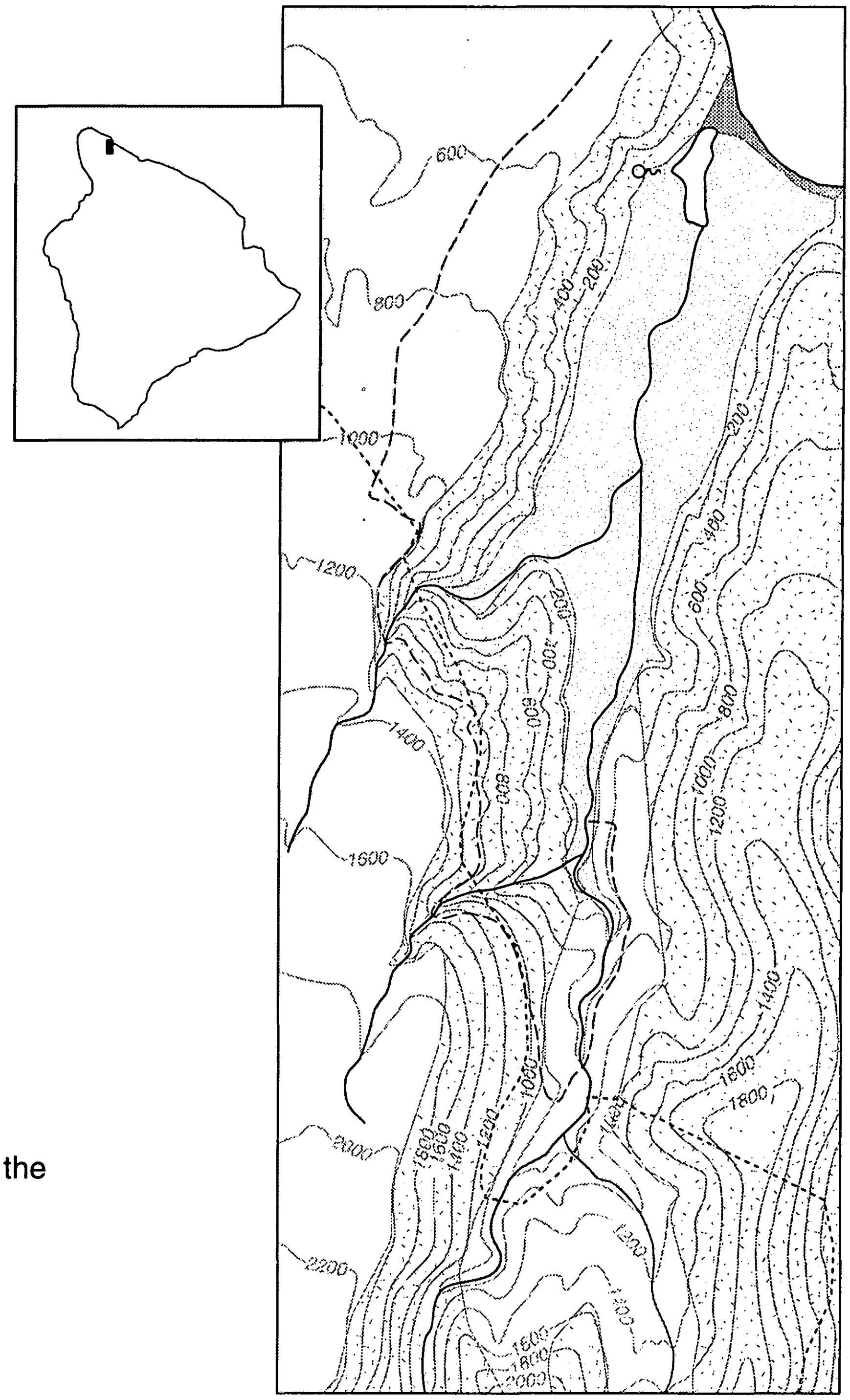
U.S. Department of the Interior

The Geohydrologic Setting of Pololu Stream, Island of Hawaii, Hawaii

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 99-4009



Prepared in cooperation with the

COUNTY OF HAWAII
DEPARTMENT OF WATER

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By Todd K. Presley

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Honolulu, Hawaii
1999

U.S. DEPARTMENT OF THE INTERIOR
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CONTENTS

FIGURES

TABLES

The Geohydrologic Setting of Pololu Stream, Island of Hawaii, Hawaii

By Todd K. Presley

Abstract

Streamflow measurements indicate that Pololu Stream, which is on the northeastern side of Kohala Volcano, is intermittent, although the stream has previously been interpreted as perennial. The main channel of the stream does not gain water from ground-water sources except at a wetland and shallow pond at the terminus of the stream channel. Ground water in the area is found as high-level dike-impounded ground water in the higher altitudes, as basal ground water in the form of a freshwater lens at lower altitudes, and as perched ground water lying above dike-impounded ground water or the freshwater lens. The water tables of the dike-impounded ground water and the basal ground water are below the altitude of the streambed of Pololu Stream and its tributaries except near the ocean at the wetland and pond area. Two of the three tributaries to the stream are perennial, fed by springs that are possibly perched. These tributaries lose water in their lower reaches and go dry before joining Pololu Stream. The third tributary has flow from a leaking flume in Kohala Ditch; the flow reaches Pololu Stream, flows for about 4,000 feet, then is lost in the lower reaches of the stream.

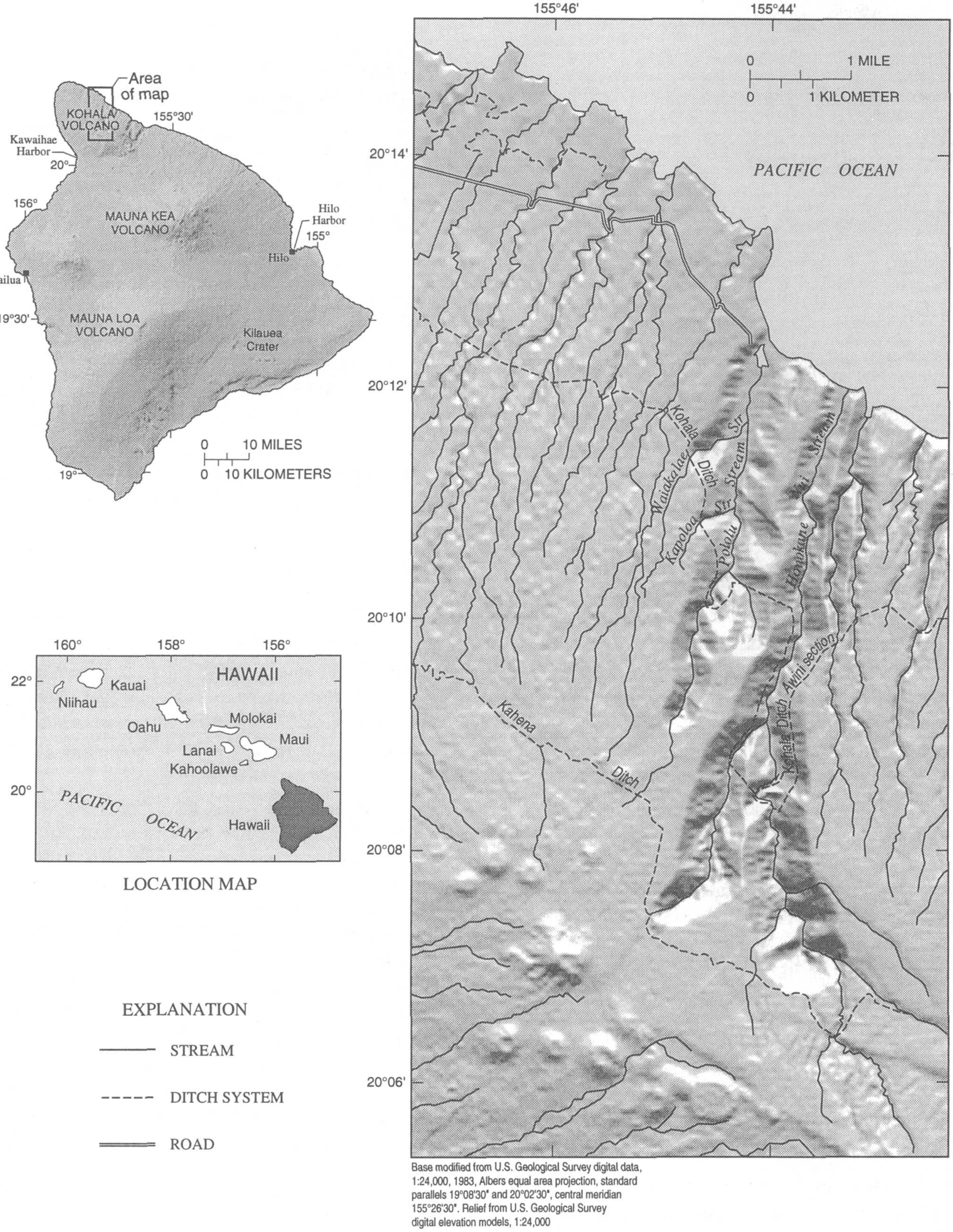
Streamflow is affected by geology. Where the streambed is composed of a single thick volcanic lava flow, streamflow is maintained, whereas farther downstream streamflow disappears where the streambed is composed of alluvium.

The pond and wetland at the terminus of the stream channel are where the land surface intersects the basal ground-water body. Although the pond is perennial, conditions at the pond can be highly variable. During dry periods, seepage and wave overwash from the ocean, small amounts of rainfall, and springs add water to the pond. During high rainfall, the lower reach of Pololu Stream flows, the lower valley floods, the beach berm erodes, and the pond is transformed into a stream outlet to the ocean.

INTRODUCTION

Pololu Stream is located on the northeastern flank of the Kohala Volcano, island of Hawaii (fig. 1). The remnants of the volcano form Kohala Mountain, the northernmost mountain of the island. Pololu Stream crosses areas of dike-impounded ground water in the rift zone of the volcano and an area of the basal ground water body on the flanks of the volcano.

Some of the streams that drain Kohala Mountain are perennial and others are intermittent, and may have perennial flow for at least part of their reach. Pololu Stream was previously interpreted as being perennial (Stearns and Macdonald, 1946; Davis and Yamanaga, 1963). Streams in the mountain areas of many of the eroded Hawaiian volcanoes commonly gain or lose water along their courses depending on the altitude relative to the water levels of dike-impounded or perched water bodies (Takasaki and Mink, 1985; Izuka, 1992). Where the streambed is above the ground-water body, the stream loses water. In the mountainous inland areas, reaches of streams can gain from spring discharge where the stream valley has eroded into dike-impounded ground-water bodies or perched water bodies (Stearns and Macdonald, 1946, p. 228–239). Near the shoreline or at lower elevations, the stream may intersect the basal ground-water body.



Base modified from U.S. Geological Survey digital data, 1:24,000, 1983, Albers equal area projection, standard parallels 19°08'30" and 20°02'30", central meridian 155°26'30". Relief from U.S. Geological Survey digital elevation models, 1:24,000

Figure 1. Island of Hawaii and streams, tributaries, and ditches in the Pololu Valley area.

Because of concern over the effect of water development in the Hawi area on Pololu Stream and to expand what is known about ground-water/surface-water interactions on volcanic islands, the Hawaii County Department of Water Supply entered in to a cooperative study with the U.S. Geological Survey (USGS) to study the geohydrologic setting of Pololu Stream.

Purpose and Scope

The purpose of this report is to provide a detailed geohydrologic description of Pololu Stream, and to describe the relation between ground water and Pololu Stream. Streamflow measurements were made at selected locations along the stream during a single day (a technique called a seepage run). The measurements were made during a prolonged dry period of several months to determine the baseflow characteristics of Pololu Stream and its tributaries. A pond at the terminus of the stream channel was surveyed to measure its altitude relative to sea level. Water-quality measurements and water-level data were collected at the pond during a 2-day period. Previous geologic and hydrologic studies were reviewed and a geologic reconnaissance of the stream channel was done.

Acknowledgments

We are deeply indebted to the cooperation of Mike Gomes and Richard Gordon of Chalon International, the landowner and caretaker of the Kohala Ditch system.

DESCRIPTION OF THE STUDY AREA

Kohala Volcano is elongated and asymmetrical, and reaches a maximum altitude of 5,605 ft (fig. 1). The mountain has a distinct rainfall distribution caused by the orographic effect of the mountain on the prevailing tradewinds (fig. 2). The northeastern, windward side of the mountain where Pololu Stream flows is cool and wet, receiving more than 160 in/yr of rainfall near the summit (Giambelluca and others, 1986). The southwestern, leeward side is in the rain shadow of the summit, receiving less than 10 in/yr in the driest areas. The prevailing tradewind direction is from the east-northeast (Blumenstock and Price, 1967; Armstrong, 1973).

The northeastern side of Kohala Volcano has been modified by an extensive submarine landslide (Moore and others, 1989). The headwall of the landslide extends from Pololu Valley to Waipio Valley, and produces a marked reentrant of the shoreline between these valleys (fig. 3). Prominent subaerial valleys are found only within the length of the reentrant shoreline. These amphitheater-headed valleys deeply dissect the volcano and are also in the area of highest rainfall.

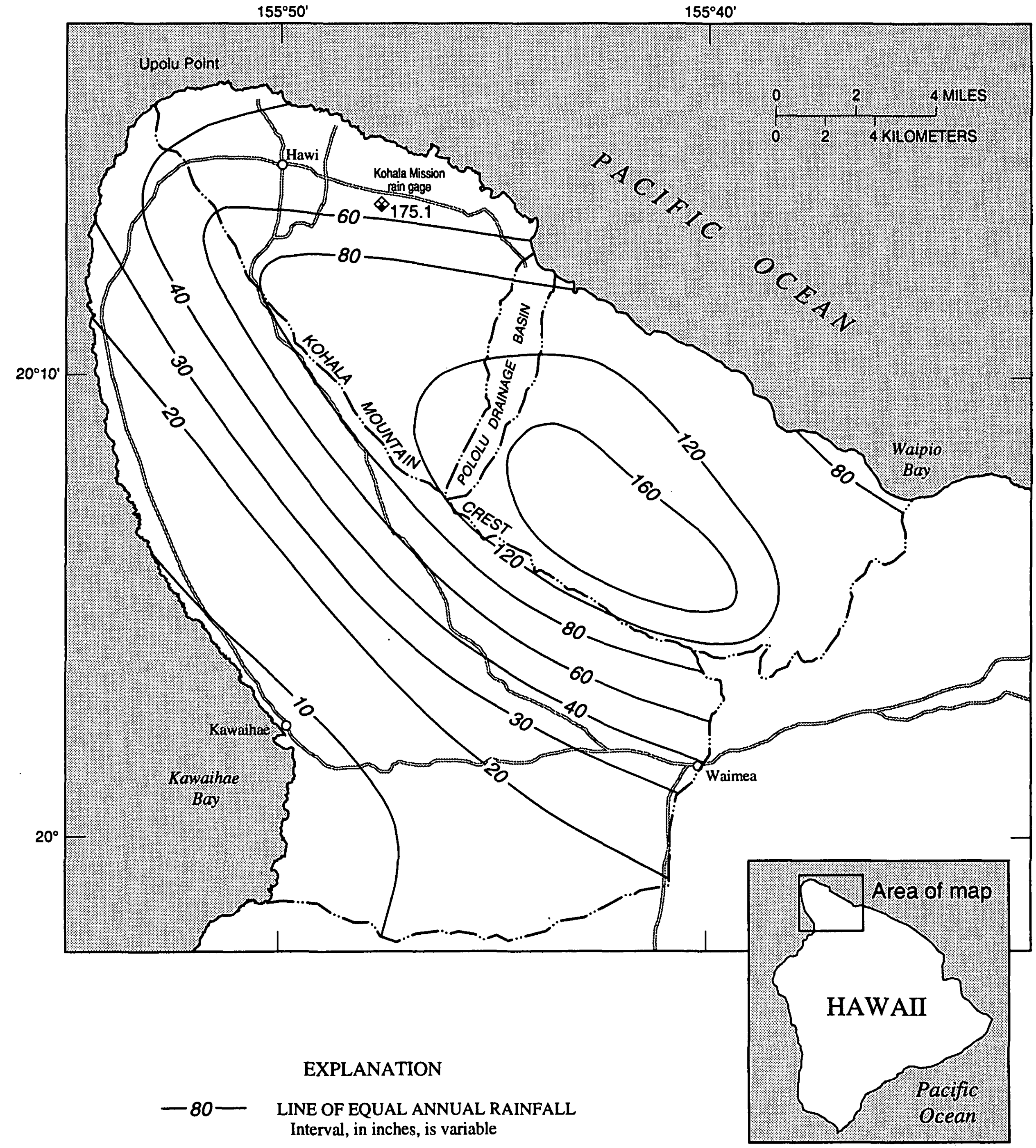
Pololu Valley trends in a roughly north-south direction and is about 4 mi long, about 2,000 ft wide, and about 1,400 ft deep at its greatest depth. The ridges on either side of the valley terminate as sea cliffs about 400 ft high.

Pololu Stream has three tributaries (fig. 1 and also fig. 7). An unnamed eastern tributary joins Pololu Stream at an altitude of about 920 ft. Kapoloa and Waiakalae Streams join Pololu Stream from the west side of the valley at altitudes of 180 ft and 35 ft, respectively.

Except during periods of very high flow, Pololu Stream has no outlet to the ocean. About 2,000 ft from the shoreline, the stream channel enters a wetland that has a shallow and brackish pond surrounded by reeds and grasses. The wetland terminates against a beach berm about 200 ft from the ocean.

Ditch systems.--Two irrigation ditches, Kohala Ditch and Kahena Ditch (fig. 1), intersect the streams and tributaries of the Pololu drainage basin. The Kohala Ditch is a system of water tunnels, flumes, diversions, and ditches that collects stream and spring flow and conveys the water to a distribution system near the town of Hawi (fig. 2). The ditch was constructed between 1905 and 1907 to supply irrigation water to a number of small sugar plantations (Wilcox, 1996). When fully operational (before 1975), the ditch supplied a range of flow between 22 and 30 Mgal/d and extended 23 mi to the southeast to Waikaloa Stream (figs. 1 and 3).

Since 1975 parts of the Kohala Ditch have fallen to disuse. The currently operational part of the ditch is 18 mi long and starts at the east branch of the Honokane Nui Stream (fig. 1). A 1,800-ft tunnel penetrates into a dike-impounded ground-water body at an altitude of about 1,900 ft and adds about 9 Mgal/d to the 3 Mgal/d of surface water diverted from the east branch of Honokane Nui Stream (Mike Gomes, Chalon International, oral commun., 1996). In Pololu Valley, the ditch has diversions on the unnamed eastern tributary, the upper



EXPLANATION

—80—	LINE OF EQUAL ANNUAL RAINFALL Interval, in inches, is variable
◈175.1	RAIN GAGE AND STATE IDENTIFICATION NUMBER
··—··—	DRAINAGE DIVIDE
═══	ROAD

Figure 2. Mean annual rainfall, Kohala area, island of Hawaii (from Giambelluca and others, 1986).

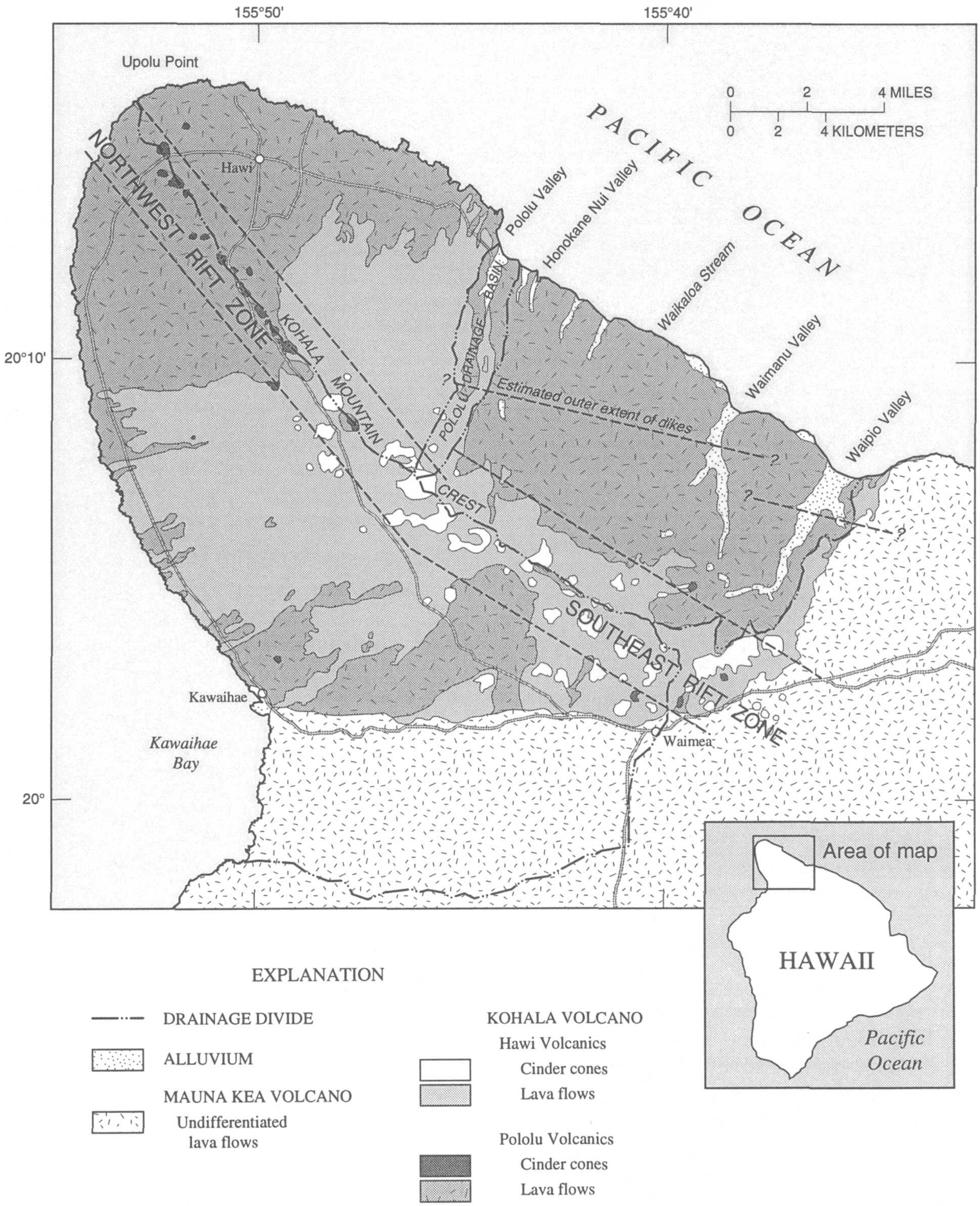


Figure 3. Surficial geology (from Stearns and Macdonald, 1946; Langenheim and Clague, 1987) and estimated extent of dikes (from Underwood and others, 1995), Kohala Volcano, island of Hawaii.

part of Pololu Stream, and on Waiakalae Stream. About 0.5 Mgal/d leaks from the diversion flume on the unnamed eastern tributary during dry periods, and the leakage flows down the tributary. The diversion at Waiakalae Stream adds a small amount relative to the ditch flow. In the past, water from above the waterfall of the adjacent Kapoloa Stream was diverted by a flume to the upper part of Waiakalae Stream, which eventually flowed into the diversion at Waiakalae Stream to the ditch. At present, Kapoloa Stream and other small springs are no longer diverted to the ditch.

The Kahena Ditch was constructed between 1912 and 1914 and diverted streams above the heads of the larger valleys (fig. 1). The Kahena Ditch had a diversion where it crossed the headwaters of Pololu Stream, but presently the diversion is not functional. The ditch was not a reliable source of water, and thus has not been maintained (Wilcox, 1996).

GEOHYDROLOGIC SETTING OF POLOLU STREAM

Geology

The volcanic rocks of the Kohala Volcano have been divided into the shield-building Pololu Volcanics and the overlying alkalic Hawi Volcanics (Stearns and Macdonald, 1946; Spengler and Garcia, 1988; and Wolfe and Morris, 1996). The lava flows emanated from vents along two main rift zones, the northwest rift zone and the southeast rift zone, which trend at about N 35°W and S 65°E, respectively (fig. 3), from a central caldera at the summit that is buried by later flows.

The location and orientation of the rift zones shown in figure 3 are based on the mapping of Stearns and Macdonald (1946) and the hydrologic interpretations of Underwood and others (1995). Rift zones are where the greatest density of intrusive dikes can be found. The number of dikes in the rift zones generally increases with depth and proximity to the caldera. The density of dikes in the rift zones can be as great as 1,000 per mile, but a more probable range is between 100 to 200 per mile (Macdonald, 1956).

The line showing the extent of dike intrusion towards the east was estimated by Underwood and others (1995) from dikes mapped by Stearns and Macdonald (1946) in Pololu, Honokane Nui, and Waimanu Valleys (fig. 3). The area between the rift zone and the extent of dike intrusion is assumed to be a "marginal dike zone" (Stearns and Vaksvik, 1935; Takasaki and Mink, 1985), where the rock volume of the dikes relative to the total rock volume is less than 5 percent or number fewer than 100 per mile. In figure 3, the "estimated outer extent of dikes" was not continued beyond Pololu Valley because no dikes are exposed beyond the valley area (Stearns and Macdonald, 1946).

Dike rocks have low vesicularity and a glassy border where the intrusion was rapidly chilled by the country rock (Macdonald and others, 1983). The dikes have very low hydraulic conductivity due to jointing cracks through the impermeable dike rock. The sheet-like vertical orientation and trend of the dikes impede the flow of ground water, and intersecting dikes form compartments that can impound water to thousands of feet above sea level (Stearns and Macdonald, 1946). The occurrence of this type of ground water is called dike-impounded ground water.

Almost all of Kohala Volcano is composed of thousands of flows and intrusions of the Pololu Volcanics. The aa and pahoehoe flows of the Pololu Volcanics dip away from the rift zones at about 3 to 10 degrees (Stearns and Macdonald, 1946). The flows range in thickness from several feet to about 50 ft. A basal water body exists as a freshwater lens in these flank flows in the dike-free zone extending beyond the marginal dike zone. Aquifer tests in wells drilled in Pololu Volcanics near the town of Hawi indicate that hydraulic conductivities range from 610 to 4,300 ft/d (Underwood and others, 1995).

The Hawi Volcanics forms a thin veneer over the shield-building lavas, separated by an unconformity marked by a red soil layer. About a third of the northeast slope and about half of the southwest slope below the rift zone are covered by Hawi Volcanics (fig. 3). Most of the flows of the Hawi Volcanics are thick and massive aa flows that have little vesicularity and porosity. The Hawi Volcanics is less weathered than the Pololu Volcanics. Thicknesses of the individual lava flows range from about 10 to 150 ft on the flanks of the volcano, and are thicker locally where flows have filled valleys. The flows of the Hawi Volcanics are probably less permeable than the Pololu Volcanics because of their thickness and because they are generally thick aa flows with massive and dense cores (Stearns and Macdonald, 1946, p. 172–173, 178–180, and 226).

Soil layers and ash beds within the Pololu and Hawi Volcanics, and the well-defined soil layer between the Pololu and Hawi Volcanics, have springs that discharge from above them throughout the northeastern slope of Kohala Volcano.

Alluvium fills the lower areas of the major incised valleys. The alluvium consists of consolidated conglomerates and unconsolidated deposits of poorly sorted silts, sands, and boulders; and landslide debris characterized by blocks of volcanic rock in an earthy matrix (Stearns and Macdonald, 1946, p. 173). Stearns and Macdonald (1946) interpreted the alluvium as being less permeable than the Pololu Volcanics.

Geologic setting of Pololu Stream.-- Pololu Stream cuts through all of the geologic units mentioned earlier (fig. 3, also see fig. 7). In the uppermost part of the stream above the incised valley and head wall, the streambed lies on flows of the Hawi Volcanics. From an altitude of about 2,800 ft to about 960 ft, the head wall of the amphitheater valley is composed of numerous lava flows of the Pololu Volcanics. Between the altitudes of about 960 ft and 200 ft, and for a distance of about 5,000 ft, the streambed lies on the single flow of Hawi Volcanics that flowed into the valley. Between an altitude of about 200 ft and sea level, the streambed is underlain by alluvial deposits. The maximum thickness of the alluvial deposits, estimated by projecting the slopes of the valley walls, ranges from about 300 ft where the altitude of the valley floor is about 100 ft to more than 600 ft thick near the shore (see fig. 6).

In the wetland and pond area at the terminus of Pololu Stream near the ocean, the composition of the alluvium changes from a black to dark-brown sandy mud upstream to a silty sand at the ocean end of the pond. At the shore, the beach face and berm is composed of sand, lava boulders, and cobbles. The black volcanic sand of the berm grades into a silty sand towards the pond.

Ground Water in the Pololu Stream Drainage Basin

Ground water in the study area (fig. 4) is found as high-level dike-impounded water within the rift zones, as basal ground water (Meinzer, 1930) in the form of a low-lying freshwater lens that floats on saltwater in the volcanic flows extending oceanward from the rift zones, and as perched ground water of limited areal extent above either the high-level water or basal water (Stearns and Macdonald, 1946). Dike-impounded water underlies some of the heaviest rainfall areas in the mountainous interior and thus receives a substantial part of the recharge. The general movement of ground water is from the mountainous interior towards the ocean where it discharges as subaerial and submarine seepage.

Stearns and Macdonald (1946) report water levels in dike-impounded water as great as 2,000 ft in Honokane Nui Valley just east of Pololu Valley, and speculate that water levels could be as high as 3,000 ft near the summit of Kohala Mountain. Water levels, indicated by Underwood and others (1995) in basal water underlying Pololu Valley, range from about 18 ft inland to about 10 ft near the shoreline (fig. 5). These water levels are based on the results of a numerical ground-water model that simulated the movement of ground water only in volcanic rocks (Underwood and others, 1995). Because the model was not constructed with the alluvium in Pololu Valley as a separate geohydrologic unit, the model-predicted water levels for Pololu Valley may not be accurate. If the hydraulic conductivity of the alluvium is less than that of the underlying volcanic rock, as suggested by Stearns and Macdonald (1946), water levels in the basal water body in Pololu Valley would be higher than those shown in figure 5 by some unknown amount. Conversely, if the hydraulic conductivity of the alluvium is greater than that of the underlying basalts, the water levels would be lower.

If the water levels in Pololu Valley are similar to those estimated by Underwood and others (1995), it is clear that the basal water table is significantly below the land surface throughout most of the valley (fig. 6). Near the contact between the alluvium and the Hawi Volcanics in the upper valley, this difference in altitude is about 200 ft, and half-way down the valley, the difference is about 75 ft. The model-predicted water table only intersects the land surface near the ocean where the land surface is only a few feet above sea level. As a result, Pololu Stream would be expected to lose water or be dry over that part of the stream extending from the contact between the alluvium and the Hawi Volcanics in the upper part of the valley to a point near the ocean. Discharge measurements (fig. 7) show that all of the streamflow for Pololu Stream and tributaries diminished to zero upon reaching the alluvium, and this result supports the conceptual picture described above. On the basis of local observations, when the watershed of Pololu Valley receives enough rainfall, the stream flows

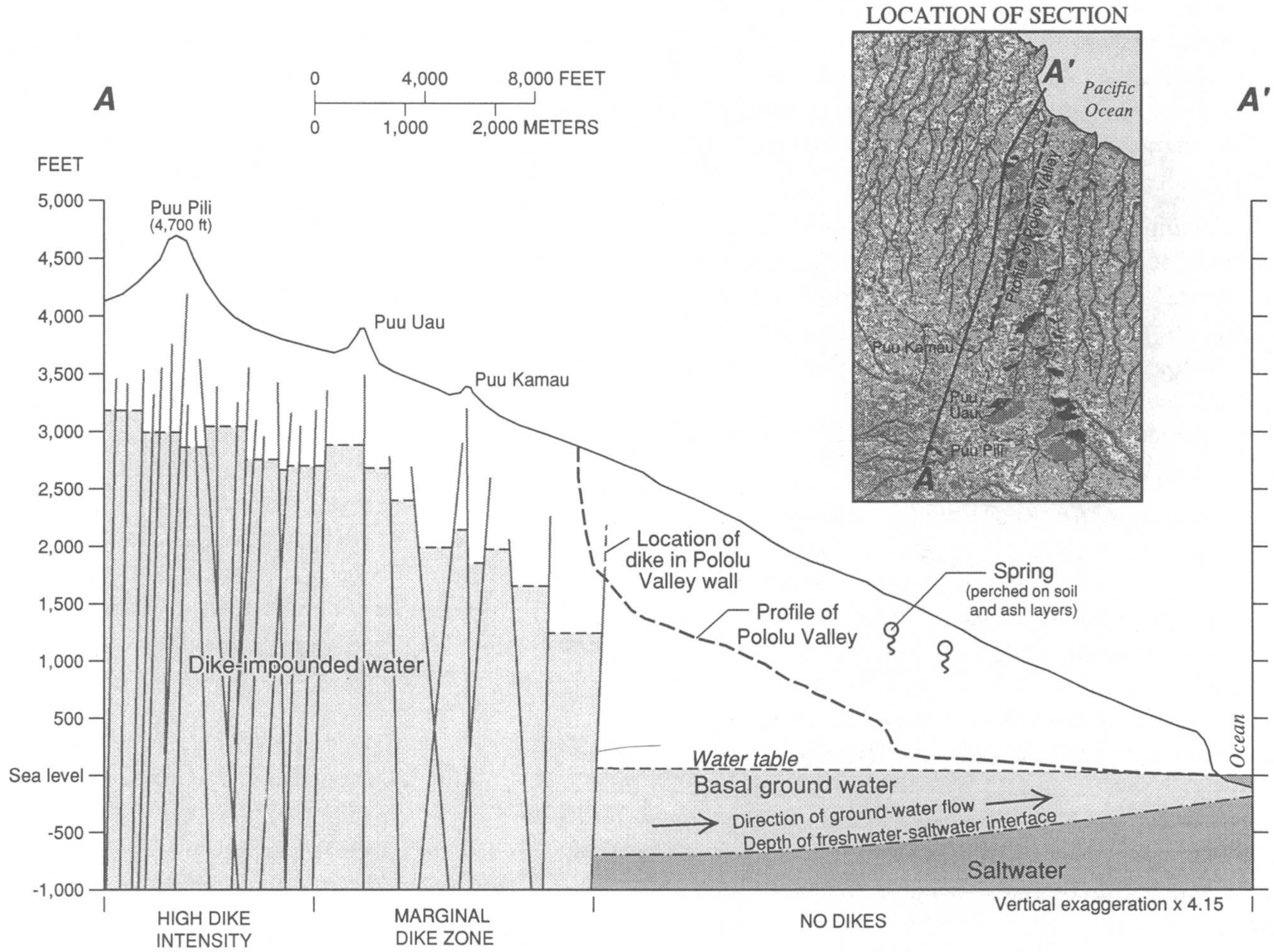


Figure 4. Section of Kohala Volcano west of Pololu Valley, island of Hawaii.

continuously from the mountains to the ocean transforming the pond into a stream outlet discharging into the ocean (Mike Gomes, Chalon International, oral commun., 1998).

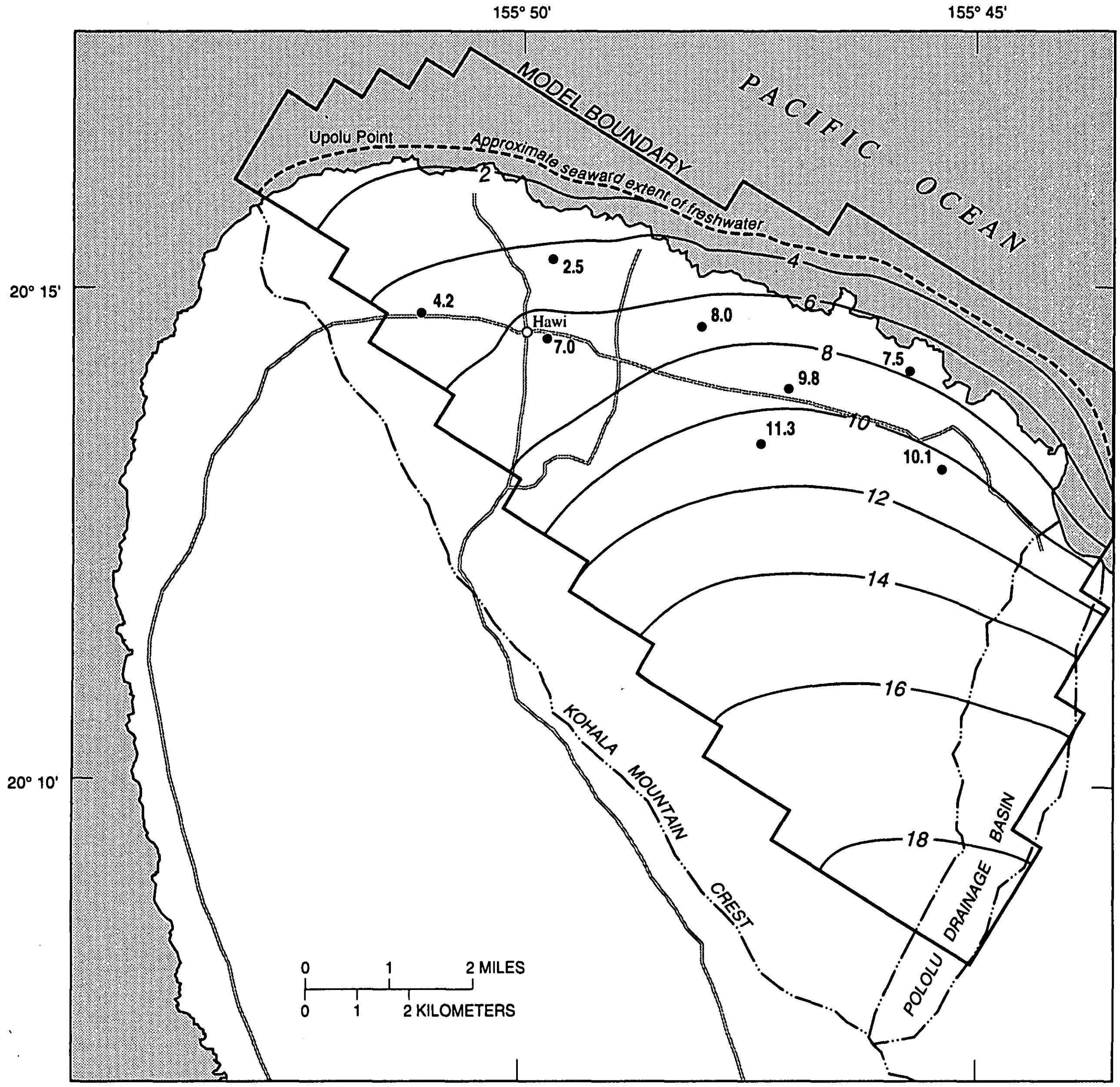
About 2,000 ft from the shoreline, the stream enters the wetland at an altitude probably less than 10 ft. Conceptually, ground-water discharge into the ocean requires that the water levels of the basal ground water be greater than average sea level. The water level in the pond is about 2.82 ft above sea level, and the permanence of the pond (to be discussed subsequently) strongly suggests that the wetland and pond are a result of the ground surface intersecting the water table.

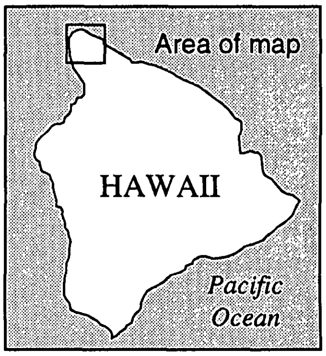
Ground water perched on soil and ash layers discharges as springs along the valley walls of Pololu Valley. Some of these springs feed two of the three tributaries to Pololu Stream; Kapoloa Stream and Waiakalae Streams. Discharge from springs in the area has been shown to vary seasonally (Stearns and Macdonald, 1946, p. 233).

Streamflow in Pololu Stream

To investigate the relation between ground water and Pololu Stream, measurements of streamflow were done on Pololu Stream and its tributaries during a single day (a technique called a seepage run).

The seepage run was done following a period of dry weather so that there was no runoff component to the streamflow. Nearly simultaneous current meter or volumetric flow measurements (during the same day) were made at selected sites where the stream and tributaries were accessible along the Kohala Ditch trail and the lower valley (fig. 7). Current-meter measurements were made by making a channel that captured all of the flow and using a small mechanical meter to measure





EXPLANATION

— 6 — LINE OF EQUAL MODEL-CALCULATED GROUND-WATER LEVEL--Interval 2 feet. Datum is mean sea level

10.1 ● WELL AND MEASURED GROUND-WATER LEVEL, IN FEET ABOVE MEAN SEA LEVEL

Figure 5. Model-calculated and measured ground-water levels, Kohala area, island of Hawaii (from Underwood and others, 1995).

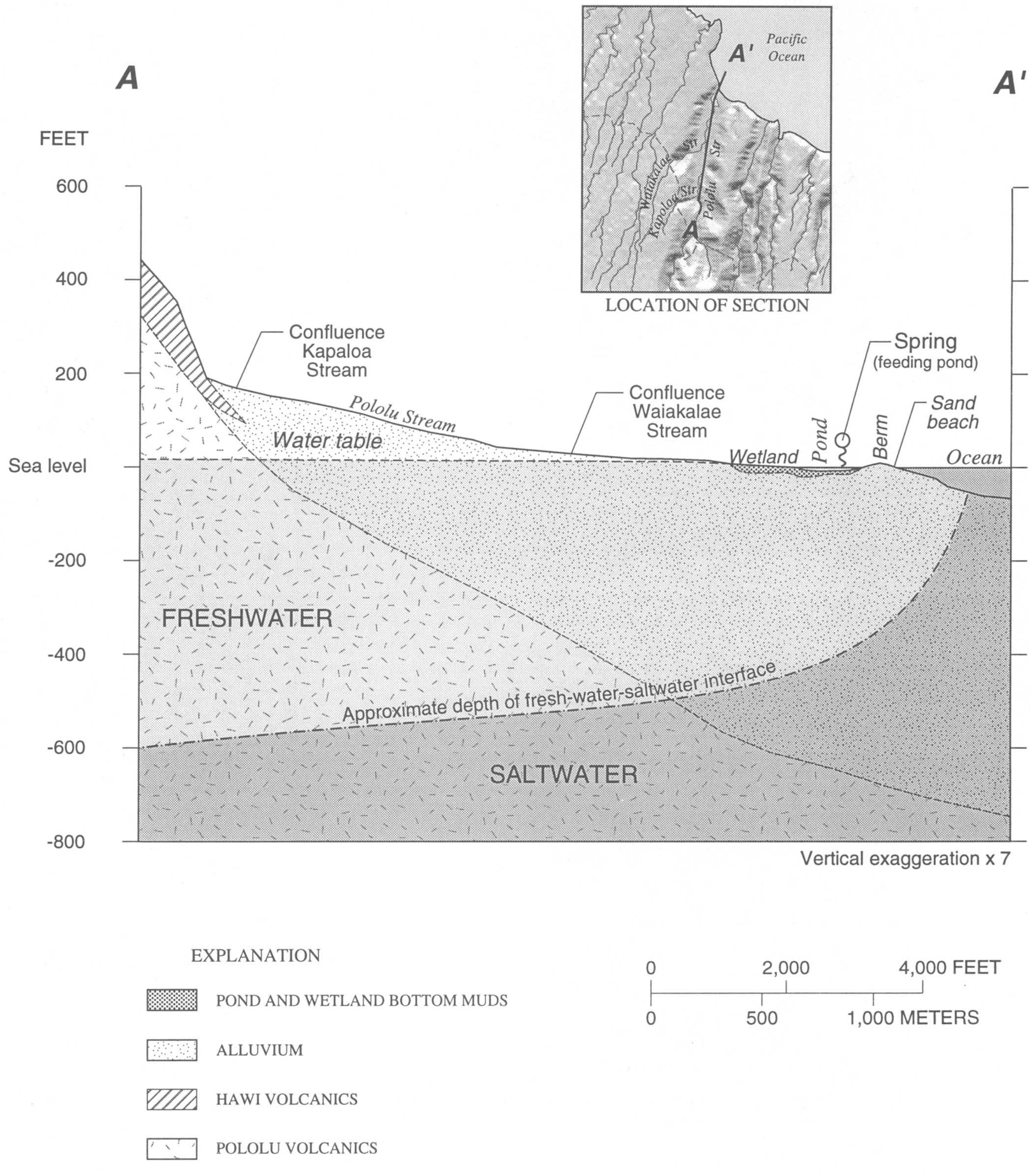
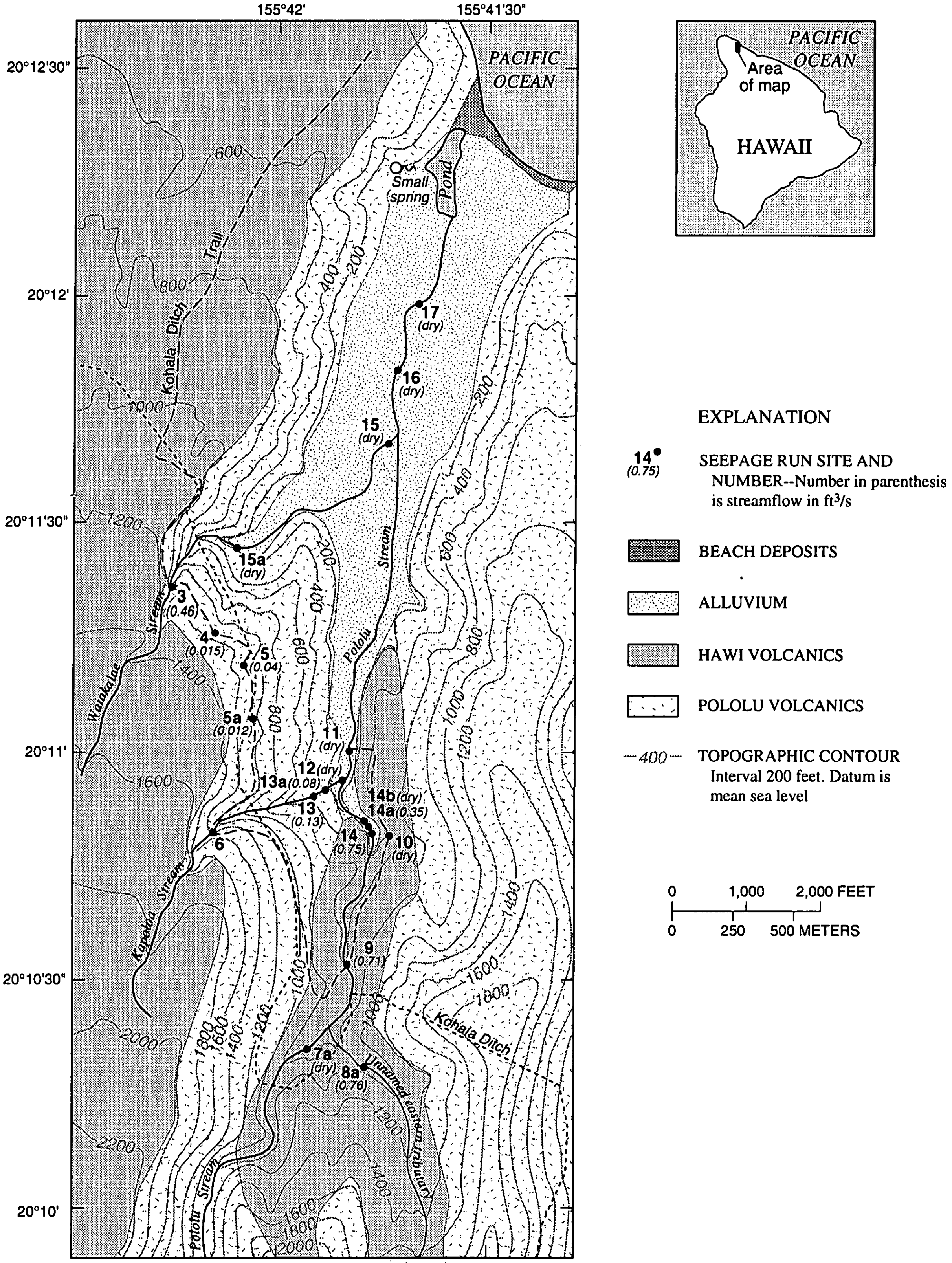


Figure 6. Section along axis of lower Pololu Stream and model-predicted water table (see fig. 5), island of Hawaii.



Base modified from U.S. Geological Survey 1:24,000 topographic quadrangles; Hawi, Honokane, Kamuela, and Kawaihae, 1982

Geology from Wolfe and Morris, 1996

Figure 7. Measurement sites of the Pololu Valley seepage run of October 1996, island of Hawaii.

Table 1. Seepage-run data for Pololu Stream, island of Hawaii, October 8, 1996

[ft^3/s, cubic feet per second; µS/cm, microsiemens per second at 25°C; °C, degrees Celsius; ~, approximately; >, greater than; meter, pygmy meter measurement; %, percent; vol, volumetric measurement; --, not measured; datum is mean sea level]

Site no. (fig. 7)	Location	Streamflow (ft^3/s)	Elevation (feet)	Specific conductance (µS/cm)	Temperature (°C)	Time	Method of measuring flow	Rating (percent off)
3	Waiakalae Stream at diversion (stream dry below diversion)	0.46	1,120	114	20.6	0855	meter	fair (8%)
4	Spring between Waiakalae Stream and Kapoloa Stream, ocean side	0.015	1,120	--	--	0920	vol	fair (8%)
5	Spring between Waiakalae Stream and Kapoloa Stream, middle	0.04	1,090	95.4	21.2	0940	meter	fair
5a	Spring between Waiakalae Stream and Kapoloa Stream, inland side	0.012	1,100	--	--	1005	vol	poor (>8%)
6	Kapoloa Stream, (no measurement, water fall)	--	1,080	--	--	--	--	--
7a	Pololu Stream (dry from here to headwaters)	dry	760	--	--	--	--	--
8a	Unnamed Eastern Tributary (all of flow from diversion leakage)	0.76	880	118.5	20.2	1249	meter	fair
9	Pololu Stream at trail crossing	0.71	620	113.8	21.8	1428	meter	fair
10	Spring on east wall of Pololu Valley	dry	420	--	--	1500	--	--
11	Pololu Stream, downstream of confluence with Kapoloa Streams	dry	160	--	--	1045	--	--
12	Kapoloa Stream, 150 feet upstream of confluence	dry	180	105	22.0	1100	--	--
13	Kapoloa Stream near base of falls (below site 6)	0.13	320	106	22.0	1122	meter	fair
13a	Kapoloa Stream, intermediate measurement, downstream of site 13	0.08	260	105	22.0	1226	meter	fair
14	Pololu Stream about 100 feet downstream of falls	0.75	280	110	22.0	1400	meter	fair
14a	Pololu Stream, intermediate measurement, downstream of site 14	0.35	260	109	24.0	1441	meter	fair
14b	Pololu Stream, downstream of sites 14 and 14a	dry	250	--	--	--	--	--
15	Waiakalae Stream, at and upstream of confluence with Pololu Stream	dry	35	--	--	--	--	--
15a	Waiakalae Stream at falls	dry	200	--	--	--	--	--
16	Pololu Stream, downstream of confluence with Waialae Stream	dry	10	--	--	0940	--	--
17	Inland end of pond, stream dry	dry	~3	--	--	--	--	--

flow velocity across the channel. Volumetric measurements were made using a measured bucket and plastic sheeting to capture the flow. Both types of measurements are rated on the basis of the estimated percentage of flow not captured by the measurement.

The seepage run in Pololu Stream was done on October 8, 1996 following a period of dry weather. The measurements and observations (fig. 7 and table 1) indicate that the main channel of Pololu Stream was dry along its entire length except in two places: where water from the Kohala Ditch was leaking into the unnamed eastern tributary which subsequently flows into the main channel, and in the wetland area near the ocean. Kapoloa and Waiakalae Streams, both tributary to Pololu Stream, were flowing as a result of perched ground-water discharge into the streams along their upper reaches. However, the flow of Waiakalae Stream was diverted to the Kohala Ditch, and the flow from Kapoloa Stream was rapidly lost once the stream reached the alluvium of the valley floor (fig. 7 and table 1).

During the seepage run, Pololu Stream and the unnamed eastern tributary were dry above an altitude of about 1,000 ft. Pololu Stream intersects at least one dike in the uppermost reach. However, the lack of ground-water discharge into the stream indicates that it does not intersect dike-impounded ground water. Stearns and Macdonald (1946) speculated that Pololu Stream does not have springs discharging from dike-impounded ground water because the adjacent Honokane Nui Stream cut deeper into the dike-impounded ground-water body and drained water that formerly supplied Pololu Stream.

Between an altitude of about 1,000 ft to a few feet above sea level, the main channel of Pololu Stream does not gain from ground water. The eastern unnamed tributary receives water from a leaky flume of the Kohala Ditch at an altitude of about 950 ft. At the time of the seepage run, the discharge was 0.76 ft^3/s. The water from the leak flowed for a distance of about 1,000 ft to the tributary's confluence with Pololu Stream at an altitude of about 720 ft. From the confluence, the water from the leak flowed for a distance of about 4,000 ft in Pololu Stream where the stream channel is composed of the valley-filling lava flow of Hawi Volcanics (figs. 6 and 7). The streamflow started to diminish where the stream channel passes from the lava flow of Hawi Volcanics to alluvium at an altitude of about 200 ft (measurement sites 14 and 14a, fig. 7). The stream was dry a short distance downstream from site 14a to the wetland, a distance of about 8,600 ft. At the wetland, at least one small spring in the western wall of the stream valley discharges into the pond. The altitude of the spring is close to the altitude of the pond.

Kapoloa and Waiakalae Streams are supplied by springs in their upper reaches, but lose water where their courses are diverted or reach the alluvium of the lower valley. Stearns and Macdonald (1946) describe the sources of these springs as perched water bodies resting on ash and soil layers. No dikes are mapped in the area of the streams.

During the seepage run, streamflow in Kapoloa Stream was 0.13 ft^3/s near the base of the lowest waterfall at 320 ft altitude at site 13 (fig. 7). About 200 ft downstream, the flow diminished to 0.08 ft^3/s (site 13a). The stream was dry 200 ft beyond site 13a at site 12, which is about 150 ft above the confluence with Pololu Stream and where the stream reaches the alluvium of the lower valley.

All of the water from Waiakalae Stream was diverted into the Kohala Ditch at an altitude of about 1,120 ft at the time of the seepage run. Flow in Waiakalae Stream above the diversion was 0.46 ft^3/s. The stream was dry downstream of the diversion.

The Wetland Pond at the Mouth of Pololu Stream

At the time of an altitude survey and chloride sampling between October 23 and October 25, 1996, the pond at the terminus of Pololu Stream was about 1,000 ft long, 100 ft wide and less than 3 ft deep. The altitude of the pond was 2.82 ft. The pond terminated about 200 ft away from the ocean and was separated by a 4- to 5-ft high, wave-formed beach berm.

The depth of the pond ranged from about 1 ft in the middle to about 3 ft near the ocean outlet. The pond bottom ranged from a few feet above mean sea level to a few feet below, thus the pond is potentially subject to tidal influence. Also, the water-level altitude in the pond, at 2.82 ft, was lower than the ground-water level in the basalt shown in figure 5.

Measurements of temperature, specific conductance, and chloride concentration of the pond water were made over the 2-day period. The pond stage was recorded continuously during this period and the altitude of the pond was surveyed. The climate had been dry for the previous few months.

Water chemistry of the pond.--The pond is brackish mixture of ground water, surface water from runoff, and saltwater from the ocean. Measurements of temperature, specific conductance, and chloride concentration (table 2) were made at the locations shown in figure 8. Measurements and water samples were collected from the pond during a high tide and a low tide as predicted by locally available tide chart calenders. Values of specific conductance were obtained using an Orion specific-conductance probe and titrations for chloride concentration of the water were done at the USGS in Honolulu. The temperature of the pond water ranged from 23.3°C to 31.3°C. The chloride concentration of the pond water increased towards the ocean (fig. 2). Chloride concentration at the inland extent of the pond ranged from 5,670 to 6,690 mg/L between October 23 and 24, whereas chloride concentration of the water at the ocean end ranged from 8,600 to 10,600 mg/L during the same period. For comparison, seawater chloride concentration is about 19,000 mg/L.

The trend of chloride concentration increasing towards the ocean probably results from the seepage and spill-over of saltwater into the pond. Water from waves breaking on the beach infiltrates the sands of the berm. Some of this water then seeps out on the pond

Table 2. Specific conductance of water with respect to tide, Pololu Valley, island of Hawaii
[ft, feet; °C, degrees Celsius; µS/cm, microsiemens per second at 25°C; mg/L, milligrams per liter; --, not measured; datum is mean sea level]

Site no. (fig. 8)	Location	Approximate distance from ocean end (ft)	Date	Time	Tide	Kawaihae tide level from tidal record (feet above arbitrary datum)	Pond level from hydrograph (feet above mean sea level)	Temperature (°C)	Specific conductance (µS/cm)	Chloride concentration (mg/L)
17a	Inland end of pond	1,500	10/23/96	1430	high	4.7	2.75	30.3	16,700	5,670
			10/24/96	0855	low	3.0	2.82	24.2	18,600	6,690
17b	Middle of pond closer to inland end	1,200	10/23/96	1440	high	4.7	2.75	31.3	18,200	--
			10/24/96	0900	low	3.0	2.82	24.1	19,800	--
17c	Middle of length of pond below small seep	1,000	10/23/96	1443	high	4.7	2.75	28.3	21,300	--
			10/24/96	0904	low	3.0	2.82	25.3	26,800	--
17d	Ocean side of small spring	400	10/23/96	1455	high	4.7	2.75	28.5	22,800	7,990
			10/24/96	0910	low	3.0	2.82	24.3	27,000	9,960
17e	Ocean end of pond	0	10/08/96	0830	high	4.5	--	25.5	5,820	1,720
			10/23/96	1500	high	4.7	2.75	28.3	23,100	8,600
			10/24/96	0915	low	3.0	2.82	23.3	29,500	10,600
			10/25/96	1220	low	3.0	2.97	26.9	38,900	15,000

side of the berm, flows over the silty sands that are much less permeable, and reaches the pond. Additionally, larger waves spill directly over the berm into the pond.

Water-level fluctuation in the pond.--Water levels were recorded over the 2-day period of surveying using an electronic data recorder located at the beach end of the pond (fig. 8). Water levels fluctuated in the pond (fig. 9), however there was little correlation of the fluctuation with tidal data from Hilo and Kawaihae Harbors (fig. 1). Tidal fluctuation over the 2-day period at Hilo and Kawaihae was about 2.4 ft while fluctuation in the pond was about 0.3 ft over the same period. The trends of the water levels in the pond do not follow the tidal pattern: not all of the high tides are represented in the record, and water levels do not drop with the outgoing tide. This lack of tidal response indicates that the pond bottom, composed of silty muds, has poor hydraulic connection with the ocean.

The increase in pond level shown in figure 9 may have resulted from wave spill-over into the pond. Additionally, the increase in chloride concentration and specific conductance (table 2) at the ocean end supports this conclusion.

Presence and size variation of the pond.--Aerial photography of the pond over a period of 26 years indicates that the pond is perennial. Figure 10 shows a series of outlines of the pond traced from aerial photographs. Because of the distortion of the photographs, the sizes, shapes, and locations are approximate, but they still show variation in length and shape of the pond and the persistence of the pond through time. The photographs were taken during the late fall and winter of 1965, 1970, 1975, 1977, 1982, 1991, and the summer of 1987. Figures 11, 12, and 13 show daily, monthly, and the departure from the mean of a 12-month moving mean of rainfall from a daily-read rain gage, 4.75 mi northwest of Pololu Valley (fig. 2; Kohala Mission rain gage, State rain gage 175.1). The daily data show that there was little rainfall during the days preceding the day of most of the photographs. Figure 10 shows that monthly rainfall was low or recently low for the photographs taken in 1975, 1977, 1982, 1987, and 1991. The departure of the 12-month moving mean from the long term mean (fig. 11), shows that the photographs of 1975, 1977, and 1987 were taken during dryer years. All of the photographs except for 1975 and 1977 show a channel to the berm, however. Observations from caretakers of the valley describe the pond as a persistent feature (Mike Gomes, Chalon International, oral commun., 1998). The findings from the photography are consistent with the concept of the pond being perennial and maintained by ground water.

Generalized water flux for the wetland area.--A schematic section and block diagram of the pond area are shown in figure 14. Arrows show the different

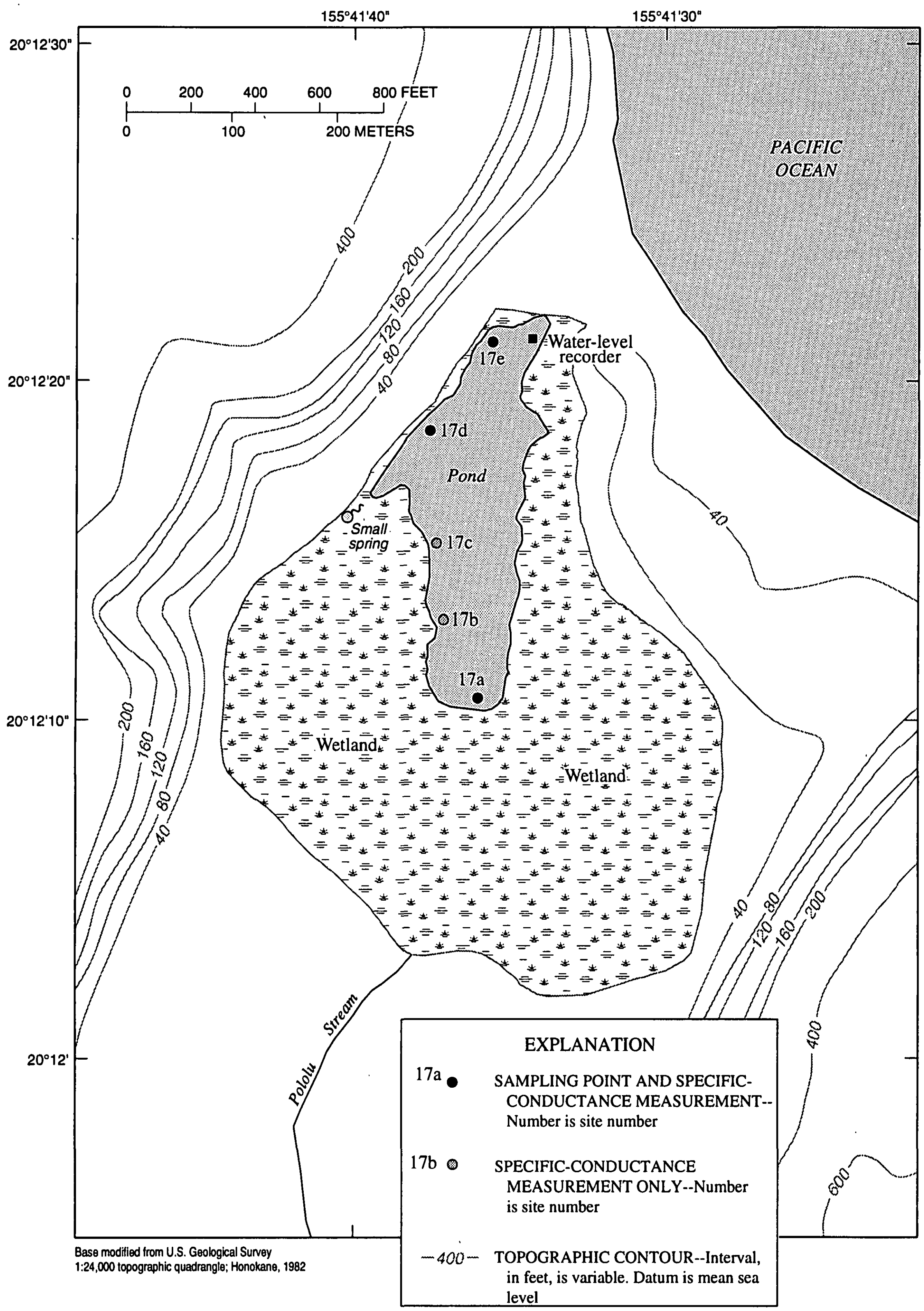


Figure 8. Sampling and measurement sites at pond in Pololu Valley, island of Hawaii.

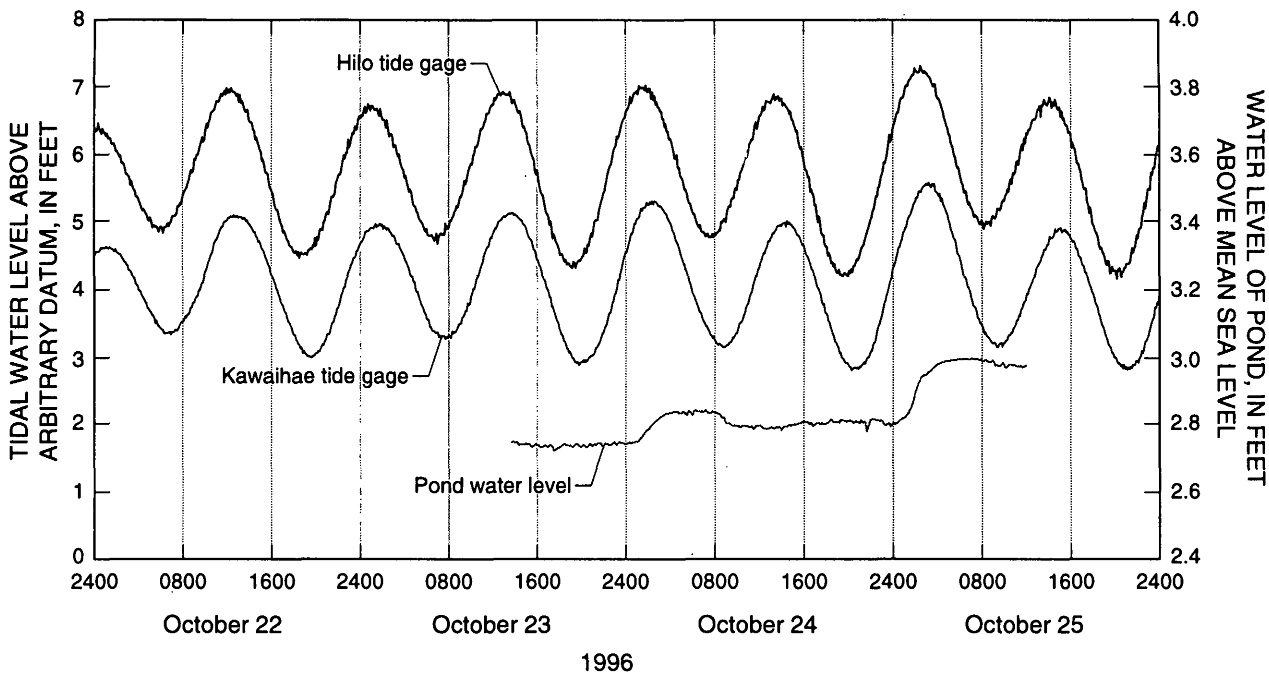


Figure 9. Water-level hydrograph of the pond in Pololu Valley over a 2-day period, and tidal records for Kawaihae and Hilo Harbors, island of Hawaii (tide data from NOAA).

mechanisms for sources and sinks of water in the wetland and the ground water in the alluvium. Ground water entering into and discharging from the wetland is represented by arrow **a**. Other sources contribute to the wetland and pond, such as direct surface runoff from Pololu Stream and small tributaries surrounding the pond (arrow **b**), saltwater seepage through the wave-saturated berm (arrow **c**), wave over-wash (arrow **d**), spring flow (**e**) and rainfall (**f**). The wetland and pond area loses water from evaporation and evapotranspiration (arrow **g**). The schematic block diagram shows a possible depiction of the water table near the pond, where the higher water table in the basalt forms a seepage face along the canyon walls.

SUMMARY AND CONCLUSIONS

A study was done on the Pololu Stream, island of Hawaii, to describe the geohydrologic setting of the stream. The study included a review of geologic and hydrologic data, a series of streamflow measurements to help determine the interaction of ground water and surface water, and the determination of altitude, salinity, and water-level response of a brackish pond at the terminus of the stream channel. Aerial photographs of the pond also were analyzed to investigate the variability and existence of pond size relative to rainfall.

Measurements of stream discharge made during a single day indicate that the main channel of Pololu Stream is not perennial above the wetland. Study results indicate that the main stream channel lies above either dike-impounded water or the basal ground-water body, and does not intersect perched water. The unnamed eastern tributary above an altitude of 960 ft and Pololu Stream above 720 ft are dry. A leak in a flume of the Kohala Ditch discharged about 0.76 ft^3/s into the unnamed eastern tributary of Pololu Stream. The water from the leak flows for about 5,200 ft along the unnamed eastern tributary and Pololu Steam. Streamflow diminishes to zero at about the 200-ft altitude where the streambed reaches alluvium. Two tributary streams, Waiakalae and Kapoloa Streams, are perennial in their upper reaches owing to the discharge of perched water bodies. The amount of water in the streams was

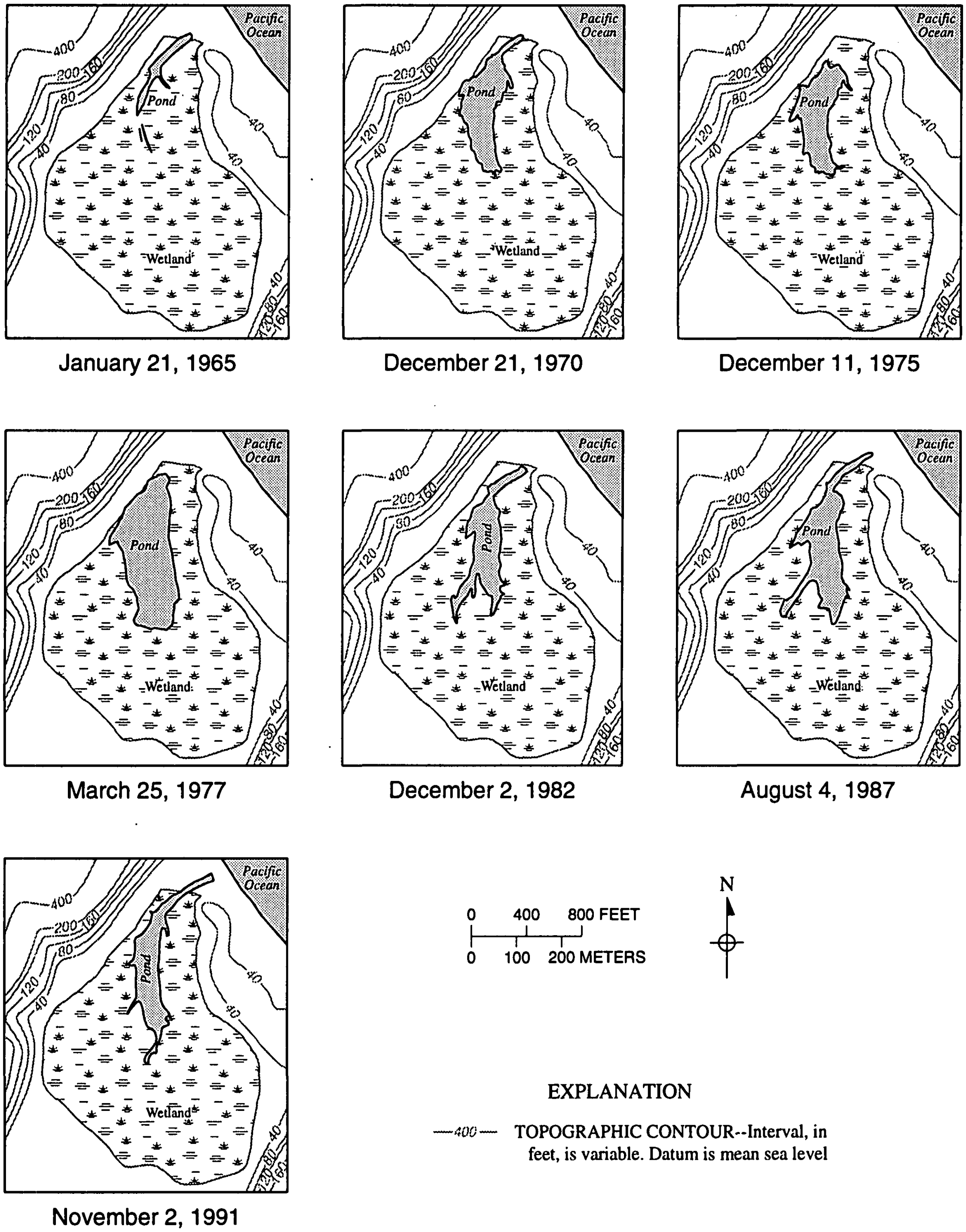


Figure 10. Outlines of the pond digitized from aerial photos, Pololu Valley, island of Hawaii.

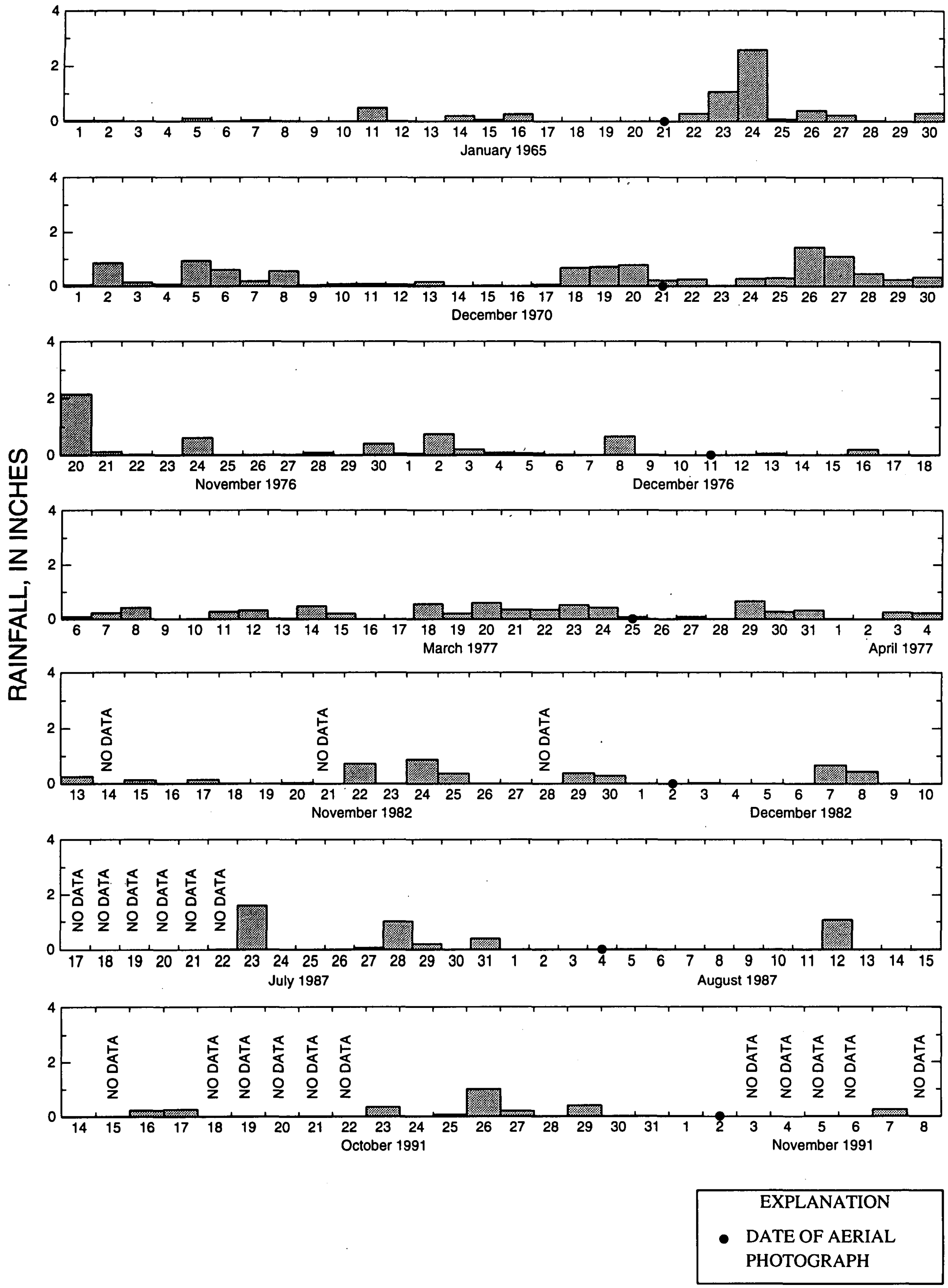


Figure 11. Daily rainfall for Kohala Mission rain gage (State rain gage number 175.1), island of Hawaii (National Climatic Data Center data from Hydrosphere, 1996).

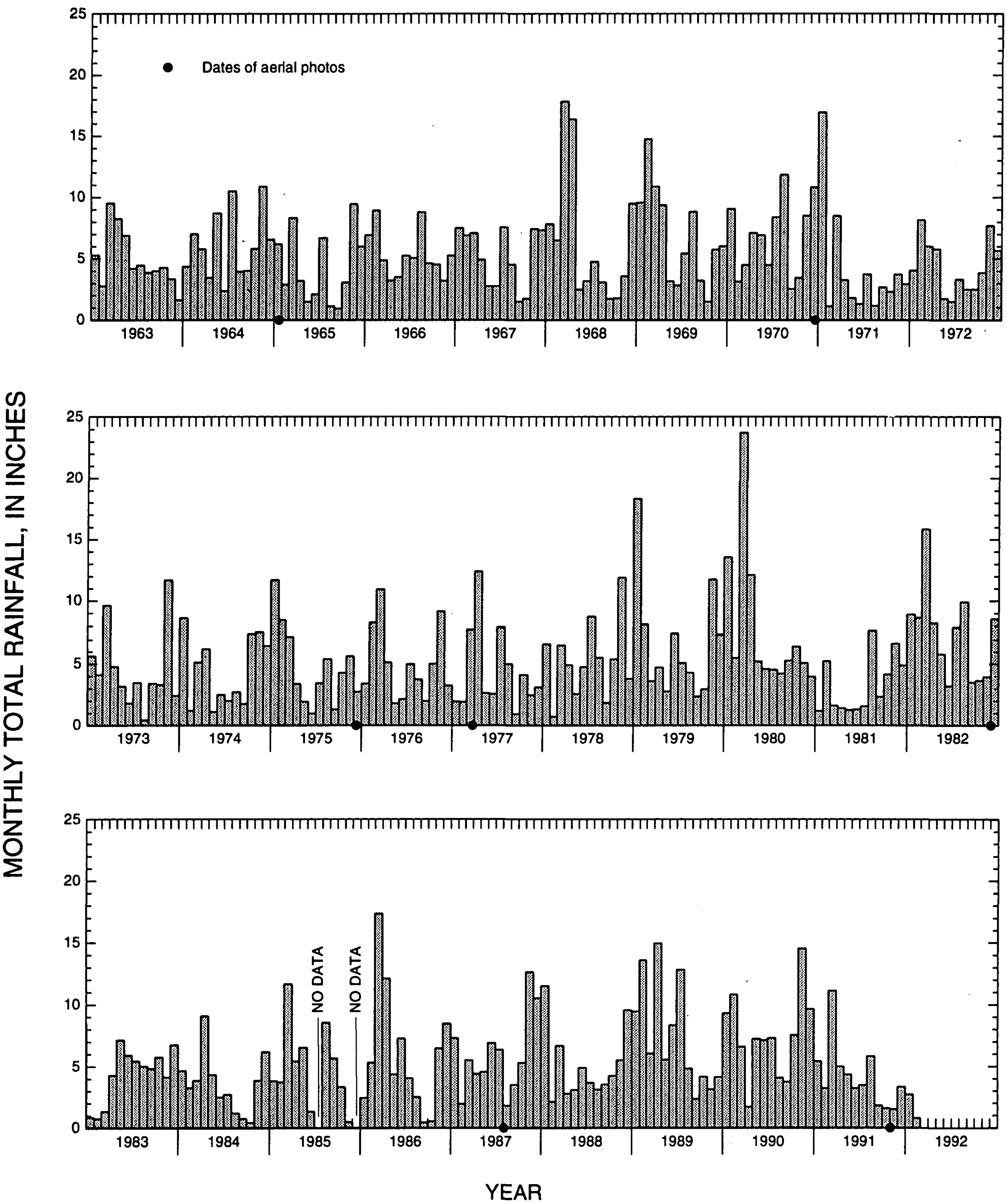


Figure 12. Monthly total rainfall for Kohala Mission rain gage (State gage number 175.1), island of Hawaii (National Climatic Data Center data from Hydrosphere, 1996).

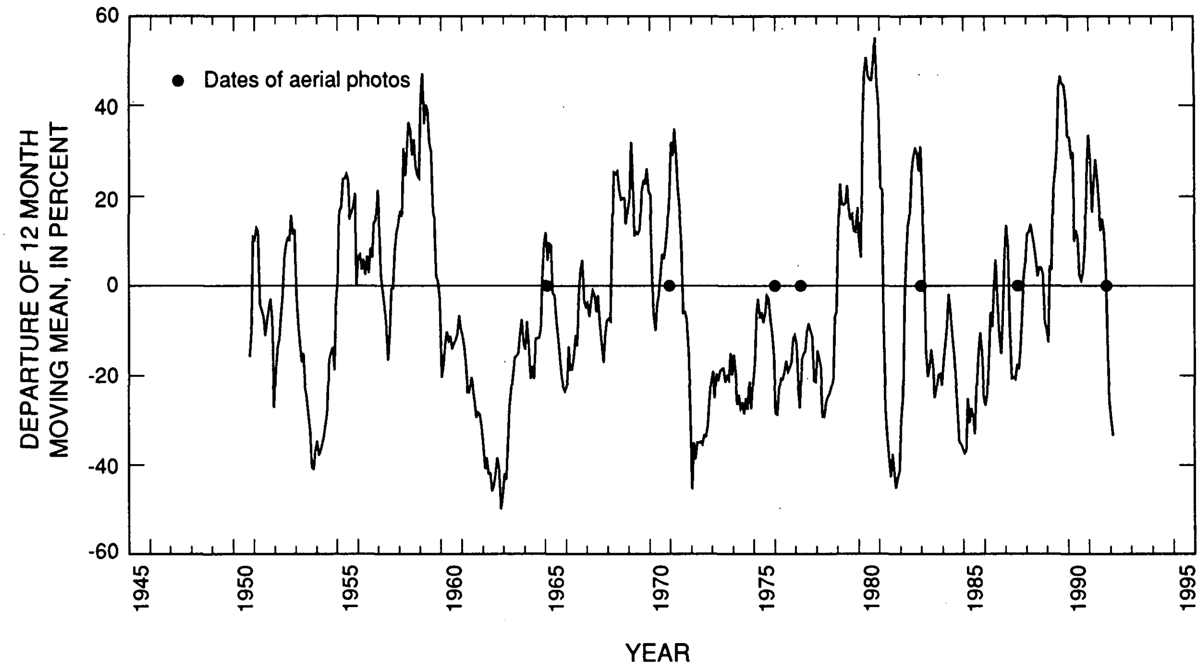


Figure 13. Percent departure of 12-month moving mean from mean of all months of record for Kohala Mission rain gage (State rain gage number 175.1), island of Hawaii.

0.46 ft^3/s for Waiakalae Stream and 0.13 ft^3/s for Kapoloa Stream during the seepage run, which was made on October 8, 1996, following a period of dry weather. Waiakalae Stream is diverted to the Kohala Ditch at an altitude of about 1,120 ft, and Kapoloa Stream flows to an altitude of about 200 ft and diminishes to zero where the streambed reaches the alluvium.

The wetland pond at the terminus of the stream is shallow and brackish. The water level of the pond was measured at about 2.82 ft above sea level at the time of the survey. The bottom of the pond is near or below sea level, and intersects the ground-water table. The pond receives additional freshwater from runoff and direct rainfall. Seawater enters the pond from seepage through the uppermost part of the beach berm and wave overwash.

The shape, size, and salinity of the pond is variable. Aerial photographs taken over a period of 26 years indicate that the pond is always present, although it varies in size. Rainfall data show that the area was relatively dry at the time some of the photographs were taken. The chloride concentration of the pond water varies with location, increasing towards the ocean. The chloride concentration of the sampled water was about 25 percent that of seawater at the up-valley end of the pond and almost 50 percent that of seawater near the ocean outlet during the period of the survey. During periods of high rainfall and associated high streamflow, the wetland floods with freshwater runoff and the pond transforms to a stream outlet.

The water level of the pond did not coincide with tidal fluctuation during the 2-day monitoring period. The lack of tidal response indicates that the pond, which has a bottom composed of sandy muds and silty muds inland, has a poor hydraulic connection with the ocean. The rise in pond level is likely due to the spill-over of waves into the pond.

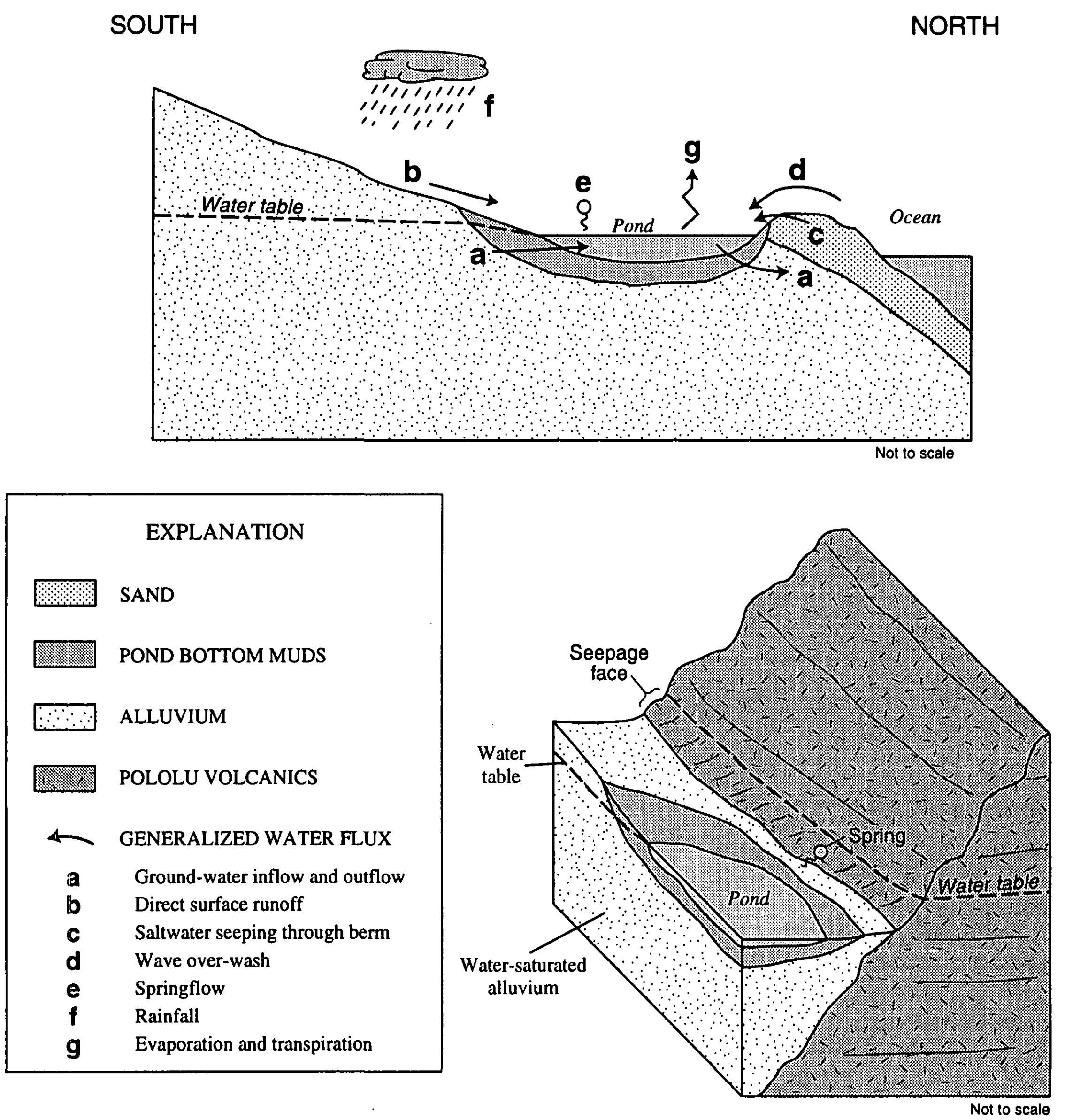


Figure 14. Schematic section and block diagram of wetland and pond area of Pololu Valley, island of Hawaii.

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