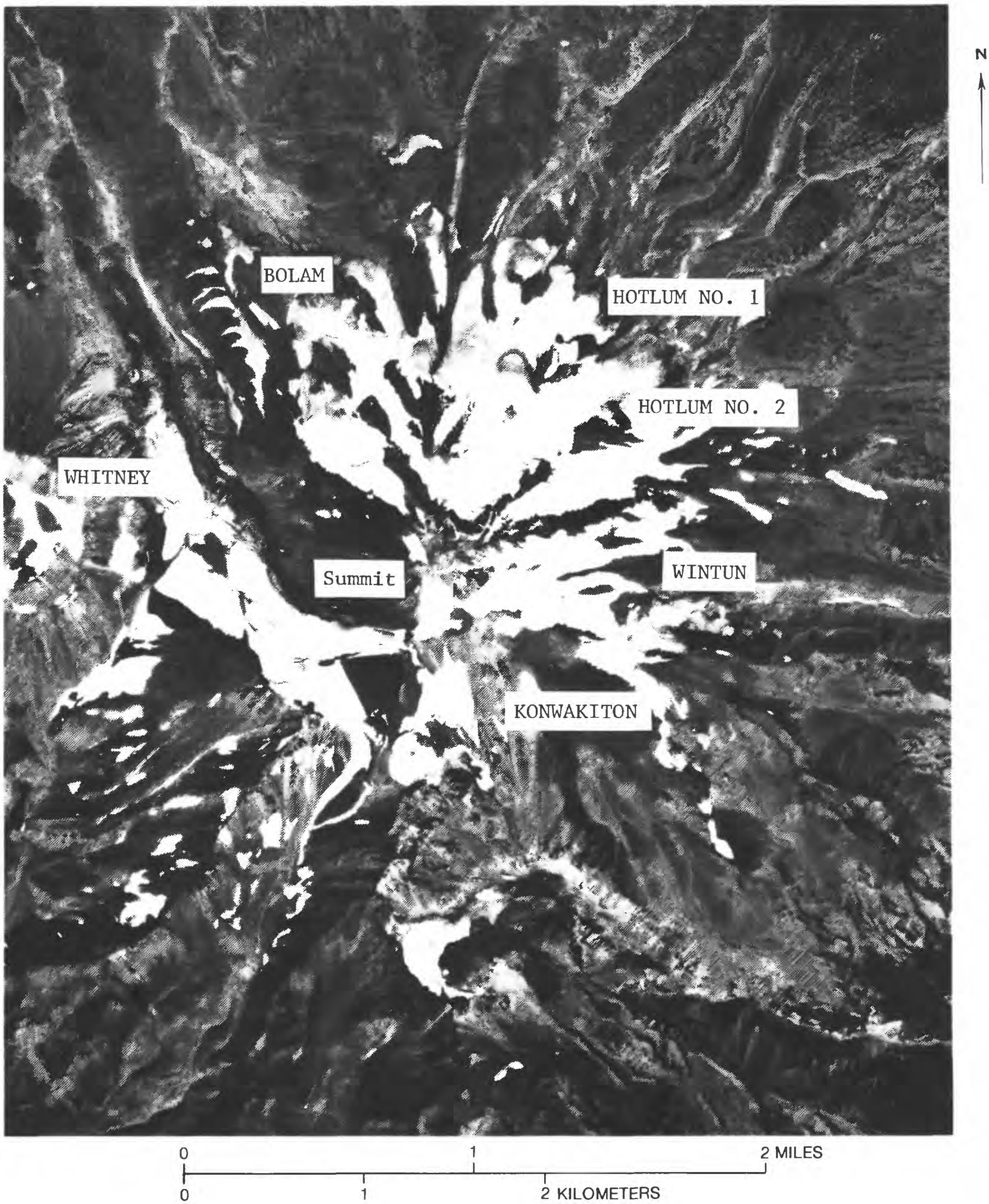


FIGURE 5. Location and size of glaciers on Mount Shasta in 1981. (Photographed September 3, 1981.)

TABLE 2. -- Area, volume, and terminus altitude of glaciers and snowfields on Mount Shasta in 1981 and comparative data for Mount St. Helens prior to 1980 eruption

[1981 data from Driedger and Kennard, 1984]

Basin	Glacier or snowfield	Area, in square feet ($\times 10^6$)	Volume, in cubic feet ($\times 10^9$)	Altitude interval of largest area of glacier and snowfield (feet)	Approximate terminus altitude (feet)
The Whaleback-Ash Creek Butte Depression.	Hotlum No. 1	14.4	1.0	10,000-11,000	10,300
	Snowfields	.7	.05		--
	Total------	15.1	1.1		
Shasta Valley-----	Whitney	13.8	0.9	10,000-11,000	9,800
	Bolam	11.4	.8		9,800
	Snowfields	3.9	.2		--
	Total------	29.1	1.9		
Sacramento River--	Snowfields	6.8	0.3	11,000-12,000	10,000
McCloud River-----	Wintun	13.2	0.9		9,600
	Hotlum No. 2	5.0	.3	11,000-12,000	10,400
	Konwakiton	3.2	.2		[1]11,500
	Snowfields	1.4	[2].07		--
	Total------	22.8	[2]1.4		
Total----------------------------		73.8	4.7	--	--
Mount St. Helens (total).	All 13 glaciers	[3]54.0	[3]6.3	--	[3]4,900

[1]From Williams (1934). Konwakiton Glacier prior to 1924 extended 3/8 mile downstream, giving a terminus altitude of about 9,200 feet.

[2]Subtotal of 1.4×10^9 ft^3 from Driedger and Kennard (1984) reflects rounding of data.

[3]From Brugman and Meier (1981).

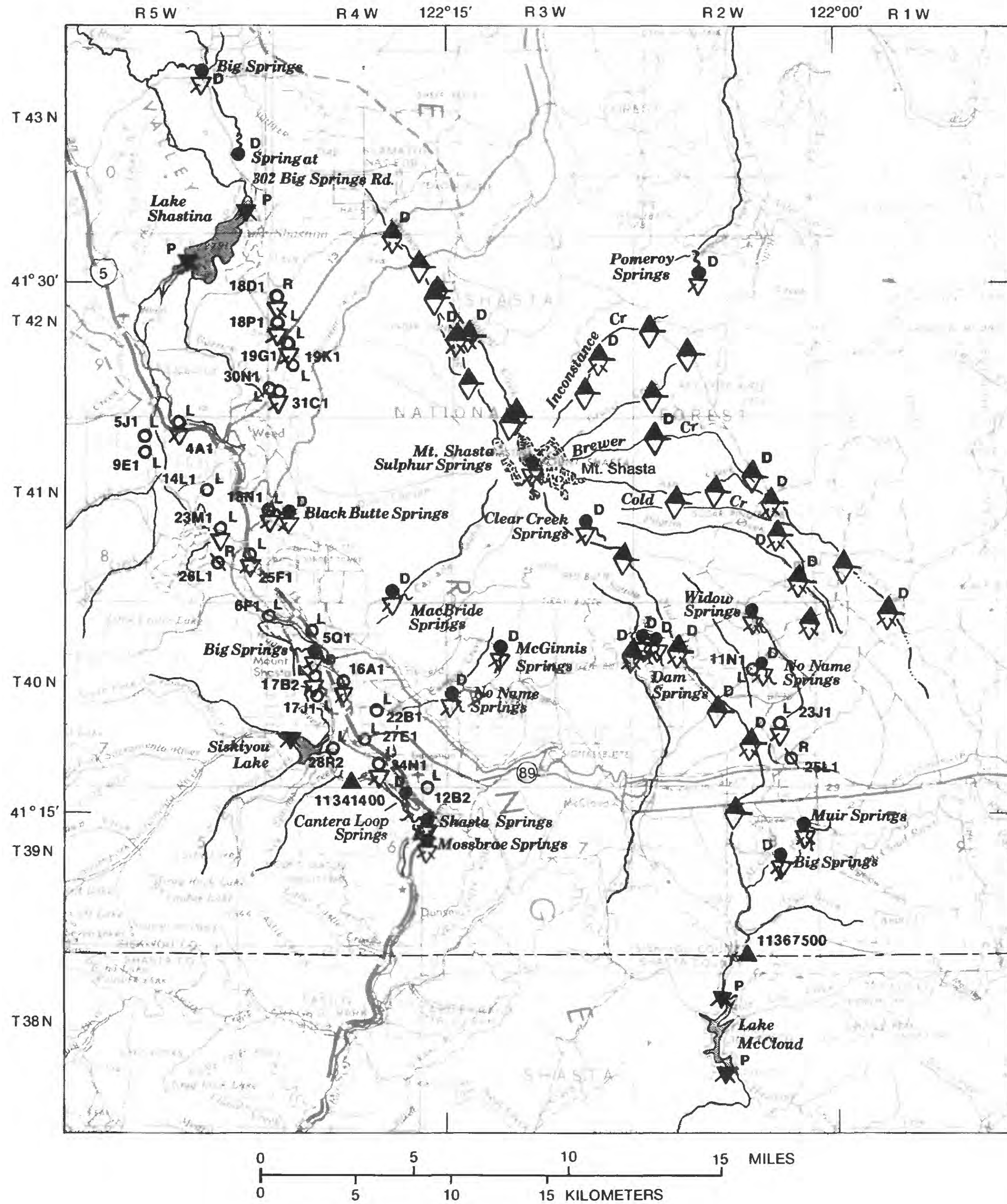


FIGURE 6. Location of wells, springs, and measuring sites on streams and lakes in vicinity of Mount Shasta.

EXPLANATION

WELLS -

- R — Continuously recorded temperatures
- R — Continuously recorded levels
- L — Levels and chemical quality
- L — Levels only
- Chemical quality only

SPRINGS -

- D — Discharge and chemical quality
- Chemical quality and temperature only
- D — Discharge only

STREAM SITES -

- 11367500 — Gaging station and number
- D — Discharge, sediment, chemical quality, and temperature
- D — Discharge and sediment only

LAKE SITES -

- P — Chemical quality, temperature, and depth profile

FIGURE 6. -- Continued.

Many springs issue from joints in the andesites of the volcanic rocks of the Western Cascades exposed in Box Canyon near Mount Shasta (city). This indicates that water is transmitted and stored in the joints of this rock. Where joints are not found, the andesite is virtually impermeable (Bertoldi, 1973). A fault traverses the basal lava flows and crosses the McCloud River near Big Springs. Large volumes of ground water issue from the basalt flows at Big Springs along the McCloud River, indicating that water transmission is aided by localized fractures or faulting or interbasalt rubble zones in this area.

Volcanic Rocks of the High Cascades (Pliocene to Holocene)

Most of the rock units in the study area formed during Mount Shasta's four major episodes of cone building are termed volcanic rocks of the High Cascades (formerly referred to as High Cascades Series by Williams, 1949). On the slopes of Mount Shasta, the volcanic rocks of the High Cascades serve as an intake area and storage reservoir for ground water. Most of the mountain is mantled with thin, rocky soils that overlie highly fractured volcanic rocks. The soils and fractured rocks can readily absorb large quantities of water derived from rain and snow. Glacial melt supplies water to the mountain's streams, but even this stream water infiltrates the porous volcanic rocks of the High Cascades, and streamflows diminish downstream. Unfractured lava flows, however, yield no water and may restrict ground-water flow.

Northeast of McCloud, rock fragments of vesicular lava are abundant; well drillers report drilling through as much as 70 feet of lava before gravel and sand are encountered. Water is not encountered when drilling through lava flows of the McCloud area. Water is found, however, beneath the lava flows in sand and gravel deposits.

The lava flows of Lava Park near U.S. Highway 97 (fig. 4 and pl. 1), among the latest flows from Mount Shasta, are not more than a few centuries old (Miller, 1980). The steep, blocky fronts of two of these flows border U.S. Highway 97 on the south. The highway is constructed across two other lava flows. The recent volcanic rocks visible along U.S. Highway 97 near Weed absorb the snowmelt water that flows in Whitney Creek, and the creek disappears completely before it reaches the Shasta River.

In the Juniper Flats area of the Shasta Valley (pl. 1), an extensive basalt flow known as Plutos Cave Basalt of Holocene age covers more than 50 mi^2. The basalt appears to have issued from fissures near the northwestern base of Mount Shasta, probably no more than several thousand years ago (Mack, 1959). Drillers' logs indicate the lava flow to be more than 800 feet thick in some areas. The lava flow, composed of black, vesicular, olivine-rich augite basalt, contains many large lava tubes including the Pluto Cave. Lava tubes were formed when the top and sides of a flow cooled and solidified while the interior of the flow remained hot and molten. The molten lava continued to flow, escaping the solidified frame through fractures in the side or front of the flow and leaving a tunnel.

The Plutos Cave Basalt yields hundreds of gallons per minute to wells in the area of Big Springs, where flowing springs also are plentiful. Wells in the Juniper Flats part of the basalt (fig. 6), however, have small yields, averaging 12 gal/min as reported by drillers, and some are more than 500 feet deep. Depths to water range from 700 feet below land surface in Juniper Flats at the southern end of the flow to less than 25 feet near Big Springs (pl. 1). This variability in depth to water is explained by a fairly gentle dip in the water table to the northwest, whereas the land surface dips at a steeper angle and intersects the water table at Big Springs.

The lava tubes, apparent in surface exposures such as the entrance to the Pluto Cave, are thought to exist also at depth. The tubes may act as channels to convey ground water from recharge areas to areas of discharge such as the springs at Big Springs. Some drillers' logs indicate "voids" of approximately 5 feet where circulation is lost during drilling. These voids may indicate either lava tubes or interbasalt rubble zones.

Glacial Drift and Pyroclastic Flow Assemblages

Deposits on the southwest flanks of Mount Shasta have been described by the California Department of Water Resources (1964, p. 23-25) during the Box Canyon Dam investigation and by the U.S. Geological Survey study of wastewater infiltration near Mount Shasta (city) (Bertoldi, 1973). These deposits are diamictons, consisting of poorly sorted sand, clay, and boulders and identified as "glacial drift." Recent evidence suggests, however, that some deposits on the western flanks of Mount Shasta previously classified as glacial drift are pyroclastic-flow assemblages which originated during the eruptions of Shastina and Black Butte (Miller, 1978; Crandell and others, 1983).

An apron of pyroclastic-flow deposits originating during eruptions of the Shastina cone and Black Butte Dome had been identified by Miller (1978). The Holocene Shastina deposits extend from the Shastina cone west down the flanks of the mountain along Diller Canyon into the town of Weed and along Boles Creek west of Weed (pl. 1). The Black Butte deposits are younger than the Shastina deposits and extend from Black Butte south to the southern edge of Mount Shasta (city).

Well 41N/5W-4A1 (fig. 6 and pl. 1), drilled entirely within the Shastina pyroclastic flow, yielded 20 gal/min during drillers' tests. In other wells drilled through diamictons, drillers report encountering ground water above resistant "tuff" beds, suggesting that the tuffs act to perch water within the deposits. Yields of these wells were reported by drillers to range from 20 to 220 gal/min. Some wells drilled into diamictons did not yield water, but when drilled deeper into underlying fractured lava flows, water was encountered.

The shallow depth to which the diamictons extend may account for the lack of water within these deposits, because water tables are generally deeper than the deposits. However, the fine texture of the sand and ash matrix and lack of sorting in the deposits also may cause low permeabilities of this material.

Fluvial Deposits

Deposits in the Whitney Creek drainage north of U.S. Highway 97 consist of layers of boulders and sands tens of feet thick. These deposits have been previously described as glacial outwash (Mack, 1959) and later as debris-flow deposits (Miller, 1980).

The deposits consist of coarse, poorly sorted bouldery deposits bearing insignificant amounts of water. Wells drilled through these deposits yield water only after reaching into the basalt flows beneath.

Lake Deposits

The andesites of the Western Cascades are overlain in places by lake deposits laid down when a lava flow blocked the Sacramento River in the vicinity of Mott. The deposits consist mostly of well-sorted interbedded clay, silt, sand, and gravel (Bertoldi, 1973). Laboratory studies have shown the lake deposits to be very permeable (Bertoldi, 1973).

GROUND-WATER HYDROLOGY

Abundant ground water, generally found on all sides of Mount Shasta, usually flows away from topographic high points toward the Shasta, the McCloud, and the Sacramento Rivers. At Mount Shasta Sulphur Springs near the summit of Mount Shasta (pl. 1), the ground water that discharges may be an exception, originating at lower altitudes and being transported upward by geothermal pressure to its discharge area. The communities of Weed, Mount Shasta, Dunsmuir, and McCloud all depend on ground water as their major supply of water. Three different springs in the study area are named Big Springs (fig. 6). To differentiate among the three like-named springs, in this report they are referred to as Big Springs near Grenada, Big Springs near Mount Shasta (city), and Big Springs near McCloud.

Occurrence and Movement

Ground water is present in fluvial, glacial, and pyroclastic deposits on the flanks and surrounding valleys of the Mount Shasta Volcano. Ground water occupies the openings between the constituent grains that make up these unconsolidated deposits. In the lava flows, ground water present in fractures flows along rubble layers between lava flows and possibly in lava tubes.

In the glacial and pyroclastic deposits, resistant "tuff" layers have restricted vertical movement of water near Mount Shasta (city) (Bertoldi, 1973). Horizontal movement of water is probably associated with the presence of "tuff" layers. For example, Cantara Loop Springs issue from several sites along the cut bank above Cantara Loop Road approximately 0.5 mile west of Mott (fig. 6 and pl. 1). The proximity of the sites to one another at similar altitudes indicates a possible seepage of ground water perched on a relatively impermeable bed.

Unfractured lava flows also may act to confine or perch ground water. Clear Creek Springs (fig. 6), 9 miles north of McCloud at an altitude of 8,480 feet, issue from a thin covering of topsoil where the soil contacts a volcanic flow beneath it. This indicates that some snowmelt penetrates the sparse soils at the upper altitudes, but is perched by lava flows instead of being allowed to percolate to deeper zones.

Water-level contours that represent the surface of the ground-water body in the vicinity of Weed and Mount Shasta (city) are shown on plate 1. The altitudes of the water levels in wells were determined from measurements made during August 1982 (Poeschel and others, 1986). The direction of ground-water movement is at right angles to the contours in a downslope direction from areas of recharge near Black Butte and Mount Shasta to areas of discharge near Weed and Mount Shasta (city).

Recharge

In the vicinities of McCloud, Mount Shasta (city), and Weed, ground-water recharge results from infiltration of precipitation that falls on the slopes of Mount Shasta. Recharge from infiltration of rainfall or snowmelt occurs both during the wet season from October to April and also during warm months, when the seasonal snowpack melts. Ground-water levels at several wells, such as 41N/5W-25F1, 42N/4W-19G1, and 42N/4W-19K1 (fig. 6) (Poeschel and others, 1986), show only slight fluctuations from season to season and reflect steady-state conditions.

Several streams on the flanks of Mount Shasta show a reduction in flow in a downstream direction and are losing streams, as indicated by measurements made on Mud, Ash, Gravel, Bolam, and Whitney Creeks (table 3). The downstream loss is attributed to infiltration of streamflow into the highly permeable pyroclastic and fluvial debris that compose the beds and banks of most streams.

The reach affected by streamflow depletion is a function of the quantity of initial streamflow. In all cases, streamflows of Ash and Whitney Creeks were depleted before reaching a confluence with a perennially flowing stream. Only flows on Mud Creek are perennial and reach the McCloud River.

TABLE 3. -- Discharge of creeks draining flanks of Mount Shasta

[ft^3/s, cubic feet per second; $(ft^3/s)/mi$, cubic feet per second per mile]

Creek	Measurement		Discharge (ft^3/s)		Approximate distance between upstream and downstream stations (miles)	Rate of decrease [$(ft^3/s)/mi$]
	Date	Time (hours)	Upstream station	Downstream station		
Ash-----	05-26-81	1300	4.97	--	5	0.3
		1100	--	3.24	5	--
	08-19-81	1100	4.57	--	5	.3
		1200	--	3.19	5	--
	10-04-84	--	5.99	5.79	5	.04
Mud-----	05-20-81	1420	18.5	--	4	--
		1645	--	14.8	4	.9
	08-18-81	1125	10.5	--	4	--
		1320	--	8.97	4	.4
Whitney--	07-21-81	1030	3.82	--	3.5	--
		0800	--	4.01	3.5	--
	08-24-81	1930	1.22	--	3.5	--
		2350	--	.19	3.5	.3
Average--						0.4

Streamflow measurements on Ash, Mud, and Whitney Creeks (fig. 6) were made to determine the magnitude and rate of inflow into the streambeds and alluvial fans. Measurements of these streams were generally scheduled to consider the time of travel between sites. On Ash Creek on May 26, 1981, in a 5-mile-long reach downstream from Military Pass Road (pl. 1), streamflow decreased from 4.97 to 3.24 ft^3/s (table 3). On October 4, 1984, the flow in the same reach decreased from 5.99 to 5.79 ft^3/s. The average rate of streamflow decrease for all streams is 0.4 $(ft^3/s)/mi$ (table 3).

The ground-water-level contours (pl. 1) indicate an area of recharge at the mouth of Diller Canyon, a large V-shaped notch on the west rim of Shastina that ends in a broad, alluvial fan (fig. 3). The lobed water-level contour pattern in the recharge area (pl. 1) is attributed to seepage of rainwater and snowmelt that discharges from the canyon into the porous soils of the alluvial fan.

Discharge

Discharge of ground water in the vicinity of Mount Shasta is largely by natural means, such as seepage into streams and springs. Artificial losses that contribute to ground-water discharge include pumped and flowing wells.

Springs

Three well-known areas of ground-water discharge surrounding Mount Shasta are called Big Springs, a name which appropriately describes the quantities of ground water being discharged at these sites.

Big Springs near Grenada (fig. 6; Grenada shown in fig. 1) is the largest of several springs in the southern Shasta Valley referred to as the Big Springs watershed. In this area, the aquifer is recharged by seepage from Whitney Creek streamflow. This seepage then travels downslope through the Plutos Cave Basalt to the Big Springs area. Big Springs yields as much as 36 ft^3/s during late summer (U.S. Department of Agriculture, Soil Conservation Service, 1981) to form a small lake. The lake flows into Big Creek, a tributary of the Shasta River.

The discharge of Big Springs near Mount Shasta (city) (fig. 6) was approximately 20 ft^3/s during the summers of 1981 and 1982 (Poeschel and others, 1986). The city does not use the spring to supplement its water supply, but has preserved the spring site in Mount Shasta City Park. The spring probably issues from the diamicton, is glacial or pyroclastic in origin, and may result from one of the resistant tuff layers. Spring water flows through Big Springs Creek to the California State Fish Hatchery near Mount Shasta (city) and into Cold Creek, which is a tributary to the Sacramento River (pl. 1).

The third and largest of the big springs is Big Springs near McCloud (fig. 6 and pl. 1). Ground water discharges from the banks of the McCloud River, substantially supplementing the streamflow. During streamflow measurements made above and below the spring during August 1981, the increase due to inflow of Big Springs was 616 ft^3/s, 97 percent of the streamflow at that point. The rocks in the area are basalt flows, perhaps locally fractured by faulting, or containing interbasalt rubble zones that allow the transmission of water.

The cities of Weed, Mount Shasta, McCloud, and Dunsmuir depend on springs as their major source of community water supplies. Beaughton Springs, 1 mile east of Weed (pl. 1), provided a maximum of 1.23 ft^3/s of water to the Weed supply during the summer of 1981 (Jose Casillas, former Director of Public Works, City of Weed, oral commun., 1982).

The main source of water for Mount Shasta (city) is Howard Springs (pl. 1) 2 miles east of the city. During the drought years of 1976-77, the average yield of this spring was approximately 2.5 ft^3/s. The yield of this spring was approximately 4.0 ft^3/s during August 1982 and averages about 3.0 ft^3/s (Ned Boss, former Director of Public Works, City of Mount Shasta, oral commun., 1982).

The water for the town of McCloud (fig. 6) is supplied by Intake Spring and by Upper and Lower Elk Springs, 4.5 miles north and 4.5 miles northeast of McCloud, respectively. The average combined discharge for the two spring areas is estimated at about 15 ft^3/s (Glen Summerfield, General Manager, McCloud Community Service District, oral commun., 1982).

The measured discharges of smaller springs in the vicinity of Mount Shasta are described by Poeschel and others (1986). Many of these springs flow intermittently, depending upon rainfall and the condition of the snowpack; highest flows are observed during the summer months.

Wells

The water supplies for the communities of Mount Shasta and Weed are supplemented by water from wells. The Mayzei well in Weed is pumped; the Mount Shasta (city) well is artesian and is capable of producing 2.2 ft^3/s (Ned Boss, former Director of Public Works, City of Mount Shasta, oral commun., 1982). The artesian pressure may originate from tuff beds which are relatively impermeable and which confine the aquifers in this area. Other large wells in Shasta Valley within the Big Springs area include well No. 1, near the east shore of Lake Shastina. This well was test pumped at a rate of 1.8 ft^3/s. Other wells in the area produce up to 8.0 ft^3/s.

Several large wells in the Juniper Flats subdivision of Mount Shasta Vista are in community use. Smaller, single-family domestic wells are used in the outskirts of Weed, Mount Shasta (city), and McCloud, as well as in the Juniper Flats area. The location of wells that were sampled for water quality or measured for water levels is shown in figure 6. The yields of these wells are considered small, ranging from 0.01 to over 0.50 ft^3/s. Although the yields of these wells are low, discharges are considered sufficient for domestic use.

Water Levels

Seasonal water-level fluctuations in wells were reported by Poeschel and others (1986) to range from less than 1 to almost 27 feet. Average water-level fluctuations were 10 feet during 1982 in the Mount Shasta (city) and Black Butte areas. In the Weed and Lake Shastina areas, fluctuations averaged 3.5 feet. Near McCloud, levels fluctuated an average of 18 feet. Ground-water levels were continuously recorded at wells 40N/2W-25L1 and 41N/5W-26L1 from August 1981 to September 1982; hydrographs of these wells are shown in figure 7.

Seasonal fluctuations are caused by several conditions, including recharge from rainfall and snowmelt and discharge by pumpage for irrigation. Larger than average fluctuations, such as those in the McCloud area, may be caused by low storage coefficients. Wells are drilled to shallow depths (about 100 feet) and have low yields that are suitable for domestic use. Water is found at depths of about 80 feet in water-bearing sand and gravel deposits capped by lava flows, probably of unfractured andesite.

Quality of Water

Water from 17 springs and 12 wells in the vicinity of Mount Shasta (fig. 6) was sampled during May through September 1981 and August through September 1982. All samples were analyzed for major ions, nutrients, and trace constituents; results were documented by Poeschel and others (1986). Analyses of water from well 40N/4W-17B2 and from MacBride Springs in MacBride Springs Campground near Mount Shasta (city), which are representative of the ground water in the Mount Shasta area, are shown in table 4.

In general, wells and springs sampled contained water of a mixed cation bicarbonate type. Calcium and sodium together were the predominant cations in most samples. An exception to this was the water sampled from the thermal spring near the summit of Mount Shasta, which had a mixed cation sulfate water type. This spring was not associated with the ground-water system sampled at the other springs and wells.

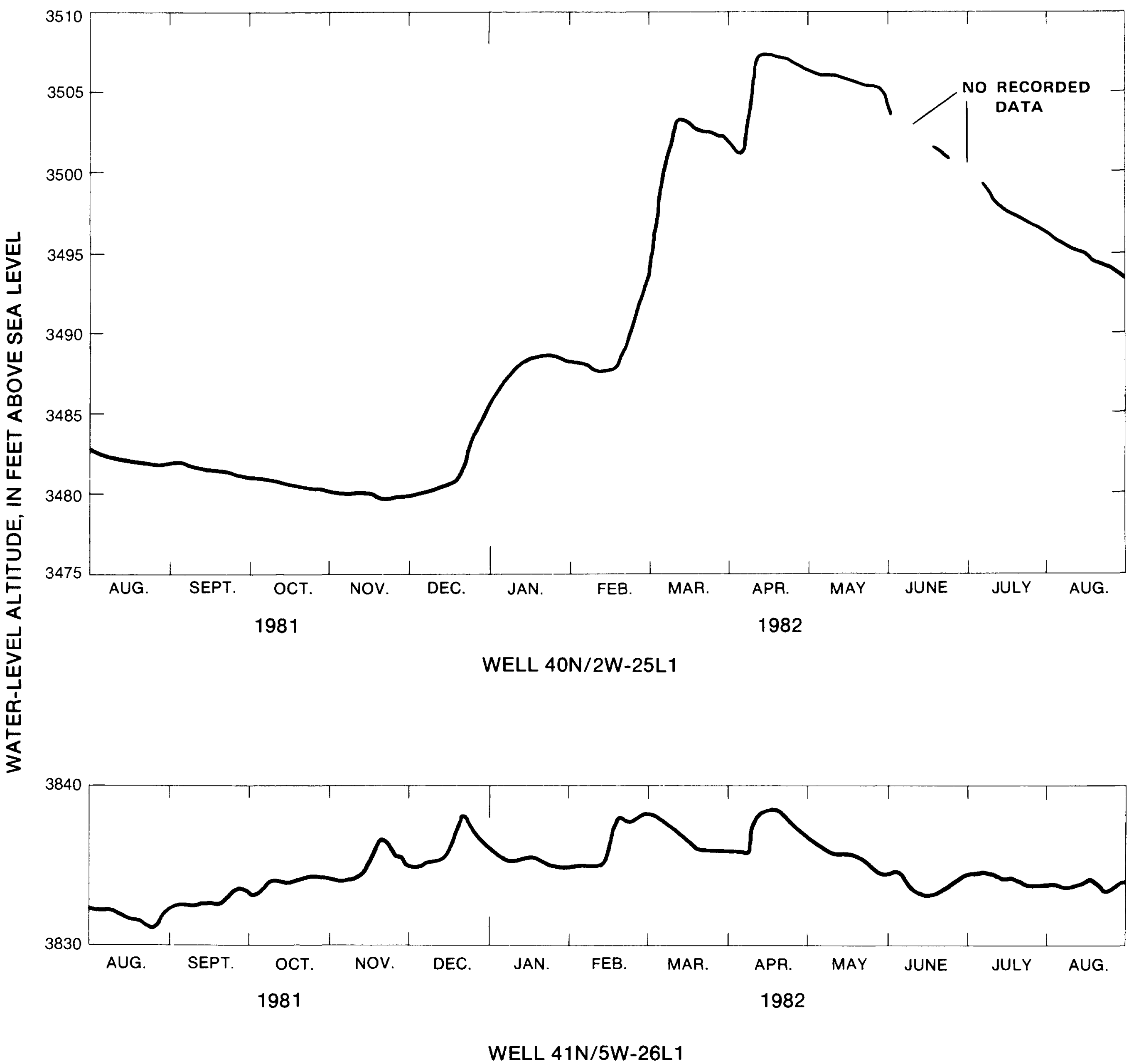


FIGURE 7. Hydrographs of wells in the Mount Shasta area, August 1981 through August 1982.

TABLE 4. -- Temperature, specific conductance, pH, and selected constituent concentrations of ground water sampled at representative sites on September 16, 1981

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter]

Properties and constituents	Ground water from	
	Well 40N/4W-17B2	MacBride Springs in MacBride Springs Campground, near Mount Shasta (City)
Temperature (°C)	12.5	5.5
Specific conductance (µS/cm)	116	47
pH (units)	6.9	6.5
Concentrations (mg/L)		
Hardness (as $CaCO_3$)	33	15
Calcium, dissolved (as Ca)	5.2	4.6
Magnesium, dissolved (as Mg)	4.9	.8
Sodium, dissolved (as Na)	12	3.5
Potassium, dissolved (as K)	2.0	1.8
Alkalinity (as $CaCO_3$)	52	22
Sulfate, dissolved (as SO_4)	<5.0	<5.0
Chloride, dissolved (as Cl)	2.1	<.1
Fluoride, dissolved (as F)	.1	.0
Solids, residue at 180 °C, dissolved	121	68
Silica, dissolved (as SiO_2)	59	45
Nitrogen, NO_2+NO_3, dissolved (as N)	.83	<.10
Nitrogen, ammonia total (as N)	.050	.080
Nitrogen, ammonia dissolved (as NH_4)	.18	.08
Nitrogen, organic total (as N)	.57	.52
Nitrogen, organic dissolved (as N)	.29	.24
Nitrogen, ammonia + organic total (as N)	.62	.60
Nitrogen, ammonia + organic disolved (as N)	.43	.30
Nitrogen, total (as N)	1.3	.63
Nitrogen, dissolved (as N)	1.3	.47
Phosphorus, total (as P)	.140	.010
Phosphorus, dissolved (as P)	.140	.020

Specific conductance ranged from 11 μS/cm at Clear Creek Spring near McCloud to 354 μS/cm at well 42N/4W-31C1. The wells with waters that had the highest specific conductance (indicating hard water) were located in andesite flows in the vicinity of U.S. Highway 97. Water quality in the sample sites met U.S. Environmental Protection Agency (1975) drinking-water standards for the constituents measured.

Mount Shasta Sulphur Springs, located west of the Mount Shasta summit, had a water temperature of 74.0 °C when sampled August 13, 1981. Historical records from 1854 to 1981 (table 5) indicate that temperatures ranged from 71.0 °C in 1977 to 84.4 °C in 1878 and 1928. Waters from this spring are similar to those found in other acid sulfur springs associated with volcanism at other locations in California and Yellowstone National Park in Wyoming (table 6). All these waters are strongly acidic and have high sulfate and low chloride concentrations.

TABLE 5. -- Water temperatures at Mount Shasta Sulphur Springs

[Data for 1854 to 1931 from Williams (1934); data for 1976-77 from Wharton and Vinyard (1979); °C, degrees Celsius]

Date	Water temperature (°C)
September 20, 1854	82.2
July 1878	84.4
July 17, 1924	72.2
September 25, 1925	75.5
July 13, 1926	80.0
September 11, 1927	79.4
August 8, 1928	84.4
September 8, 1929	81.1
August 22, 1931	74.4
August 3, 1976	76.5
October 9, 1977	71.0
August 13, 1981	74.0

TABLE 6. -- Chemical analyses of acid sulfate spring waters associated with volcanism

	pH	Sulfate (milligrams per liter)	Chloride (milligrams per liter)
The Geysers, Sonoma County, California[1]------	1.8+	5,700	0.5
Bumpass Hell, Shasta County, California[1]------	--	720	1.1
Norris Basin, Yellowstone Park, Wyoming[1]------	2.0	760	15
Mud Volcano Group, Yellowstone Park, Wyoming[1]------	--	3,200	Trace
Mount Shasta Sulphur Springs, Siskiyou County, California-----	2.1	2,200	4.5

[1]From White and others (1980).

SURFACE-WATER HYDROLOGY

Streamflow in the vicinity of Mount Shasta is affected by topographic, climatic, and geologic features of the area, such as precipitation, snowmelt, glacial melt, and large inflows from numerous springs. Observations of streams on the flanks of Mount Shasta indicate that peaks from glacial melt usually occur from July to September. Data for the gaging station Mud Creek near McCloud indicate that maximum mean daily flows from snowmelt usually occur during May or June, and maximum mean monthly flows occur during July (fig. 8). There were 2 years, however, when the maximum mean daily discharge occurred during December or March, representing the effect of high precipitation from frontal-type storms rather than from snowmelt.

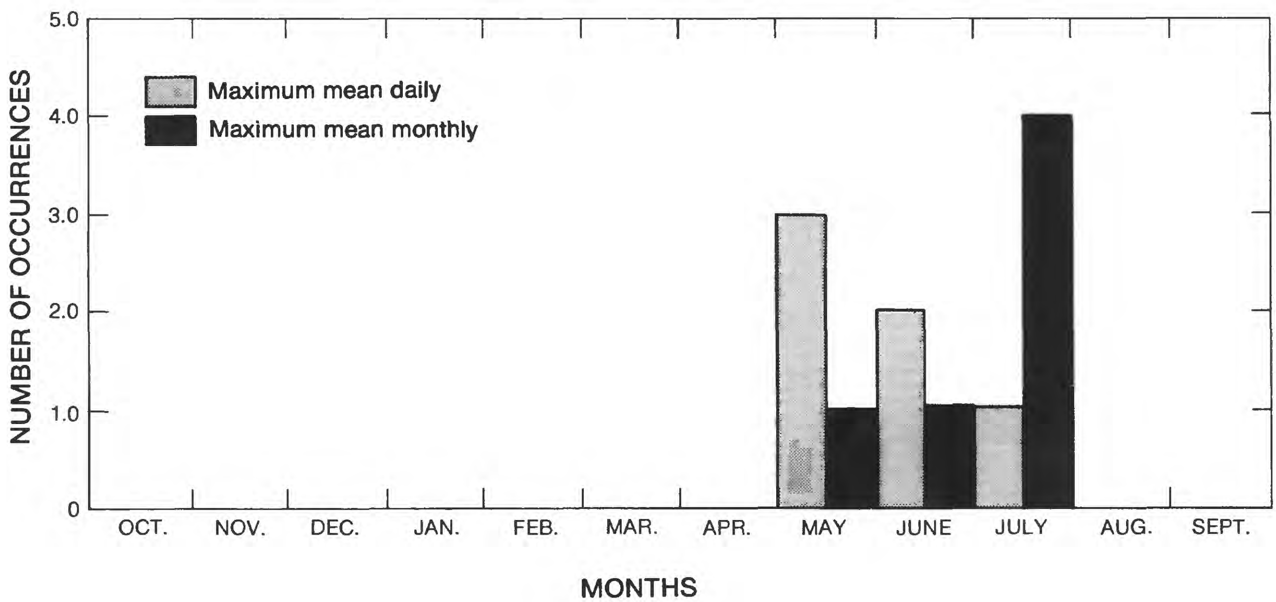


FIGURE 8. Distribution of maximum mean daily and mean monthly snowmelt flows for Mud Creek near McCloud (11367260) for years 1927-32.

Flows later in the summer that represent glacial melt generally contain lower concentrations of suspended sediment than flows earlier in the season (Poeschel and others, 1986). Suspended-sediment data indicate concentrations of almost 20,000 mg/L for Bolam Creek early in the snowmelt season, with concentrations of about 1,000 mg/L later in the season. A part of the change in sediment concentration throughout the season is attributed to variations in the sources of material. At the beginning of the snow- and glacial-melt season, the channels are loaded with rock avalanches and debris dislodged from steep (up to 30 °) channel banks during the winter. After this material has been transported downstream during early season flows (usually to the alluvial fan), sediment concentrations of flows tend to drop by more than 50 percent.

An abundant source of debris and pyroclastic material forms the channel banks, which are readily susceptible to fluvial erosion. As a result, these banks are eroded by lateral migration of the stream, causing large amounts of material to drop into the channel (fig. 9).

Gaging Stations

Streamflow data for ten gaging stations in the vicinity of Mount Shasta (pl. 1) were evaluated to determine runoff characteristics of various area streams. Mean monthly discharges are shown in figure 10 for five stations for the 1930 or 1960 water years; these 2 years were selected to provide the best comparison of data because flows during those years were near the

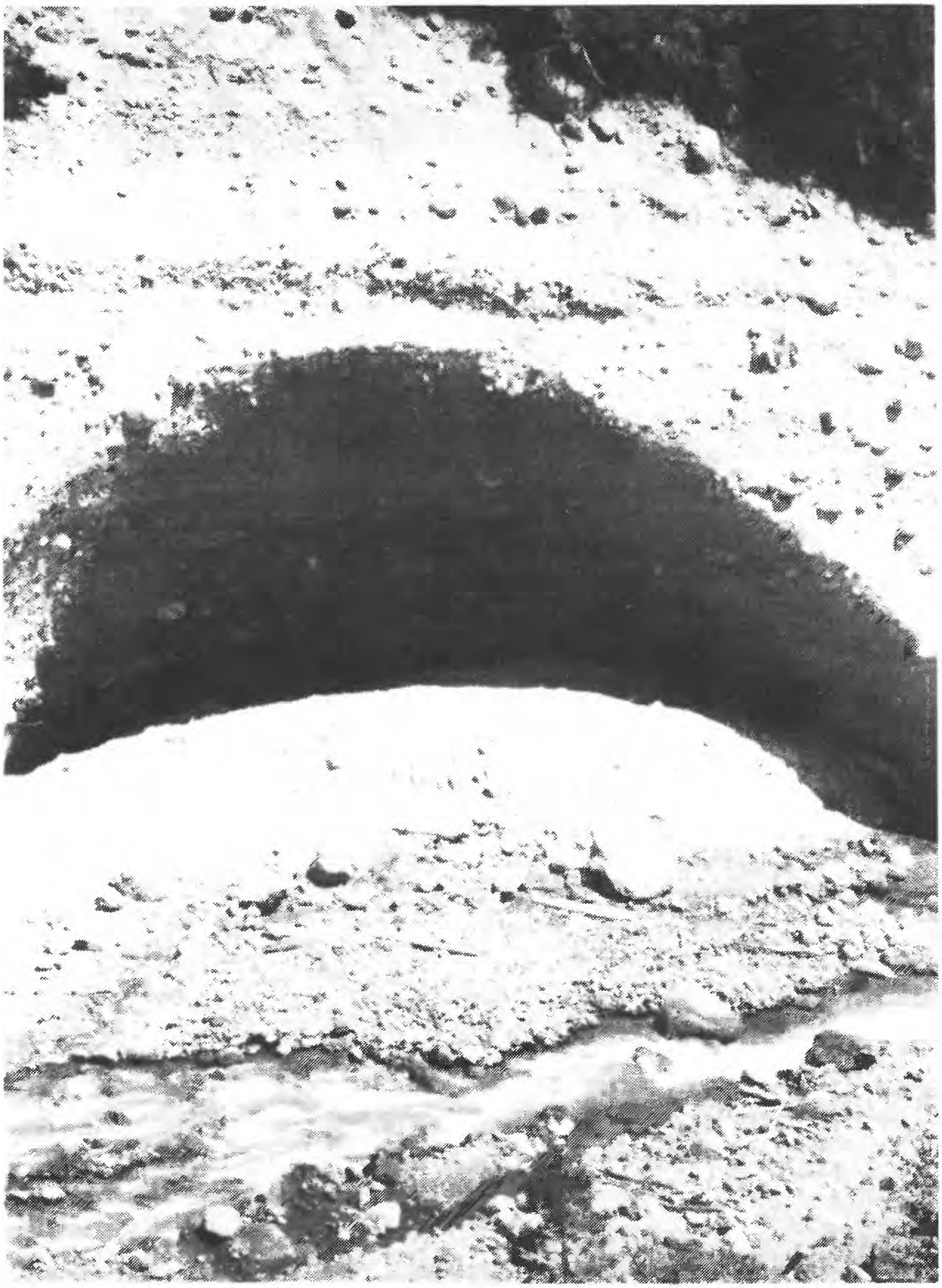
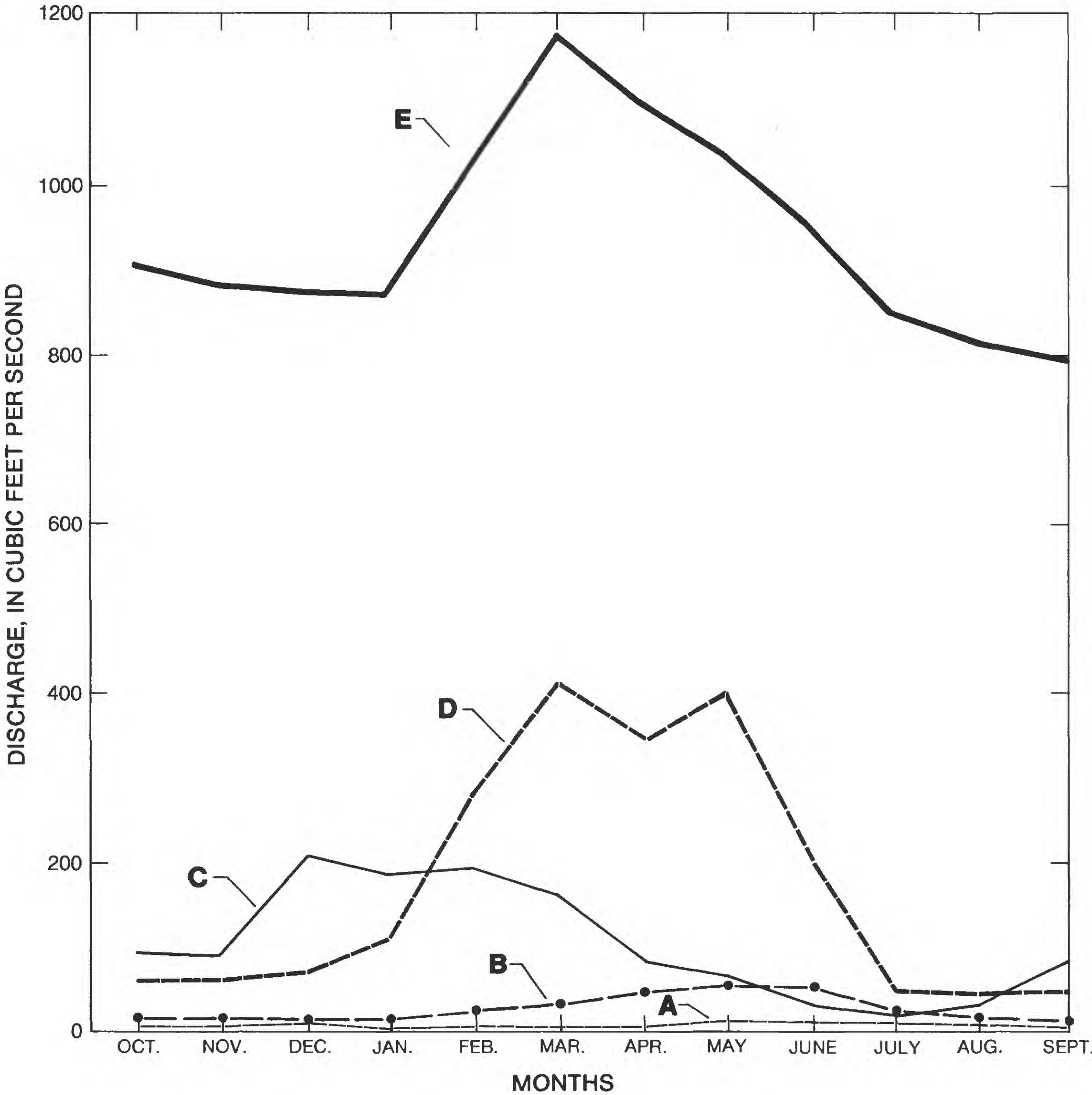


FIGURE 9. Eroded left bank of Mud Creek in section 8, T. 40 N., R. 2 W., showing a source of potential channel blockage and material for fluvial transport. (Photographed June 1982.)



EXPLANATION

A (11367260) **Mud (Elk) Creek** near McCloud (water year 1930)
B (11489500) **Antelope Creek** near Tennant (water year 1960)
C (11517000) **Shasta River** near Montague (water year 1930)
D (11341400) **Sacramento River** near Mount Shasta (water year 1960)
E (11367500) **McCloud River** near McCloud (water year 1930)

FIGURE 10. Comparison of mean monthly discharge for selected streams in vicinity of Mount Shasta.

long-term average, and distribution of flow within the year was representative of most years. As seen in figure 10, the highest mean monthly discharges occurred in December, March, May, and June. High flows in December result from precipitation caused by frontal-type storms moving east from the Pacific; high flows in March, May, and June are due to snowmelt.

High flows on Mud Creek near McCloud (curve A in fig. 10) do not usually occur until May, June, or July when temperatures are high enough to significantly melt the snowpack and glaciers above the 9,000-ft altitude. Most of the difference in the discharge of the Sacramento River near Mount Shasta (curve D, fig. 10, drainage area 135 mi^2) from that of the Shasta River near Montague (curve C, fig. 10, drainage area 673 mi^2) is due to the areal distribution of precipitation.

A summary of streamflow characteristics for gaging stations in the vicinity of Mount Shasta is presented in table 7. All available stations in the vicinity of Mount Shasta were used to represent flow conditions typical of the study area and the annual and highest mean monthly discharges. All data are for the water year ending September 30, except for the lowest mean discharge for 1, 30, and 365 days, which are for the year ending March 31.

A review of the data on plate 1 and in table 7 and figure 2 indicates:

1. Average annual discharge, expressed as unit discharge, ranges from 0.21 to 3.1 $(ft^3/s)/mi^2$. This variation is attributed to the influences of basin location and geology, which affect runoff nearly as much as basin size.

2. Streams located south and east of the mountain in the area of greatest precipitation have the highest average, daily mean, and peak discharges per square mile. Average discharges of gaged streams in that area range from 0.64 to 3.08 $(ft^3/s)/mi^2$.

3. Streams located in Shasta Valley generally have the lowest average, daily mean, and peak discharges per square mile. The average discharge of the Shasta River at Yreka is about 0.2 $(ft^3/s)/mi^2$, which is less than that for the Sacramento River (2.84 $(ft^3/s)/mi^2$ at Delta), and the McCloud River (2.59 $(ft^3/s)/mi^2$ near McCloud). This difference is attributed to the lack of precipitation and high infiltration rate in Shasta Valley.

4. The stream with highest mean annual unit runoff is Angel Creek near McCloud (3.08 $(ft^3/s)/mi^2$). The high runoff of Angel Creek is typical of other streams in the area, such as the Sacramento and the McCloud Rivers, and is caused by the higher precipitation in the area.

5. The annual variation in streamflow, expressed in terms of standard deviation of annual mean discharge, in percent, ranges from 11 to 44. Most streams have an annual variation of about 40 percent. Annual mean streamflow data were used to minimize the effect of upstream regulation. Low percentages (18 and 19), such as for Mud (Elk) Creek at McCloud and McCloud River below Big Springs, near McCloud, are attributed to the effect of the nearly constant inflow from glaciers or Big Springs.

TABLE 7. -- Streamflow characteristics at gaging stations in vicinity of Mount Shasta ending with 1983 water year

[Station location shown on plate 1; mi^2, square miles; $(ft^3/s)/mi^2$, cubic feet per second per square mile. >, greater than; --, no data]

Station No.	Station Location	Drainage area (mi^2)	Period of record (water years)	Average discharge: Discharge (ft^3/s)	Average discharge: Unit [$(ft^3/s)/mi^2$]	Standard deviation of annual mean discharge, in percent
Sacramento River hydrologic area						
11341400	Sacramento River near Mount Shasta[1]	135	1960-83	261	1.93	39.6
11341500	Sacramento River at Castella[2]	256	1910-23	682	2.66	42.1
11342000	Sacramento River at Delta[1 2]	425	1945-83	1,209	2.84	44.0
McCloud River hydrologic area						
11367200	McCloud River below Big Springs, near McCloud	322	1955-59	909	2.82	11.0
11367250	Mud Creek at Road 13, near McCloud[3]	11.4	1981	--	--	--
11367260	Mud (Elk) Creek near McCloud	13.1	1929-32	8.4	.641	18.0
11367300	Angel Creek near McCloud	17.1	1956-59	52.7	3.08	39.8
11367500	McCloud River near McCloud	358	1932-79	927	2.59	19.4
The Whaleback-Ash Creek Butte Depression hydrologic area						
11489500	Antelope Creek near Tennant	18.6	1952-79	35.2	1.89	38.2
Shasta Valley hydrologic area						
11516808	Whitney Creek at U.S. Highway 97 crossing, near Weed[4]	14.4	1981	--	--	--
11517000	Shasta River near Montague[2]	673	1911-13 1916-22 1923-33	144	.214	39.0
11517500	Shasta River near Yreka[1 2]	793	1934-41 1946-	190	.240	40.8

See footnotes at end of table.

TABLE 7. -- Streamflow characteristics at gaging stations in vicinity of Mount Shasta ending with 1983 water year--Continued

Station No.	Maximum mean discharge for indicated number of consecutive days: 1-day (year) (ft3/s)	30 days (year) (ft3/s)	Water year (ft3/s) (year)	Annual unit [(ft3/s)/mi2)]	Minimum mean discharge for indicated number of consecutive days: 1-day (year) (ft3/s)	30 days (year) (ft3/s)	Water year (ft3/s) (year)	Annual unit [(ft3/s)/mi2]	Maximum instantaneous discharge: Date	Discharge (ft3/s)	Unit discharge [(ft3/s)/mi2]	Recurrence interval (years)
11341400-------	9,600 (1974)	1,760 (1983)	525 (1983)	3.89	14 (1973)	30 (1979)	74 (1977)	0.548	12-22-64	12,200	90.4	34
11341500-------	13,500 (1916)	3,190 (1915)	1,090 (1914) (1915)	4.26	108 (1917)	110 (1920)	294 (1920)	1.15	01-02-14	16,000	62.5	14
11342000-------	53,900 (1974)	9,600 (1958)	2,710 (1983)	6.37	117 (1978)	120 (1978)	228 (1977)	.536	01-16-74	69,800	164	>100
11367200-------	7,210 (1956)	1,770 (1956)	1,030 (1958)	3.20	678 (1958)	697 (1958)	802 (1957)	2.49	12-21-55	10,100	31.4	--
11367250-------	[5]24.0 (1981)	--	--	--	0.58 (1982)	--	--	--	--	--	--	--
11367260-------	80.0 (1930)	--	--	--	0 (1930-31)	--	--	--	12-14-29	80	6.11	--
11367300-------	1,510 (1956)	316 (1956)	71 (1956)	4.15	7.2 (1956)	7.9 (1956)	33 (1959)	1.93	12-20-55	2,000	117.0	--
11367500-------	10,100 (1974)	2,590 (1970)	1,410 (1974)	3.94 (1933)	524 (1933)	533 (1933)	605	1.69	12-21-55	11,800	33.0	44
11489500-------	930 (1974)	193 (1958)	72 (1974)	3.87 (1960)	3.60 (1977)	5.40 (1977)	9.60	5.16	11-11-73	1,350	72.6	48
11516808-------	21.80	--	--	--	0	--	--	--	--	--	--	--
11517000-------	2,780 (1927)	736 (1927)	254 (1921)	0.377 (1919)	0.10 (1925)	7.20 (1933)	87	.129	02-11-25	5,700	8.47	34
11517500-------	10,400 (1965)	1,650 (1965)	364 (1974)	0.459 (1982)	1.50 (1940)	7.70 (1934)	78	.098	12-22-64	21,500	27.1	>100

[1]Discharge affected by regulation.
[2]Not shown on plate 1.
[3]Data also shown in table 8 as miscellaneous site 6.
[4]Data also shown in table 8 as miscellaneous site 36.
[5]Maximum mean daily discharge.

Miscellaneous Sites

Streamflow data were collected periodically at most of the streams on the flanks of Mount Shasta during 1981-84 to determine the magnitude of typical flows, diurnal fluctuations, and variations in streamflow in a downstream direction (Poeschel and others, 1986). These data were usually obtained near road crossings (pl. 1). Most streams on the flanks of Mount Shasta fed by glacial- or snowmelt are ephemeral, especially those in basins with low annual precipitation, such as Whitney Creek and Diller Canyon (pl. 1). Three generally perennial streams, Ash, Mud, and Squaw Valley Creeks, are affected primarily by precipitation from frontal storms that usually occur during winter and to glacial- and snowmelt. In addition, Whitney Creek basin is affected by precipitation from thunderstorms (cyclonic-type precipitation) (Nutting, 1935).

A summary of discharge data obtained at miscellaneous sites is given in table 8. The highest runoff was measured in Mud Creek at the pipeline crossing (location shown on pl. 1), even though several other streams have larger basins or glaciers that contribute runoff.

Streams located in the northwest and northeast quadrants of the mountain and draining into Shasta Valley, The Whaleback-Ash Creek Butte Depression, or the Sacramento River generally have smaller unit runoff than streams located on other sides of the mountain. This is attributed to an absence of glaciers and lower precipitation on the basins of Avalanche Gulch, Cascade Gulch, Diller Canyon, and Whitney and Bolam Creeks.

Several streams show the effects of variable glacial- and snowmelt during the day. A comparison of diurnal-stage variation on Mud and Whitney Creeks is shown in figure 11. Because of time of travel (gage location shown on pl. 1) and the need for temperatures to reach a minimum melt level, stages are at minimum about midday, with peak stages occurring between 1800 and 2400 hours.

TABLE 8. -- Streamflow summaries for miscellaneous stream sites in vicinity of Mount Shasta

[Site location shown on plate 1; mi^2, square miles; ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile; --, no data]

Site No.	Site Location	Drainage area (mi^2)	Channel distance from summit (miles)	Periodic measurements of streamflow (ft^3/s)[1] Highest	Periodic measurements of streamflow (ft^3/s)[1] Lowest	Maximum measured streamflow Date	Maximum measured streamflow Unit discharge [$(ft^3/s)/mi^2$]
1	Squaw Valley Creek at Road 31, near McCloud----------	1.87	[2]5.09	2.65	0	05-27-81	1.42
2	Squaw Valley Creek at State Highway 89, at McCloud----	20.29	11.62	24.4	--	08-02-84	1.20
3	Mud Creek below Clear Creek Fork, near McCloud--------	4.33	4.30	30.5	13.1	08-02-84	7.04
4	Mud Creek at Mud Creek Dam, near McCloud--------------	7.19	6.88	36.4	10.5	08-02-84	5.06
5	Mud Creek at pipeline crossing, near McCloud----------	8.34	9.67	41.8	9.7	08-02-84	5.01
6	Mud Creek at Road 13, near McCloud[3]------------------	9.48	11.14	36.8	4.92	08-02-84	3.88
7	Mud Creek at State Highway 89, near McCloud-----------	12.49	12.75	39.5	8.0	08-02-84	3.16
8	Pilgrim Creek at Military Pass Road, near McCloud-----	2.96	9.31	4.78	0	08-09-84	1.61
9	Cold Creek at Military Pass Road, near McCloud--------	4.94	8.17	3.84	0	07-30-84	.78
10	Cold Creek at mouth, near Road 41N16, near McCloud----	5.52	8.75	9.93	--	07-30-84	1.80
11	Ash Creek downstream from springs, near McCloud-------	3.10	4.57	14.6	5.38	07-30-84	4.71
12	Ash Creek at Upper Road crossing, near McCloud--------	3.65	6.14	16.4	5.0	07-30-84	4.49
13	Ash Creek at Road 19 crossing, near McCloud-----------	6.19	7.69	14.6	4.57	07-30-84	2.36
14	Ash Creek at Military Pass Road, near McCloud---------	13.28	10.61	17.5	4.57	07-30-84	1.32
15	Ash Creek at Road 13, near McCloud--------------------	14.45	12.27	15.3	3.19	08-19-81 07-30-84	1.06
16	Ash Creek at State Highway 89, near McCloud-----------	--	--	--	--	08-19-81 07-30-84 10-04-84	0 0 0
17	Brewer Creek at upper crossing, near McCloud----------	1.62	4.05	2.74	--	08-09-84	1.69
18	Brewer Creek at lower crossing, near McCloud----------	5.53	6.95	1.53	--	08-09-84	.28
19	Gravel Creek at crossing No. 4, near Weed-------------	1.71	4.51	1.45	--	08-01-84	.85
20	Gravel Creek at crossing No. 3, near Weed-------------	1.94	4.82	1.32	--	08-01-84	.68
21	Gravel Creek at crossing No. 2, near Weed-------------	2.46	5.63	1.12	0	08-01-84	.46
22	Gravel Creek at crossing No. 1A, near Weed------------	3.24	5.88	--	--	--	--
23	Gravel Creek at crossing No. 1 (Military Pass Road), near Weed---	3.67	6.52	.30	0	08-01-84	.08

See footnotes at end of table.

TABLE 8. -- Streamflow summaries for miscellaneous stream sites in vicinity of Mount Shasta--Continued

Site		Drainage area (mi^2)	Channel distance from summit (miles)	Periodic measurements of streamflow (ft^3/s)[1]		Maximum measured streamflow	
No.	Location			Highest	Lowest	Date	Unit discharge [$(ft^3/s)/mi^2$]
24	Inconstance Creek at upper reach, near Weed	1.01	3.66	2.07	0.29	08-01-84	2.05
25	Inconstance Creek at lower reach, near Weed	2.71	4.89	.47	.22	07-21-81	.17
26	Inconstance Creek 0.6 mile upstream from Military Pass Road, near Weed	7.07	6.54	--	--	07-21-81	0
27	West Fork Bolam Creek upstream from Coquette Falls, near Weed	.85	3.04	1.81	.84	07-31-84	2.13
28	East Fork Bolam Creek upstream from Coquette Falls, near Weed	.84	3.05	1.16	.48	07-31-84	1.38
29	Bolam Creek at Switchback No. 2, near Weed	2.37	4.98	3.16	0	07-31-84	1.33
30	Bolam Creek at Jeep trail crossing, near Weed	4.65	5.70	4.72	1.02	07-31-84	1.02
31	Bolam Creek at mouth, near Weed	5.22	7.14	3.66	--	07-31-84	.70
32	Whitney Creek upstream from Whitney Falls, near Weed	1.97	4.33	6.01	.21	07-31-84	3.05
33	Whitney Creek downstream from Whitney Falls, near Weed	2.60	5.75	2.63	0	07-21-81	1.01
34	Whitney Creek upstream from mouth of Bolam Creek, near Weed	2.98	7.10	3.62	1.70	07-31-84	1.21
35	Whitney Creek at Southern Pacific railroad crossing, near Weed	8.45	7.99	9.56	.50	07-31-84	1.13
36	Whitney Creek at U.S. Highway 97 crossing, near Weed[4]	13.27	9.29	4.01	0	07-21-81	.30
37	Whitney Creek at County Road crossing, near Weed	14.52	10.65	7.37	--	07-31-84	.51
38	Cascade Gulch at Everitt Richardson Memorial Highway, near Mount Shasta	4.32	6.04	.002	--	08-09-84	.0005
39	Panther Creek at logging road crossing, near Mount Shasta	3.00	6.40	--	--	--	--
40	McCloud River upstream from Lower Falls and 7.2 miles east of McCloud	([5])	([5])	77.0	9.31	--	--

[1]Selected streamflow data from Poeschel and others (1986).
[2]Headwater of stream is 1.5 miles south of summit.
[3]Data also given in table 7 as gaging station 11367250.
[4]Data also given in table 7 as gaging station 11516808.
[5]Not applicable.

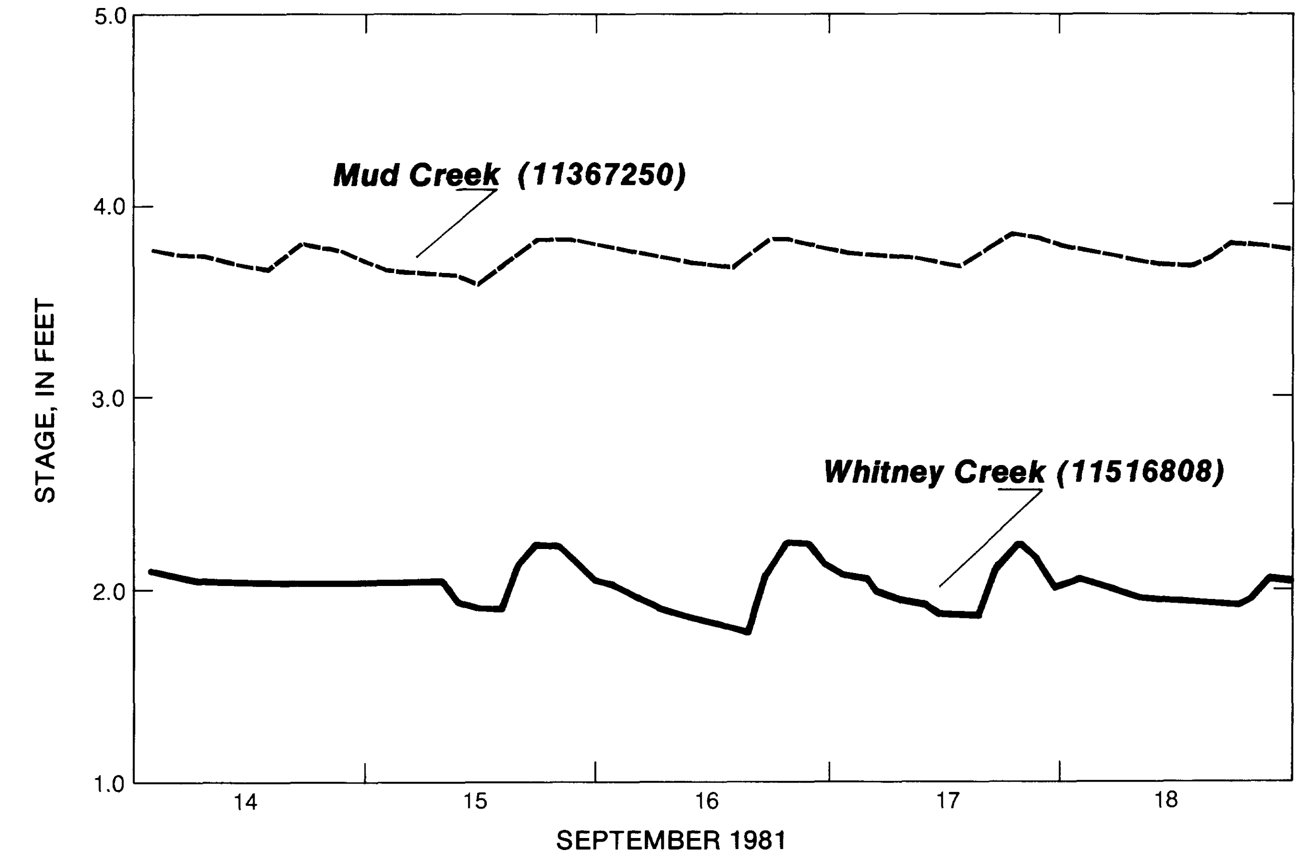


FIGURE 11. Comparison of stage for Mud and Whitney Creeks for September 14-18, 1981, showing effect of glacial-melt runoff.

SUMMARY

Mount Shasta in northern California is one of the largest and highest stratovolcanoes in the Cascade Range. Future events that may be hazardous to life and property in the vicinity of Mount Shasta include volcanic activity and debris flows caused by nonvolcanic events, such as glacial melt and precipitation. The lower flanks of Mount Shasta consist of a broad, smooth apron of fans of pyroclastic-flow, debris-flow, and fluvial deposits; all these deposits are porous and highly permeable. Streams that originate on Mount Shasta enter three river systems--the Shasta, the Sacramento, and the McCloud Rivers. Many streams draining the flanks are intermittent, and flows disappear into the volcanic and fluvial debris on the flanks and at the base of the volcano. Four major hydrologic areas surround Mount Shasta: Sacramento River, McCloud River, The Whaleback-Ash Creek Butte Depression, and Shasta Valley.

Ground water, which is generally abundant, is found on all sides of Mount Shasta and generally flows away from topographic high points toward the Shasta, the Sacramento, and the McCloud Rivers. The communities of Weed, Mount Shasta (city), Dunsmuir, and McCloud depend on ground water as their major water supply. The difference of volcanic and fluvial deposits in the area causes wide variations in ground-water properties; no single aquifer can be identified. Primary sources of ground water include fracture joints in andesite deposits near Mount Shasta (city), sand and gravel beneath vesicular lava flows near McCloud, and lava tubes of the Plutos Cave Basalt, the most prolific aquifer in Shasta Valley. Poor sources of ground water are the pyroclastic flow assemblages located on the southwest flanks of the mountain and fluvial deposits in the Whitney Creek drainage. Those areas where streams have high rates of streamflow losses are considered major recharge areas.

Many springs are located on the flanks of Mount Shasta; the largest is Big Springs near McCloud from which about 616 ft^3/s was measured. Yields from wells that supplement water supplies for Mount Shasta (city) as well as for domestic use range from 0.01 to 8.0 ft^3/s. Water levels in wells fluctuate from less than 1 to almost 27 feet during the year. Seasonal fluctuations are caused by variation in rainfall and snowmelt, discharge by pumpage for irrigation, and thickness and areal extent of the aquifer. The quality of well and spring water generally is suitable for most uses, with chemical properties of a mixed cation bicarbonate type. The quality of all ground water used for drinking purposes meets standards of the U.S. Environmental Protection Agency. Water sampled at Mount Shasta Sulphur Springs near the summit was found to be similar to water sampled from acid sulfate springs at other volcanoes--high in sulfate and low in chloride, very acidic, and with an average temperature of about 78 °C.

Glaciers on Mount Shasta are located above the 9,000-foot altitude and lie on all sides of the mountain except the southwest. The total volume of all glaciers on the mountain is 4.7×10^9 ft^3 and is the smallest volume of the major glaciated volcanoes of the Cascade Range. The largest glacier on Mount Shasta, in terms of area and volume, is Hotlum No. 1 on the northeast side of the mountain.

Mount Shasta's rain-shadow effect causes a great range in precipitation and runoff; mean annual precipitation is about 53 inches at McCloud on the south side of the mountain and about 18 inches near Yreka, located north-northwest of the mountain. Maximum flows from snowmelt usually occur in May or June, but high flows caused by precipitation may occur in December or March. Suspended-sediment concentrations of 20,000 mg/L have been recorded early in the snowmelt season, but concentrations decrease to about 1,000 mg/L later in the summer. The magnitude of streamflow is independent of basin size. Streams located south and east of the mountain have the highest flows in terms of unit runoff; those located in Shasta Valley have the lowest runoff. The McCloud River near McCloud has the least fluctuation in flow throughout the year--probably because a large part of the flow is derived from springs.

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