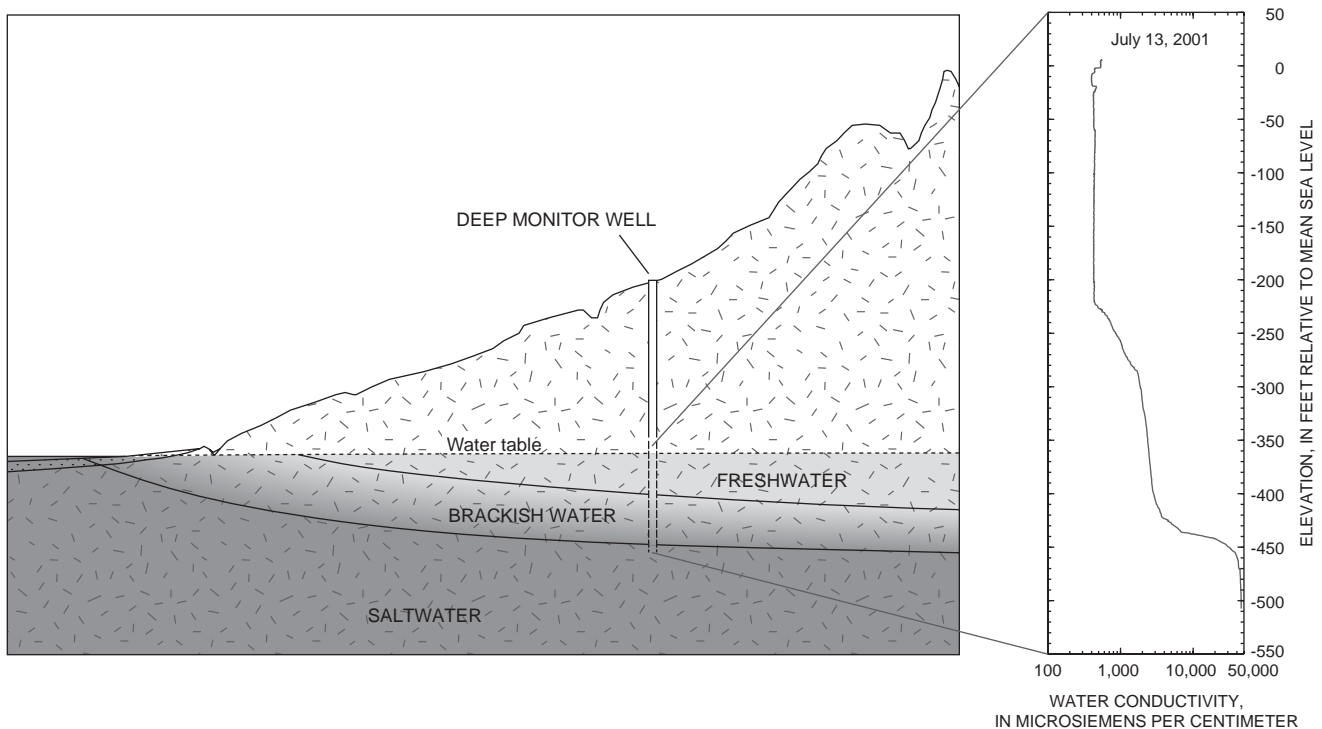


# Drilling, Construction, Water-Level, and Water-Quality Information for the Kualapuu Deep Monitor Well 4-0800-01, Molokai, Hawaii

U.S. GEOLOGICAL SURVEY

Open-File Report 01-350



Prepared in cooperation with the  
STATE OF HAWAII DEPARTMENT OF HAWAIIAN HOME LANDS and  
MAUI COUNTY DEPARTMENT OF WATER SUPPLY

# Drilling, Construction, Water-Level, and Water-Quality Information for the Kualapuu Deep Monitor Well 4-0800-01, Molokai, Hawaii

---

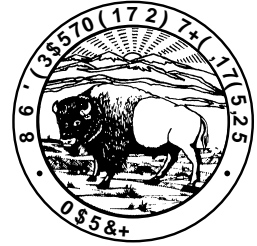
*By* Delwyn S. Oki, U.S. Geological Survey  
Glenn R. Bauer, State of Hawaii Commission on Water Resource Management

U.S. GEOLOGICAL SURVEY  
Open-File Report 01-350

Prepared in cooperation with the  
STATE OF HAWAII DEPARTMENT OF HAWAIIAN HOME LANDS and  
MAUI COUNTY DEPARTMENT OF WATER SUPPLY

Honolulu, Hawaii  
2001

U.S. DEPARTMENT OF THE INTERIOR  
GALE A. NORTON, Secretary



U.S. GEOLOGICAL SURVEY  
Charles G. Groat, Director

The use of firm, trade, and brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

---

For additional information write to:

District Chief  
U.S. Geological Survey  
677 Ala Moana Blvd., Suite 415  
Honolulu, HI 96813

Copies of this report can be purchased  
from:

U.S. Geological Survey  
Branch of Information Services  
Box 25286  
Denver, CO 80225-0286

# CONTENTS

Abstract . . . . .	1
Introduction . . . . .	1
Regional Setting . . . . .	3
Location . . . . .	3
Acknowledgments . . . . .	3
Drilling and Well Construction . . . . .	3
Geologic Log . . . . .	6
Water-Level Information . . . . .	6
Water-Conductivity and Water-Temperature Profiles . . . . .	6
Summary and Conclusions . . . . .	9
References Cited . . . . .	10

## FIGURES

1–2. Maps showing:	
1. Geographic features, island of Molokai, Hawaii, and locations of the Kualapuu area and the Kualapuu deep monitor well (4-0800-01). . . . .	2
2. Generalized surficial geology of Molokai, Hawaii . . . . .	4
3. Drawing showing construction details for the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii . . . . .	7
4. Graph showing water-conductivity and -temperature profiles measured in the Kualapuu deep monitor well (4-0800-01) on April 3 and July 13, 2001, Molokai, Hawaii . . . . .	8

## TABLES

1. Location, elevation, and State number of the Kualapuu deep monitor well, Molokai, Hawaii . . . . .	5
2. Summary of construction of the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii . . . . .	5
3. Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii . . . . .	11
4. Water-level measurements made during the period from February 1 to July 13, 2001, Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii . . . . .	6



# Drilling, Construction, Water-Level, and Water-Quality Information for the Kualapuu Deep Monitor Well 4-0800-01, Molokai, Hawaii

By Delwyn S. Oki, U.S. Geological Survey

Glenn R. Bauer, State of Hawaii Commission on Water Resource Management

## Abstract

A monitor well was completed in January 2001 by the U.S. Geological Survey in the Kualapuu area of central Molokai, Hawaii that allows for monitoring the thicknesses of the freshwater body and the upper part of the underlying freshwater-saltwater transition zone. The well was drilled in cooperation with the State Department of Hawaiian Home Lands and the Maui County Department of Water Supply, and is located near the area that supplies much of the drinking water on Molokai. The well is at a ground-surface elevation of about 982 feet and penetrated a 1,585-foot section of soil and volcanic rock to a depth of 603 feet below sea level. Prior to casing, a cave-in caused the bottom 55 feet of the well to be filled with rocks originating from a zone above. Thus, the final well depth reported by the driller was 1,530 feet.

Measured water levels in the well during the period from February 1 to July 13, 2001 range from 8.68 to 9.05 feet above sea level. The most recent available water-conductivity profile from July 13, 2001 indicates that the lowest salinity water in the well is in the upper zone from the water table to a depth of about 220 feet below sea level. Below this upper zone, water salinity increases with depth. The water-temperature profile from July 13, 2001 indicates that the lowest temperature water (20.2 degrees Celsius) in the well is located in the upper zone from the water table to a depth of about 200

feet below sea level. Water temperature increases to 24.5 degrees Celsius near the bottom of the measured profile, 507 feet below sea level.

## INTRODUCTION

Management of the ground-water resources of the island of Molokai, Hawaii has been hindered by the uncertainty in the vertical distribution of ground-water salinity in the aquifer in the Kualapuu area (fig. 1), where demand for water is high. [For the purposes of this report, the Kualapuu area corresponds to the Kualapuu aquifer system (State of Hawaii, 1990) as defined by the State of Hawaii Commission on Water Resource Management (CWRM)]. In the State of Hawaii, vertical profiles of water salinity are commonly obtained from deep monitor wells. These profiles are used to estimate the thicknesses of the freshwater body and underlying freshwater-saltwater transition zone. Because of the need for information on the thicknesses of the freshwater body and freshwater-saltwater transition zone, the U.S. Geological Survey (USGS), in cooperation with the State of Hawaii Department of Hawaiian Home Lands (DHHL) and the Maui County Department of Water Supply (DWS), drilled a deep monitor well (State well number 4-0800-01) in the Kualapuu area between February 2000 and January 2001. This report documents (1) the well location, (2) drilling and well-construction information from the drillers, (3) geologic descriptions of the rock cuttings brought to the surface during drilling, (4) available water-level information, and (5) available information from water-conductivity and -temperature profiles from the deep monitor well.

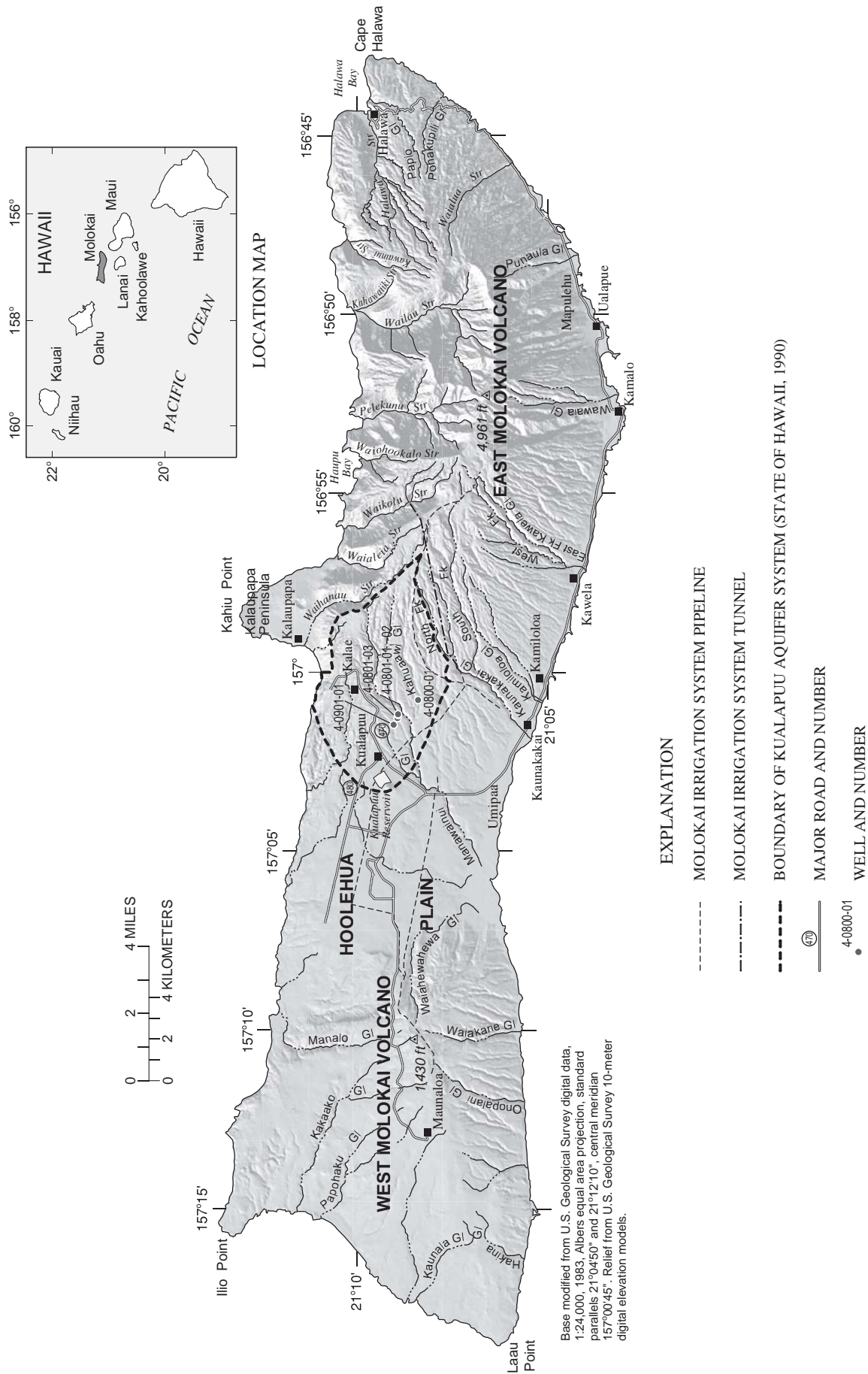


Figure 1. Geographic features, island of Molokai, Hawaii, and locations of the Kualapuu area and the Kualapuu deep monitor well (4-0800-01).

## Regional Setting

The Kualapuu deep monitor well is located on the western flank of the East Molokai Volcano (fig. 2). The surface rocks near the well were mapped as the lower member of the East Molokai Volcanics (Stearns and Macdonald, 1947; Langenheim and Clague, 1987). The lower member of the East Molokai Volcanics consists of shield-stage tholeiitic, olivine-tholeiitic, and picritic-tholeiitic basalts, and postshield-stage alkalic basalt, and forms the bulk of East Molokai Volcano. Estimated ages of rocks of the lower member range from 1.47 million years (McDougall, 1964) to  $2.00 \pm 0.86$  million years (Naughton and others, 1980). In general, the upper member consists of postshield-stage mugearite, with lesser amounts of hawaiite and trachyte, and forms a relatively thin veneer, about 50 to 500 ft thick, over the lower member (Stearns and Macdonald, 1947). Estimated ages of rocks of the upper member are from 1.31 to 1.46 million years (McDougall, 1964).

Numerous vent features, including cinder and spatter cones, exist along the western and southern flanks of the East Molokai Volcano. Many of the vents, including the cinder cone Puu Luahine, do not appear to lie along the trends of the two primary rift zones of the volcano (fig. 2). The summit of Puu Luahine is about 3,000 ft south-southwest of the Kualapuu deep monitor well. The presence of vents in the Kualapuu area may indicate that low permeability intrusive rocks exist near the well.

In the southwestern part of the Kualapuu area, where the Kualapuu deep monitor well was drilled, a freshwater body overlies a brackish-water transition zone, which in turn overlies saltwater. Several production wells (fig. 1) northwest of the Kualapuu deep monitor well develop water from the freshwater part of the system. Measured water levels from these wells generally have ranged from about 8 to 12 ft above sea level (Oki, 2000).

## Location

The Kualapuu deep monitor well is located in the central part of Molokai on land owned by DHHL and currently (2001) leased by the Molokai Homestead Livestock Association for grazing purposes. The well was drilled north of Kahuaawi Gulch at an elevation of

about 982 ft (table 1). The well is about 2.1 mi southeast of the intersection of highways 470 and 480 near the town of Kualapuu. Using the State of Hawaii well-numbering system, CWRM assigned the number 4-0800-01 to the Kualapuu deep monitor well.

## Acknowledgments

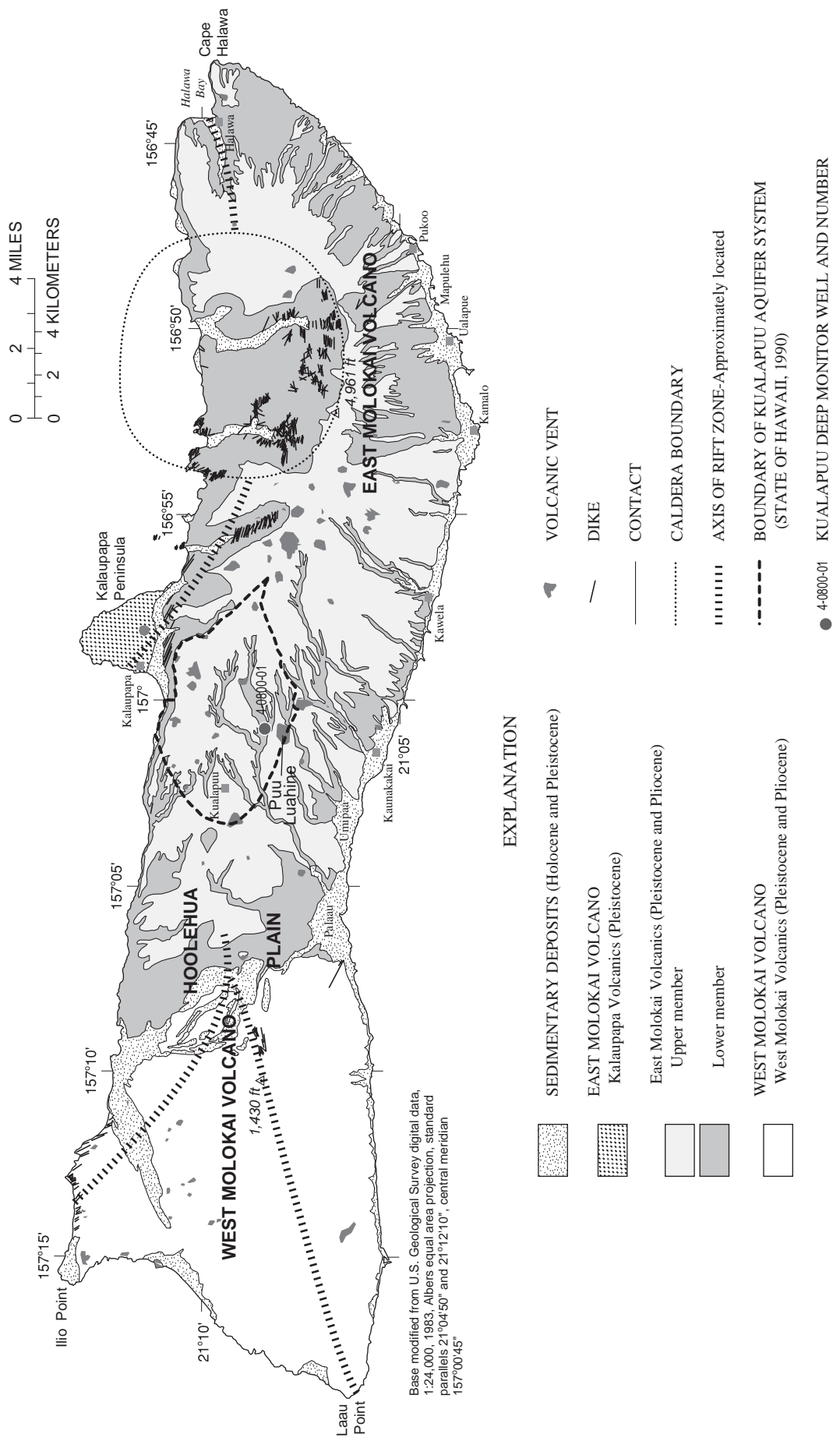
The Kualapuu deep monitor well was funded through a cooperative agreement between DHHL, DWS, and the USGS. The USGS acknowledges DHHL for permission to drill on their land and the Molokai Homestead Livestock Association for allowing access to the drill site. The efforts of Carolyn Darr of DHHL were instrumental in securing permission to drill on DHHL land. George Maioho and Kimo Puailihau of DHHL were extremely helpful in dealing with site selection and logistical problems associated with the drilling operation. The USGS also is grateful to the State Department of Agriculture for providing access to water needed for drilling. The State Department of Land and Natural Resources and the Maui County Department of Public Works assisted in moving the drill rig to and from the site. Kimo Akina of the U.S. Geological Survey provided drilling information. John Ocampo and Elroy Mollena of DHHL provided support for the collection of the water-conductivity and -temperature profiles from the deep monitor well.

## DRILLING AND WELL CONSTRUCTION

The well was drilled by the air-rotary drilling method, in which compressed air and foam were injected down through the hollow drill stem and returned to the surface in the annular space between the drill stem and borehole wall to remove rock cuttings and water from the well. A summary of events and progress related to the well construction is provided in table 2.

The well was drilled to a depth of 700 ft with a 10-5/8-in. tricone bit. The well was then opened to a larger diameter with a 17-1/2-in. bit to a depth of 250 ft prior to setting 250 ft of nominal 12-in. solid (unperforated) steel casing. The remainder of the well, from depths of 700 to 1,585 ft, was drilled with a 9-7/8-in. tricone bit. The well is cased with 1,530 ft of 4-in. steel casing, the bottom 600 ft of which is perforated.





**Figure 2.** Generalized surficial geology of Molokai, Hawaii (from Stearns and Macdonald, 1947; and Langenheim and Clague, 1987).

**Table 1.** Location, elevation, and State number of the Kualapuu deep monitor well, Molokai, Hawaii  
[Elevation datum is mean sea level]

Latitude	21°08'25" (NAD27 datum)
Longitude	157°00'44" (NAD27 datum)
Ground elevation at brass plate in concrete pad	981.90 feet
Measuring-point elevation at top of 4-inch steel casing	982.59 feet
Distance and direction from Kualapuu	2.1 miles southeast
Distance and direction from nearest shoreline	3 miles south
State well number	4-0800-01

**Table 2.** Summary of construction of the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii

Date	Significant events
February 3, 2000	Started drilling with 17-1/2-in. bit to a depth of 8 ft. Set temporary casing, and then began drilling with 10-5/8-in. tricone bit to a depth of 25 ft.
February 4 to March 13, 2000	Drilled from depths of 25 to 505 ft using 10-5/8-in. tricone bit.
March 14, 2000	Injected air to lift rocks that had accumulated at the bottom of the well since previous day from a cave-in. Drilled from depths of 505 to 525 ft using 10-5/8-in. tricone bit.
March 15 to 31, 2000	Drilled from depths of 525 to 700 ft using 10-5/8-in. tricone bit. Difficult to keep bottom of well open because of caving. As much as 80 ft of rocks accumulated at the bottom of the well from the end of one workday to the beginning of the next. Used significant amount of foam to lift rocks off bottom of well.
April 4 to May 29, 2000	Opened well to a larger diameter using 17-1/2-in. bit for 12-in. casing.
May 31, 2000	Set 250 ft of 12-in. solid (unperforated) steel casing.
June 6, 2000	Poured 6 cubic yards of grout in annular space between 17-1/2-in. borehole and 12-in. steel casing.
June 13, 2000	Began drilling with 9-7/8-in. tricone bit. Drilled from depths of 700 to 720 ft.
June 14 to 29, 2000	Drilled from depths of 720 to 845 ft. Difficult to keep bottom of well open because of caving. As much as 100 ft of rocks accumulated at the bottom of the well from the end of one workday to the beginning of the next. Used significant amount of foam to lift rocks off bottom of well.
July 3, 2000	Filled bottom of well with grout up to a depth of 460 ft to stabilize caving zones.
July 5, 2000	Started drilling through the grout at a depth of 460 ft.
July 7, 2000	Drilled through the grout to a depth of about 840 ft.
July 17 to September 19, 2000	Drilled from depths of 840 to 1,305 ft. Difficult to keep bottom of well open because of caving. As much as 110 ft of rocks accumulated at the bottom of the well from the end of one workday to the beginning of the next. Used significant amount of foam to lift rocks off bottom of well.
September 28 to 29, 2000	Hired a drilling company to lower a video camera down the well to inspect borehole conditions.
October 2 to 6, 2000	Cleaned out bottom of well.
October 10, 2000 to January 16, 2001	Drilled from depths of 1,305 to 1,585 ft. Difficult to keep bottom of well open because of caving. As much as 140 ft of rocks accumulated at the bottom of the well from the end of one workday to the beginning of the next. Used significant amount of foam to lift rocks off bottom of well.
January 17 to 19, 2001	Cleaned out bottom of well.
January 22 to 23, 2001	Set 1,530 ft of 4-in. steel casing, bottom 600 ft perforated
January 24, 2001	Poured 3 cubic yards of grout in annular space, between 12-in. and 4-in. casings, to a depth of 110 ft.

Drilling below a depth of about 500 ft was hindered by severe caving conditions. From the end of one workday to the beginning of the next, as much as 140 ft of rock accumulated at the bottom of the well because of caving. Large volumes of foam, as much as 55 gallons per day, were used to help lift the rocks off the bottom of the well during drilling. Although the well was drilled to a depth of 1,585 ft, about 55 ft of rocks had accumulated at the bottom of the well between January 19 and 23, 2001, before the 4-in. steel casing could be set in place on January 23, 2001. As a result, the final depth of the well was reported by the driller to be 1,530 ft.

A concrete pad, about 4 ft wide and 4 ft long, was poured around the well. The elevation of a brass plate set in the southwest corner of the concrete pad is 981.90 ft, and the elevation of the top of the 4-in steel casing is 982.59 ft. (All elevations in this report are referenced to a mean sea level datum.) Construction details of the finished well are shown in figure 3.

## GEOLOGIC LOG

The geologic log (table 3, at end of report) of the Kualapuu deep monitor well was compiled by examination of rock cuttings lifted to the ground surface by the force of the compressed air and foam injected through the hollow drill stem. Although samples were collected every 5 ft, the actual depth from which the samples originated is not well known. Many of the cutting samples contain a mixture of several volcanic-rock morphologies, such as both round vesicles and angular vesicles.

The Kualapuu deep monitor well penetrated a 1,585-ft section of soil and volcanic rock. The uppermost 80 ft of this section consists of soil and highly weathered rock. Below the upper 80 ft of section, rock cuttings consist of volcanic rocks with different texture, pore sizes and shapes, color, and mass, likely representing a sequence of numerous lava flows interbedded with zones of scoria.

## WATER-LEVEL INFORMATION

The initial water level measured after completion of the well was 9.05 ft above mean sea level on February 1, 2001. Available water-level measurements for the Kualapuu deep monitor well during the period from

February 1 to July 13, 2001 range from 8.68 to 9.05 ft above mean sea level (table 4). Between February 1 and July 13, 2001, the measured water level declined by 0.37 ft.

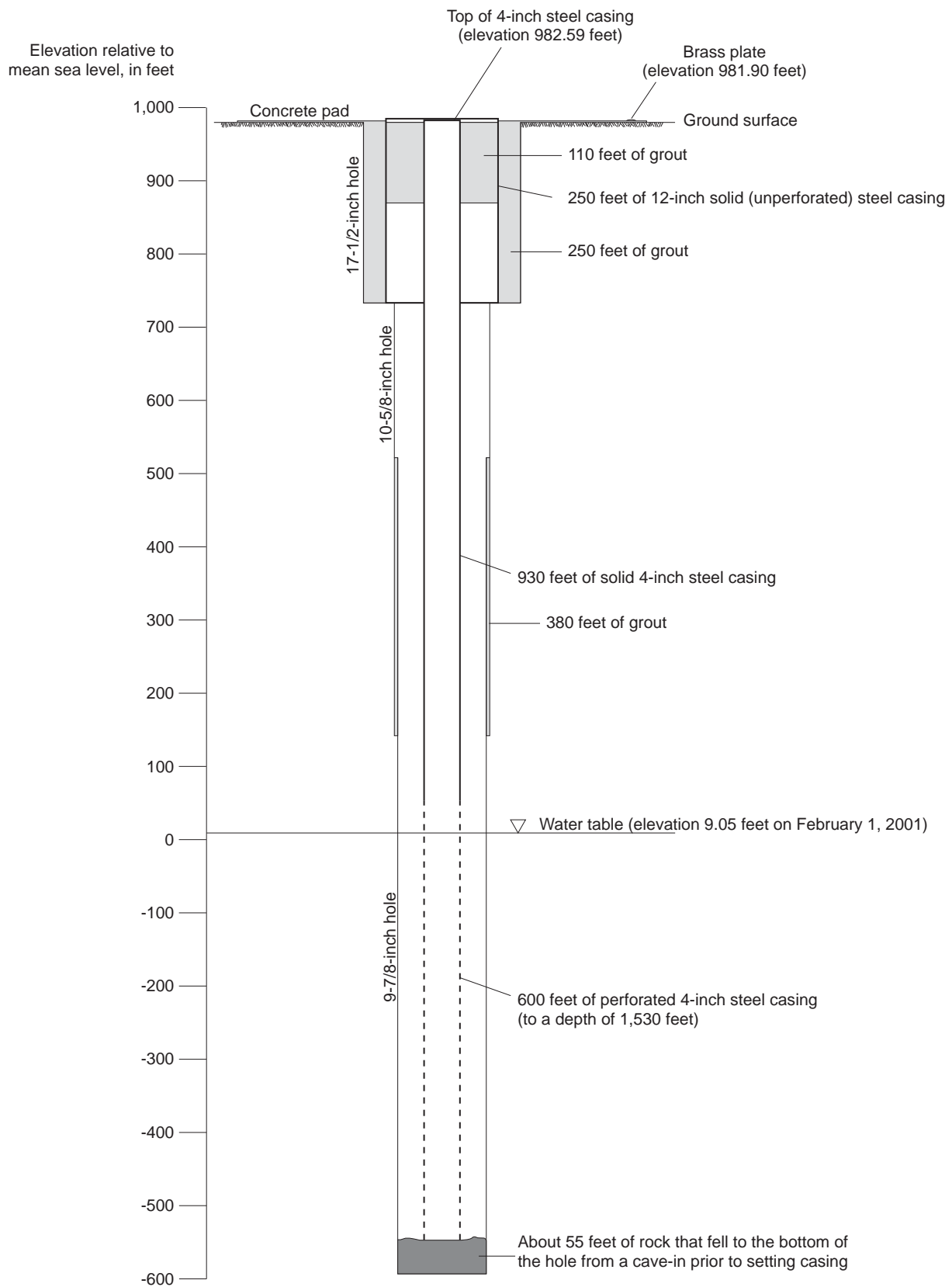
**Table 4.** Water-level measurements made during the period from February 1 to July 13, 2001, Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii

Date	Water level, in feet above mean sea level
February 1, 2001	9.05
April 3, 2001	8.87
April 23, 2001	8.85
July 13, 2001	8.68

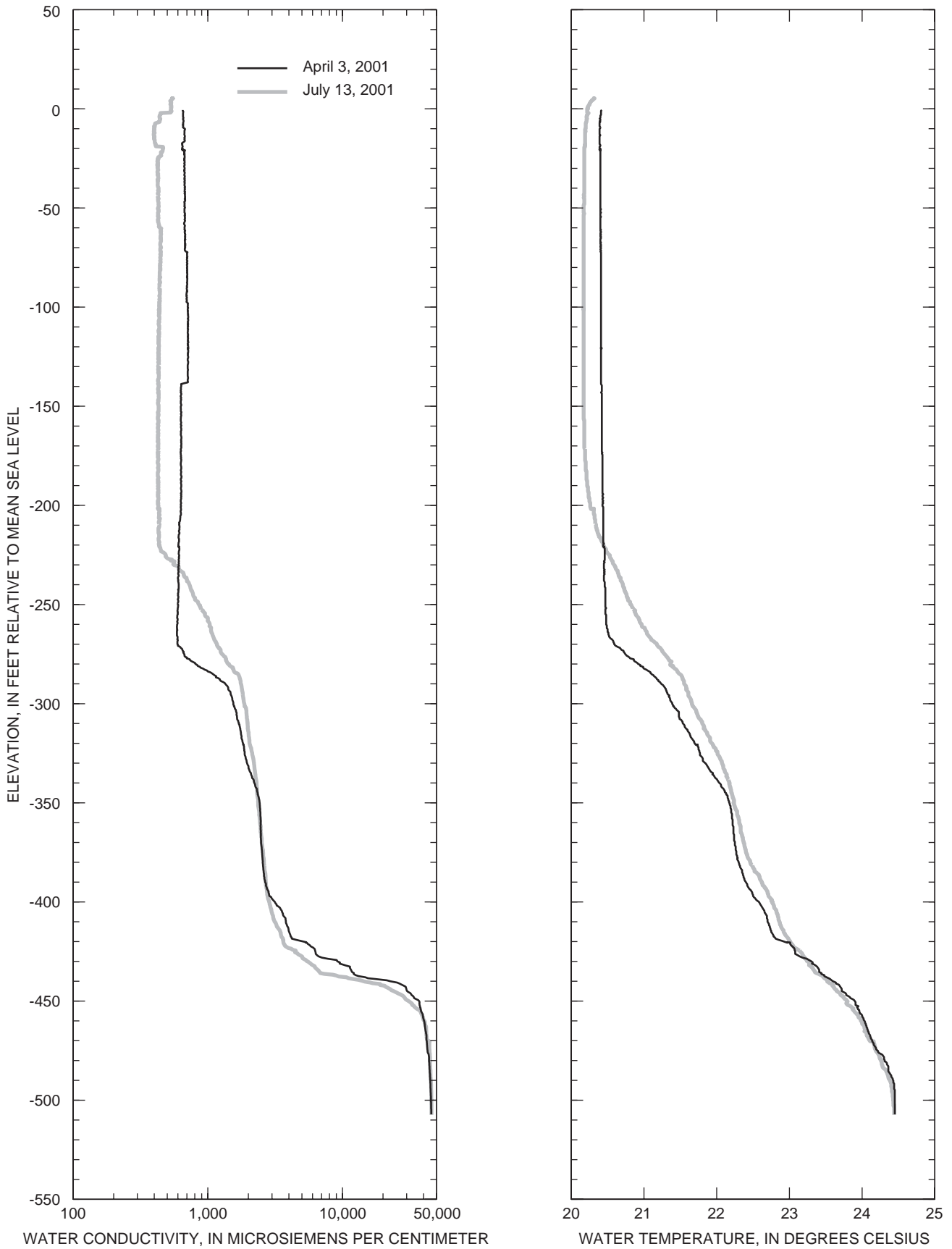
## WATER-CONDUCTIVITY AND WATER-TEMPERATURE PROFILES

An Ocean Sensors, Incorporated Model OS200 CTD tool was first lowered down the well on April 3, 2001 (about 2 months after drilling was completed) to measure conductivity and temperature of water in the well with depth. (CTD is an acronym for conductivity, temperature, and depth.) The CTD tool was lowered down the well a second time on July 13, 2001. On both occasions, the CTD was programmed to measure conductivity, temperature, and pressure at one-second intervals and was lowered at a rate of about 15-20 feet per minute using a stainless steel cable marked at 100-ft intervals. Water conductivity is an indicator of water salinity, with higher conductivity indicating higher salinity. The OS200 CTD measures water conductivity at the prevailing water temperature, and does not adjust the conductivity to a reference temperature (such as 25 °C), which would provide a measure of specific conductance. Measurement depths were computed from the pressure, conductivity, and temperature data. Depths were adjusted using a linear correction equation derived by comparing estimated depths from the pressure, conductivity, and temperature data with known depths (from the marked cable) at which the CTD was held during logging on April 3, 2001. The same correction equation was applied to adjust the estimated depths from the July 13, 2001 profile.

**Conductivity profile, April 3, 2001.**—Conductivity of water in the well was lowest and nearly uniform (about 600 to 700 microsiemens/cm) from the water table down to a depth of about 275 ft below sea level (fig. 4). Below this upper zone, water conductivity



**Figure 3.** Construction details for the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii.



**Figure 4.** Water-conductivity and -temperature profiles measured in the Kualapuu deep monitor well (4-0800-01) on April 3 and July 13, 2001, Molokai, Hawaii. Data available from the USGS Hawaii District log archive.

increased with depth in the well. Water conductivity increased gradually from about 700 microsiemens/cm at a depth of 275 ft below sea level to about 3,000 microsiemens/cm at a depth of 400 ft below sea level. The average change of conductivity with depth in the lower part of the profile (from 400 ft below sea level to 507 ft below sea level, which represents the bottom of the measured profile) was greater than the average change measured higher in the profile (from the water table to 400 ft below sea level). At a depth of about 440 feet below sea level, the conductivity of water in the well was about 25,000 microsiemens/cm, and near the bottom of the measured profile the conductivity was about 46,000 microsiemens/cm.

For comparison, water pumped in 1997 from DHHL wells 1 (4-0801-01) and 2 (4-0801-02) in the Kualapuu area had specific-conductance values of about 300 to 400 microsiemens/cm. The corresponding chloride concentrations of pumped water ranged from about 60 to 120 mg/L (Hill and others, 1998).

**Conductivity profile, July 13, 2001.**—Conductivity of water in the well was lowest and nearly uniform (about 400 to 550 microsiemens/cm) from the water table down to a depth of about 220 ft below sea level (fig. 4). Below this upper zone, conductivity of water increased with depth in the well. Water conductivity increased gradually from about 450 microsiemens/cm at a depth of 220 ft below sea level to about 3,000 microsiemens/cm at a depth of 400 ft below sea level. The average change of conductivity with depth in the lower part of the profile (from 400 ft below sea level to 507 ft below sea level, which represents the bottom of the measured profile) was greater than the average change measured higher in the profile (from the water table to 400 ft below sea level). At a depth of about 445 feet below sea level, the conductivity of water in the well was about 25,000 microsiemens/cm, and near the bottom of the measured profile the conductivity was about 46,000 microsiemens/cm.

**Temperature profile, April 3, 2001.**—The temperature of water in the well was coolest near the water table and warmest near the bottom of the measured profile (fig. 4). From the water table to a depth of about 260 ft below sea level, water temperature was nearly uniform, ranging from 20.4 to 20.5°C. From 260 ft below sea level to the bottom of the measured profile, the water temperature increased from 20.5 to 24.5°C.

**Temperature profile, July 13, 2001.**—The temperature of water in the well was coolest near the water table and warmest near the bottom of the measured profile (fig. 4). From the water table to a depth of about 200 ft below sea level, water temperature was nearly uniform, ranging from 20.2 to 20.3°C. From 200 ft below sea level to the bottom of the measured profile, the water temperature increased from 20.3 to 24.5°C.

**Comparison of measured profiles.**—In general, water-conductivity and -temperature profiles indicate that an upper zone of nearly uniform water quality exists in the well, and this zone contains water with the lowest salinity and temperature relative to water lower in the well. However, between April 3 and July 13, 2001, the thickness of this zone decreased by about 50 to 60 ft. Aspects of the water-conductivity and -temperature profiles measured on April 3, 2001 differ from the water-conductivity and -temperature profiles, respectively, measured on July 13, 2001. A comparison of changes in water conductivity and temperature from April 3 to July 13, 2001 at common depths indicates that (1) cooler, lower-salinity water entered the upper part of the well, from the water table down to a depth of about 220 ft below sea level, (2) warmer water entered the well between depths of 220 to 420 ft below sea level, (3) higher-salinity water entered the well between depths of 230 to 340 ft below sea level, and (4) lower-salinity water entered the well between depths of 400 to 450 ft below sea level.

Continued monitoring of water quality in the well with time will provide the information necessary to evaluate whether the changes in water conductivity and temperature are related to (1) natural replacement of water that was lifted up the well during drilling, (2) vertical flow of water in the well caused by a vertical hydraulic-head gradient in the aquifer, (3) regional effects of time-varying ground-water recharge and withdrawal rates, or (4) other factors.

## SUMMARY AND CONCLUSIONS

During February 2000 to January 2001, a monitor well was drilled in the Kualapuu area of central Molo-kai, Hawaii by the U.S. Geological Survey in cooperation with the State Department of Hawaiian Home Lands and the Maui County Department of Water Supply. The well is located at a ground-surface elevation of about 982 ft, near the area that supplies much of the

drinking water on Molokai, and was designed to provide information necessary to effectively manage the ground-water resources in the area.

Measured water levels from the Kualapuu deep monitor well declined from 9.05 to 8.68 ft above mean sea level from February 1 to July 13, 2001. Water conductivity in the well generally is lowest (less than 700 microsiemens/cm) near the water table and highest (about 46,000 microsiemens/cm) near the bottom of the measured profiles that were collected on April 3 and July 13, 2001. Water temperatures in the well are generally lowest (less than 20.5 °C) near the water table and highest (about 24.5 °C) near the bottom of the measured profiles. Water-conductivity and -temperature profiles indicate that an upper zone of nearly uniform water quality exists in the well, and this zone contains water with the lowest salinity and temperature relative to water lower in the well. However, between April 3 and July 13, 2001, the thickness of this zone decreased by about 50 to 60 ft.

## REFERENCES CITED

- Hill, B.R., Taogoshi, R.I., Kunishige, V.E., and Shibata, W.S., 1998, Water resources data Hawaii, water year 1997: U.S. Geological Survey Water-Data Report HI-97-1, 507 p.
- Langenheim, V.A.M., and Clague, D.A., 1987, The Hawaiian-Emperor volcanic chain, part II, stratigraphic framework of volcanic rocks of the Hawaiian Islands, chap. 1 of Decker, R.W., Wright, T.L., and Stauffer, P.H., eds., *Volcanism in Hawaii*: U.S. Geological Survey Professional Paper 1350, v. 1, p. 55–84.
- McDougall, Ian, 1964, Potassium-argon ages from lavas of the Hawaiian islands: *Geological Society of America Bulletin*, v. 75, no. 2, p. 107–128.
- Naughton, J.J., Macdonald, G.A., and Greenberg, V.A., 1980, Some additional potassium-argon ages of Hawaiian rocks: The Maui Volcanic Complex of Molokai, Maui, Lanai and Kahoolawe: *Journal of Volcanology and Geothermal Research*, v. 7, no. 3/4, p. 339–355.
- Oki, D.S., 2000, Site selection for a deep monitor well, Kualapuu, Molokai, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 99-4291, 50 p.
- State of Hawaii, 1990, Water Resources Protection Plan, volumes I and II, *Hawaii Water Plan*: State of Hawaii, Commission on Water Resource Management, variously paged.
- Stearns, H.T., and Macdonald, G.A., 1947, Geology and ground-water resources of the island of Molokai, Hawaii: *Hawaii Division of Hydrography Bulletin* 11, Territory of Hawaii, 113 p.

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii

[Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
982	to 977	0	to 5	Red lateritic clay and grit
977	to 972	5	to 10	Red lateritic clay and grit, highly weathered rock with small vesicles lined with manganese
972	to 967	10	to 15	Red lateritic clay and grit, highly weathered rock with small vesicles lined with manganese
967	to 962	15	to 20	Red lateritic clay and grit, highly weathered rock with small vesicles lined with manganese
962	to 957	20	to 25	Red lateritic clay and grit, highly weathered rock with small vesicles lined with manganese
957	to 952	25	to 30	Red-brown highly weathered rock
952	to 947	30	to 35	Red-brown highly weathered rock
947	to 942	35	to 40	Red-brown highly weathered rock containing weathered laths of plagioclase
942	to 937	40	to 45	Red-brown highly weathered rock containing weathered laths of plagioclase
937	to 932	45	to 50	Red-brown highly weathered rock containing weathered laths of plagioclase
932	to 927	50	to 55	Brown highly weathered rock more competent than previous samples
927	to 922	55	to 60	Brown highly weathered rock containing small laths of plagioclase
922	to 917	60	to 65	Brown highly weathered rock containing small laths of plagioclase
917	to 912	65	to 70	Highly weathered rock grayer in color
912	to 907	70	to 75	Highly weathered rock grayer in color, small angular vesicles
907	to 902	75	to 80	Highly weathered rock grayer in color, small angular vesicles
902	to 897	80	to 85	Dense gray rock containing sparse phenocrysts of clear plagioclase and pyroxene
897	to 892	85	to 90	Dense gray rock containing sparse phenocrysts of clear plagioclase, pyroxene, and olivine; some cuttings are vesicular with round and angular vesicles
892	to 887	90	to 95	Dense gray rock containing sparse phenocrysts of clear plagioclase, pyroxene, and olivine; some cuttings are vesicular with round and angular vesicles
887	to 882	95	to 100	Dense gray rock containing sparse phenocrysts of clear plagioclase, pyroxene, and olivine; some cuttings are vesicular with round and angular vesicles; manganese lining some of the vesicles
882	to 877	100	to 105	Dense gray rock containing sparse phenocrysts of clear plagioclase, pyroxene, and olivine; some cuttings are vesicular with round and angular vesicles; manganese lining some of the vesicles
877	to 872	105	to 110	Dense gray rock containing sparse phenocrysts of clear plagioclase, pyroxene, and olivine; some cuttings are coated with iron oxide
872	to 867	110	to 115	Dense gray rock containing sparse phenocrysts of clear plagioclase, pyroxene, and olivine; some cuttings are coated with iron oxide
867	to 862	115	to 120	Soft gray-brown rock with clay and sparse olivine phenocrysts; some dense gray rock mixed in
862	to 857	120	to 125	Soft gray-brown rock with clay; some dense gray rock mixed in
857	to 852	125	to 130	Dense gray rock; minor amount of tachylite cuttings mixed in
852	to 847	130	to 135	Mixture of dense gray to dark gray rock containing sparse phenocrysts of olivine < 1.0 mm across
847	to 842	135	to 140	Dense dark gray rock containing sparse phenocrysts of plagioclase and pyroxene (occur in different cuttings)
842	to 837	140	to 145	Dense dark gray rock containing phenocrysts of olivine ~1.0 mm across
837	to 832	145	to 150	Dense dark gray rock containing phenocrysts of olivine ~1.0 mm across; one plagioclase phenocryst ~1.0 mm long
832	to 827	150	to 155	Dense dark gray rock containing phenocrysts of olivine ~1.0 mm across
827	to 822	155	to 160	Mixture of dense gray rock and rock with round vesicles
822	to 817	160	to 165	Dense dark gray rock with small angular vesicles containing sparse pyroxene phenocrysts
817	to 812	165	to 170	Dense gray rock containing sparse phenocrysts of weathered olivine and plagioclase
812	to 807	170	to 175	Dense gray aphyric rock
807	to 802	175	to 180	Dense gray aphyric rock
802	to 797	180	to 185	Mixture of dense dark gray-black rock and slightly vesicular gray rock
797	to 792	185	to 190	Dense dark gray-black rock containing sparse weathered phenocrysts of pyroxene and olivine < 1.0 mm across
792	to 787	190	to 195	Dense dark gray-black rock; some highly weathered rotted red cuttings mixed in
787	to 782	195	to 200	Mixture of dark gray vesicular and nonvesicular rock
782	to 777	200	to 205	Mixture of dark gray vesicular and nonvesicular rock
777	to 772	205	to 210	Dark gray rock with angular vesicles
772	to 767	210	to 215	Dark gray rock with angular vesicles



**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
767	to 762	215	to 220	Dense dark gray aphyric rock
762	to 757	220	to 225	Dense dark gray aphyric rock; sparse phenocrysts of pyroxene
757	to 752	225	to 230	Mixture of gray vesicular and nonvesicular rock; vesicles are sub-angular to angular and 1.0 to 1.5 mm across
752	to 747	230	to 235	Sand-size cuttings; gray with weathered milky white plagioclase phenocrysts
747	to 742	235	to 240	Sand-size cuttings; gray with weathered milky white plagioclase phenocrysts
742	to 737	240	to 245	Dark gray rock slightly vesicular with round to subround vesicles
737	to 732	245	to 250	Dark gray rock slightly vesicular with round to subround vesicles
732	to 727	250	to 255	Dark gray rock slightly vesicular with round to subround vesicles; fewer vesicles
727	to 722	255	to 260	Dark gray rock slightly vesicular with round to subround vesicles; fewer vesicles
722	to 717	260	to 265	Highly weathered clay rock; weathered crystal-lithic material; grains of olivine and abundant plagioclase << 0.5 mm across
717	to 712	265	to 270	Highly weathered clay rock; weathered crystal-lithic material; grains of olivine and abundant plagioclase << 0.5 mm across
712	to 707	270	to 275	Highly weathered clay rock; weathered crystal-lithic material; grains of olivine and abundant plagioclase << 0.5 mm across
707	to 702	275	to 280	Highly weathered clay rock; weathered crystal-lithic material; grains of olivine and abundant plagioclase << 0.5 mm across
702	to 697	280	to 285	Dense dark gray rock
697	to 692	285	to 290	Dense dark gray rock containing microphenocrysts of olivine and weathered plagioclase
692	to 687	290	to 295	Dense dark gray rock containing microphenocrysts of olivine and weathered plagioclase
687	to 682	295	to 300	Weathered light gray massive rock
682	to 677	300	to 305	Dense red-brown rock (sample wet)
677	to 672	305	to 310	Dense red-brown rock; sample contains sparse phenocrysts of olivine ~ 0.5 mm across (sample wet)
672	to 667	310	to 315	Dark gray vesicular rock with angular to subangular vesicles (sample wet)
667	to 662	315	to 320	Brown-gray vesicular rock with angular to subangular vesicles; sparse olivine microphenocrysts
662	to 657	320	to 325	Brown-gray vesicular rock with angular to subangular vesicles; sparse plagioclase and olivine microphenocrysts
657	to 652	325	to 330	Dark gray vesicular rock with angular to subangular vesicles
652	to 647	330	to 335	Mixture of dark gray vesicular and gray nonvesicular rock with iron oxide lining surfaces, minor amount of tachylyte cuttings
647	to 642	335	to 340	Mixture of dark gray vesicular and gray nonvesicular rock with iron oxide lining surfaces, minor amount of tachylyte cuttings and red rock
642	to 637	340	to 345	Dense dark gray rock containing abundant microphenocrysts of olivine and glassy plagioclase
637	to 632	345	to 350	Dense dark gray rock containing abundant microphenocrysts of olivine and glassy plagioclase
632	to 627	350	to 355	Dense dark gray rock containing abundant microphenocrysts of olivine and glassy plagioclase
627	to 622	355	to 360	Dense dark gray rock containing abundant microphenocrysts of olivine, glassy plagioclase, and pyroxene
622	to 617	360	to 365	Dense dark gray rock containing abundant microphenocrysts of olivine, glassy plagioclase, and pyroxene
617	to 612	365	to 370	Dense dark gray rock containing abundant microphenocrysts of olivine, glassy plagioclase, and pyroxene; iron oxide coats surfaces of the rock; one plagioclase lath 1.5 mm long
612	to 607	370	to 375	Gray vesicular rock with angular vesicles
607	to 602	375	to 380	Dense gray rock with small angular vesicles
602	to 597	380	to 385	Dense gray rock with angular vesicles
597	to 592	385	to 390	Dense gray rock with angular vesicles; one weathered plagioclase phenocryst < 1.0 mm long
592	to 587	390	to 395	Dense gray rock with angular vesicles and microphenocrysts of plagioclase << 0.5 mm across
587	to 582	395	to 400	Dense gray rock with angular vesicles and microphenocrysts of plagioclase << 0.5 mm across
582	to 577	400	to 405	Brown slightly vesicular rock containing sparse phenocrysts of plagioclase 1.0 mm long; some cuttings have rounded vesicles
577	to 572	405	to 410	Dense gray aphyric rock
572	to 567	410	to 415	Mixture of dense gray slightly vesicular aphyric rock and vesicular gray rock with round vesicles

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
567	to 562	415	to 420	Mixture of dense gray slightly vesicular aphyric rock and vesicular gray rock with round vesicles
562	to 557	420	to 425	Mixture of dense gray slightly vesicular aphyric rock and vesicular gray rock with round vesicles
557	to 552	425	to 430	Dark gray vesicular rock with angular to subangular vesicles; sparse phenocrysts of plagioclase 1.0-2.0 mm long
552	to 547	430	to 435	Mixture of red scoriaceous rock and dense dark gray vesicular rock with angular vesicles and plagioclase phenocrysts 1.0 mm long
547	to 542	435	to 440	Mixture of red scoriaceous rock and dense dark gray vesicular rock with angular vesicles and plagioclase phenocrysts 1.0 mm long
542	to 537	440	to 445	Dense brown-gray rock with angular vesicles containing plagioclase phenocrysts 1.0-2.0 mm long
537	to 532	445	to 450	Mixture of brown vesicular rock with angular vesicles and dense nonvesicular rock containing sparse phenocrysts of plagioclase
532	to 527	450	to 455	Highly vesicular rock with angular vesicles and sparse plagioclase phenocrysts
527	to 522	455	to 460	Dense dark brown rock with angular vesicles and microphenocrysts of plagioclase
522	to 517	460	to 465	Gray vesicular rock with subangular vesicles
517	to 512	465	to 470	Gray vesicular rock with subangular vesicles
512	to 507	470	to 475	Dense dark gray aphyric rock
507	to 502	475	to 480	Dark gray vesicular rock with angular vesicles; sparse phenocrysts of plagioclase <1.0 mm long
502	to 497	480	to 485	Dark gray vesicular rock with angular vesicles; sparse phenocrysts of plagioclase <1.0 mm long
497	to 492	485	to 490	Dark gray vesicular rock with angular vesicles; sparse phenocrysts of plagioclase and olivine <1.0 mm long
492	to 487	490	to 495	Dark gray vesicular rock with angular vesicles; phenocrysts of plagioclase <1.0 mm long representing about 5 percent of sample
487	to 482	495	to 500	Dark gray vesicular rock with angular vesicles; sparse phenocrysts of plagioclase and olivine
482	to 477	500	to 505	Dark gray vesicular rock with angular vesicles; sparse phenocrysts of plagioclase and olivine
477	to 472	505	to 510	Mixture of brown-gray vesicular and nonvesicular rock; sparse plagioclase phenocrysts <1.0 mm long
472	to 467	510	to 515	Gray-brown vesicular rock with angular vesicles
467	to 462	515	to 520	Gray-brown vesicular rock with angular vesicles; sparse phenocrysts of plagioclase and olivine
462	to 457	520	to 525	Dense gray-brown aphyric rock
457	to 452	525	to 530	Vesicular gray-brown aphyric rock with angular vesicles
452	to 447	530	to 535	Vesicular gray-brown aphyric rock with angular vesicles
447	to 442	535	to 540	Slightly vesicular dark gray rock with small angular vesicles
442	to 437	540	to 545	Slightly vesicular dark gray rock with small angular vesicles
437	to 432	545	to 550	Mixture of dense gray nonvesicular aphyric rock and vesicular gray aphyric rock with angular vesicles
432	to 427	550	to 555	Vesicular gray aphyric rock with angular vesicles
427	to 422	555	to 560	Dense gray rock with angular vesicles; sparse phenocrysts of plagioclase
422	to 417	560	to 565	Mixture of dense gray nonvesicular aphyric rock and vesicular gray aphyric rock with angular vesicles
417	to 412	565	to 570	Dense dark gray rock; sparse phenocrysts of plagioclase
412	to 407	570	to 575	Dense gray nonvesicular rock; sparse phenocrysts of plagioclase
407	to 402	575	to 580	Dense gray vesicular rock with angular vesicles; sparse phenocrysts of plagioclase
402	to 397	580	to 585	Red-brown vesicular aphyric rock (clinker)
397	to 392	585	to 590	Red-brown vesicular aphyric rock (clinker); sparse phenocrysts of olivine and plagioclase up to 3 mm across
392	to 387	590	to 595	Red-gray scoriaceous rock with elongated vesicles; phenocrysts of plagioclase and olivine ~1.0 mm across
387	to 382	595	to 600	Red-gray scoriaceous rock with elongated and angular vesicles; phenocrysts of plagioclase and olivine ~1.0 mm across
382	to 377	600	to 605	Mixture of dense gray vesicular aphyric rock with angular vesicles and gray rock with round vesicles
377	to 372	605	to 610	Dense gray aphyric rock with some angular vesicles

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
372	to 367	610	to 615	Gray vesicular rock with angular vesicles; phenocrysts of plagioclase <1.0 mm across
367	to 362	615	to 620	Gray vesicular rock with angular vesicles
362	to 357	620	to 625	Gray vesicular rock with angular vesicles; microphenocrysts of olivine <0.5 mm across
357	to 352	625	to 630	Gray vesicular rock with angular vesicles; microphenocrysts of olivine and plagioclase <0.5 mm across
352	to 347	630	to 635	Dense nonvesicular dark gray rock
347	to 342	635	to 640	Vesicular gray rock with angular vesicles; phenocrysts of olivine and minor amount of plagioclase
342	to 337	640	to 645	Vesicular gray rock with angular vesicles
337	to 332	645	to 650	Mixture of dense gray nonvesicular aphyric rock and dark gray vesicular aphyric rock with angular vesicles
332	to 327	650	to 655	Mixture of dense gray nonvesicular aphyric rock and dark gray vesicular aphyric rock with angular vesicles
327	to 322	655	to 660	Vesicular gray rock with angular vesicles; phenocrysts of olivine and plagioclase 1-2 mm across
322	to 317	660	to 665	Mixture of dense gray nonvesicular aphyric rock and dark gray vesicular aphyric rock with angular vesicles
317	to 312	665	to 670	Vesicular gray-brown rock with angular vesicles; sparse phenocrysts of plagioclase laths 1.0 mm long
312	to 307	670	to 675	Vesicular gray-brown rock with angular vesicles; sparse phenocrysts of olivine and plagioclase laths 1.0 mm long
307	to 302	675	to 680	Mixture of dark gray nonvesicular aphyric rock and vesicular aphyric rock with angular vesicles
302	to 297	680	to 685	Slightly vesicular gray-brown aphyric rock with small angular vesicles
297	to 292	685	to 690	Gray vesicular rock with angular vesicles; phenocrysts of plagioclase 1-2.0 mm long
292	to 287	690	to 695	Dark gray vesicular aphyric rock with angular vesicles
287	to 282	695	to 700	Mixture of dark gray nonvesicular aphyric rock and vesicular aphyric rock with angular vesicles
282	to 277	700	to 705	Mixture of dark gray nonvesicular aphyric rock and vesicular aphyric rock with angular vesicles
277	to 272	705	to 710	Mixture of dark gray nonvesicular aphyric rock and vesicular aphyric rock with angular vesicles
272	to 267	710	to 715	Slightly vesicular gray-brown aphyric rock with small angular vesicles; cuttings coated with microphenocrysts of plagioclase, olivine, and possibly pyroxene
267	to 262	715	to 720	Slightly vesicular gray-brown aphyric rock with small angular vesicles; cuttings coated with microphenocrysts of plagioclase, olivine, and possibly pyroxene
262	to 257	720	to 725	Slightly vesicular gray-brown aphyric rock with small angular vesicles; cuttings coated with microphenocrysts of plagioclase, olivine, and possibly pyroxene; clay present with manganese staining
257	to 252	725	to 730	Slightly vesicular gray-brown aphyric rock with small angular vesicles; cuttings coated with microphenocrysts of plagioclase, olivine, and possibly pyroxene; clay present with manganese staining
252	to 247	730	to 735	Slightly vesicular gray-brown aphyric rock with small angular vesicles; cuttings coated with microphenocrysts of plagioclase, olivine, and possibly pyroxene; clay present with manganese staining
247	to 242	735	to 740	Slightly vesicular gray-brown aphyric rock with small angular vesicles; cuttings coated with microphenocrysts of plagioclase, olivine, and possibly pyroxene; clay present with manganese staining
242	to 237	740	to 745	Dense nonvesicular reddish brown rock; sparse olivine phenocrysts
237	to 232	745	to 750	Dense vesicular reddish brown rock with angular vesicles; sparse olivine phenocrysts
232	to 227	750	to 755	Dense vesicular reddish-brown rock with angular vesicles; sparse olivine phenocrysts
227	to 222	755	to 760	Dark gray sand-size cuttings
222	to 217	760	to 765	Dense dark gray rock; phenocrysts of olivine ~1.0 mm across
217	to 212	765	to 770	Dense dark gray aphyric rock
212	to 207	770	to 775	Dense dark gray aphyric rock
207	to 202	775	to 780	Dense dark gray rock; sparse phenocrysts of plagioclase
202	to 197	780	to 785	Dense slightly weathered dark gray aphyric rock
197	to 192	785	to 790	Slightly weathered dense dark gray aphyric rock
192	to 187	790	to 795	Slightly weathered dense dark gray aphyric rock

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
187	to 182	795	to 800	Red-brown weathered rock with angular vesicles
182	to 177	800	to 805	Mixture of dark gray nonvesicular aphyric rock and vesicular aphyric rock with angular vesicles and round vesicles
177	to 172	805	to 810	Slightly weathered gray rock; sparse phenocrysts of olivine and plagioclase
172	to 167	810	to 815	Slightly weathered gray rock; sparse phenocrysts of olivine and plagioclase
167	to 162	815	to 820	Slightly weathered gray rock; sparse phenocrysts of olivine and plagioclase
162	to 157	820	to 825	Mixture of weathered brown vesicular rock with angular vesicles, nonvesicular gray-brown rock, and dense aphyric rock
157	to 152	825	to 830	Mixture of dense brown aphyric rock with angular vesicles and vesicular gray aphyric rock with round vesicles
152	to 147	830	to 835	Mixture of dense brown aphyric rock with angular vesicles and vesicular gray aphyric rock with round vesicles
147	to 142	835	to 840	Gray vesicular aphyric rock with round vesicles
142	to 137	840	to 845	Gray vesicular aphyric rock with round vesicles
137	to 132	845	to 850	Gray vesicular aphyric rock with round vesicles; sparse dense aphyric rock
132	to 127	850	to 855	Brown scoriaceous rock with round vesicles
127	to 122	855	to 860	Brown scoriaceous rock with round vesicles
122	to 117	860	to 865	Gray-brown vesicular aphyric rock with round vesicles
117	to 112	865	to 870	Mixture of gray-brown rock with angular vesicles and dense aphyric rock
112	to 107	870	to 875	Mixture of gray-reddish brown rock with angular vesicles and dense aphyric rock
107	to 102	875	to 880	Mixture of gray-reddish brown rock with angular vesicles and dense aphyric rock
102	to 97	880	to 885	Mixture of brown scoriaceous rock with round vesicles and dense dark gray rock with angular vesicles
97	to 92	885	to 890	Mixture of brown scoriaceous rock with round vesicles and dense dark gray rock with angular vesicles
92	to 87	890	to 895	Dense dark gray aphyric rock with round vesicles
87	to 82	895	to 900	Weathered gray-brown rock with sub-angular vesicles
82	to 77	900	to 905	Slightly weathered gray-brown rock with sub-angular vesicles
77	to 72	905	to 910	Slightly weathered gray-brown rock with sub-angular vesicles
72	to 67	910	to 915	Slightly weathered gray-brown rock with sub-angular vesicles
67	to 62	915	to 920	Slightly weathered gray-brown rock with sub-angular vesicles
62	to 57	920	to 925	Mixture of gray-brown rock with round vesicles and dense dark gray aphyric rock with angular vesicles
57	to 52	925	to 930	Mixture of gray-brown rock with round vesicles and sparse plagioclase phenocrysts and dense dark gray aphyric rock with angular vesicles
52	to 47	930	to 935	Mixture of gray-brown rock with round vesicles and sparse plagioclase phenocrysts and dense dark gray aphyric rock with angular vesicles
47	to 42	935	to 940	Weathered gray-brown rock with round vesicles
42	to 37	940	to 945	Weathered gray-brown rock with sub-angular vesicles containing sparse plagioclase phenocrysts < 1.0 mm across
37	to 32	945	to 950	Weathered gray-brown rock with sub-angular vesicles
32	to 27	950	to 955	Mixture of gray aphyric rock with round vesicles and dense aphyric gray rock with angular vesicles
27	to 22	955	to 960	Weathered brown aphyric rock with round vesicles
22	to 17	960	to 965	Weathered gray-brown aphyric rock with round vesicles
17	to 12	965	to 970	Weathered gray-brown aphyric scoriaceous rock with round vesicles
12	to 7	970	to 975	Weathered gray-brown aphyric scoriaceous rock with round vesicles
7	to 2	975	to 980	Weathered brown aphyric rock with round vesicles
2	to -3	980	to 985	Mixture of gray aphyric rock with round vesicles and dense aphyric gray rock with angular vesicles
-3	to -8	985	to 990	Dark brown scoriaceous aphyric rock with round vesicles
-8	to -13	990	to 995	Dark reddish brown scoriaceous aphyric rock with round vesicles
-13	to -18	995	to 1,000	Dark gray aphyric rock with round vesicles

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
-18	to -23	1,000	to 1,005	Dark gray aphyric rock with round vesicles
-23	to -28	1,005	to 1,010	Gray aphyric rock with round vesicles
-28	to -33	1,010	to 1,015	Mixture of gray aphyric rock with round vesicles and dense aphyric gray rock with angular vesicles
-33	to -38	1,015	to 1,020	Mixture of gray aphyric rock with round vesicles and dense aphyric gray rock with angular vesicles
-38	to -43	1,020	to 1,025	Brown scoriaceous aphyric rock with round vesicles
-43	to -48	1,025	to 1,030	Mixture of red, gray, and brown rock with sub-angular vesicles containing sparse plagioclase, olivine, and possibly pyroxene phenocrysts and dense gray aphyric rock
-48	to -53	1,030	to 1,035	Mixture of red, gray, and brown rock with sub-angular vesicles containing sparse plagioclase microphenocrysts and dense gray aphyric rock
-53	to -58	1,035	to 1,040	Mixture of red, gray, and brown rock with sub-angular vesicles containing sparse plagioclase microphenocrysts and dense gray rock containing sparse olivine phenocrysts
-58	to -63	1,040	to 1,045	Mixture of red, gray, and brown rock with sub-angular to angular vesicles containing sparse plagioclase microphenocrysts and dense gray rock containing sparse olivine phenocrysts
-63	to -68	1,045	to 1,050	Gray to dark gray rock with angular vesicles containing sparse olivine and plagioclase phenocrysts < 1.0 mm across
-68	to -73	1,050	to 1,055	Mixture of dark gray aphyric rock with round vesicles and dense gray aphyric rock
-73	to -78	1,055	to 1,060	Gray scoriaceous rock with many round vesicles containing sparse olivine phenocrysts
-78	to -83	1,060	to 1,065	Mixture of dark gray rock with round vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-83	to -88	1,065	to 1,070	Mixture of dark gray and brown rock with round vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-88	to -93	1,070	to 1,075	Mixture of dark gray and brown rock with sub-angular vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-93	to -98	1,075	to 1,080	Mixture of dark gray and brown rock with sub-angular vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-98	to -103	1,080	to 1,085	Mixture of dark gray and brown rock with sub-angular vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-103	to -108	1,085	to 1,090	Mixture of dark gray and brown rock with sub-angular vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-108	to -113	1,090	to 1,095	Mixture of dark gray and brown and weathered rock with sub-angular vesicles containing sparse plagioclase phenocrysts and dense gray rock with sparse plagioclase phenocrysts
-113	to -118	1,095	to 1,100	Mixture of dark gray-brown scoriaceous rock with round vesicles containing sparse plagioclase phenocrysts and dense gray aphyric rock
-118	to -123	1,100	to 1,105	Mixture of dark gray-brown scoriaceous rock with round vesicles containing sparse plagioclase phenocrysts and dense gray aphyric rock
-123	to -128	1,105	to 1,110	Gray rock with angular vesicles containing sparse plagioclase phenocrysts
-128	to -133	1,110	to 1,115	Gray rock with angular vesicles containing sparse plagioclase phenocrysts
-133	to -138	1,115	to 1,120	Mixture of red-brown and gray scoriaceous rock with round vesicles and containing plagioclase and olivine phenocrysts and dense slightly weathered aphyric rock
-138	to -143	1,120	to 1,125	No sample collected
-143	to -148	1,125	to 1,130	Mixture of dark gray scoriaceous rock with round vesicles and gray rock with angular vesicles containing plagioclase phenocrysts
-148	to -153	1,130	to 1,135	Mixture of dark gray scoriaceous rock with round vesicles containing phenocrysts of olivine and plagioclase and gray rock with angular vesicles
-153	to -158	1,135	to 1,140	Mixture of dark gray scoriaceous rock with round vesicles and gray rock with angular vesicles containing plagioclase phenocrysts
-158	to -163	1,140	to 1,145	Slightly weathered light gray rock with angular vesicles
-163	to -168	1,145	to 1,150	Slightly weathered light gray rock with angular vesicles
-168	to -173	1,150	to 1,155	Mixture of dense gray and vesicular rock with angular vesicles containing sparse plagioclase laths <1.0 mm long
-173	to -178	1,155	to 1,160	Mixture of dense gray and vesicular rock with angular vesicles containing sparse plagioclase laths <1.0 mm long
-178	to -183	1,160	to 1,165	Mixture of aphyric dense gray and vesicular rock with angular vesicles

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
-183	to -188	1,165	to 1,170	Mixture of dense gray and vesicular rock with angular vesicles containing sparse microphenocrysts of plagioclase and olivine
-188	to -193	1,170	to 1,175	Dense gray aphyric rock with round to sub-angular vesicles
-193	to -198	1,175	to 1,180	Dense gray aphyric rock with round to sub-angular vesicles
-198	to -203	1,180	to 1,185	Dense gray aphyric rock with round to sub-angular vesicles containing sparse plagioclase phenocrysts
-203	to -208	1,185	to 1,190	Mixture of red-brown clinkery rock with small angular vesicles and containing plagioclase and olivine phenocrysts and dense gray aphyric rock
-208	to -213	1,190	to 1,195	Mixture of red-brown clinkery rock with small angular vesicles and containing plagioclase and olivine phenocrysts and dense gray rock containing plagioclase phenocrysts
-213	to -218	1,195	to 1,200	Gray rock with angular vesicles containing microphenocrysts of plagioclase and olivine
-218	to -223	1,200	to 1,205	Mixture of brown to dark gray rock with round vesicles containing microlaths of plagioclase and dense aphyric gray rock
-223	to -228	1,205	to 1,210	Brown-gray rock with round vesicles containing microphenocrysts of olivine
-228	to -233	1,210	to 1,215	Brown-gray rock with round vesicles containing microphenocrysts of olivine
-233	to -238	1,215	to 1,220	Dark gray rock with angular vesicles containing sparse olivine and plagioclase phenocrysts
-238	to -243	1,220	to 1,225	Dark gray rock with angular vesicles containing sparse olivine and plagioclase phenocrysts
-243	to -248	1,225	to 1,230	Mixture of gray-brown rock with angular vesicles and dense rock containing sparse plagioclase phenocrysts
-248	to -253	1,230	to 1,235	Mixture of gray-brown rock with angular vesicles and dense rock containing sparse plagioclase microphenocrysts
-253	to -258	1,235	to 1,240	Mixture of gray-brown rock with angular vesicles and dense rock containing sparse microphenocrysts of plagioclase and olivine
-258	to -263	1,240	to 1,245	Mixture of gray-brown rock with angular vesicles and dense rock containing sparse microphenocrysts of plagioclase and olivine
-263	to -268	1,245	to 1,250	Mixture of gray-brown rock with angular vesicles and dense aphyric rock
-268	to -273	1,250	to 1,255	Mixture of gray-brown rock with angular vesicles and dense rock with sparse phenocrysts, possibly pyroxene
-273	to -278	1,255	to 1,260	Mixture of gray-brown rock with angular vesicles and dense rock with sparse phenocrysts of plagioclase and possibly pyroxene
-278	to -283	1,260	to 1,265	Dark gray aphyric rock with angular vesicles
-283	to -288	1,265	to 1,270	Dark gray rock with angular vesicles containing sparse microphenocrysts of olivine, plagioclase, and pyroxene
-288	to -293	1,270	to 1,275	Mixture of gray rock with angular vesicles containing olivine phenocrysts and dense gray aphyric rock
-293	to -298	1,275	to 1,280	Mixture of scoriaceous glassy rock with round vesicles and dense gray rock with angular vesicles
-298	to -303	1,280	to 1,285	Mixture of scoriaceous glassy rock with round to sub-angular vesicles and dense gray rock with angular vesicles
-303	to -308	1,285	to 1,290	Mixture of scoriaceous glassy rock with round to sub-angular vesicles and dense gray rock with angular vesicles
-308	to -313	1,290	to 1,295	Mixture of scoriaceous glassy rock with round to sub-angular vesicles and dense gray rock with angular vesicles containing sparse olivine and plagioclase phenocrysts <1.0 mm across
-313	to -318	1,295	to 1,300	Mixture of scoriaceous glassy rock with round to sub-angular vesicles and dense gray rock with angular vesicles containing sparse plagioclase phenocrysts <1.0 mm across
-318	to -323	1,300	to 1,305	Mixture of dark gray-brown rock with angular vesicles and dense gray rock; some vesicles contain white clay
-323	to -328	1,305	to 1,310	Mixture of dark gray-brown rock with angular vesicles and dense gray rock containing sparse olivine phenocrysts
-328	to -333	1,310	to 1,315	Mixture of dark gray-brown rock with angular vesicles and dense gray rock containing sparse olivine and plagioclase phenocrysts
-333	to -338	1,315	to 1,320	Dark gray to red-brown rock with angular vesicles containing microphenocrysts of olivine and plagioclase
-338	to -343	1,320	to 1,325	Dark gray to red-brown rock with angular vesicles containing microphenocrysts of olivine and plagioclase
-343	to -348	1,325	to 1,330	Dark gray to red-brown rock with angular vesicles

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
-348	to -353	1,330	to 1,335	Mixture of dense gray rock with round vesicles and dense gray rock containing microphenocrysts of plagioclase and olivine
-353	to -358	1,335	to 1,340	Mixture of dense gray rock with round vesicles and dense gray rock containing microphenocrysts of plagioclase and olivine
-358	to -363	1,340	to 1,345	Mixture of dark gray rock with angular vesicles and dense gray rock containing sparse olivine phenocrysts
-363	to -368	1,345	to 1,350	Mixture of dark gray rock with angular vesicles and dense gray rock containing sparse olivine phenocrysts; a large cutting contains a large plagioclase glomerocryst 2-3 mm across
-368	to -373	1,350	to 1,355	Mixture of dark gray rock with angular vesicles and dense gray rock containing sparse olivine and plagioclase phenocrysts
-373	to -378	1,355	to 1,360	Mixture of dark gray rock with angular vesicles and dense gray rock containing sparse olivine and plagioclase phenocrysts
-378	to -383	1,360	to 1,365	Slightly vesicular to dense gray rock with angular vesicles containing sparse olivine phenocrysts
-383	to -388	1,365	to 1,370	Dark gray rock with angular vesicles containing sparse olivine phenocrysts
-388	to -393	1,370	to 1,375	Dark gray slightly vesicular rock with angular vesicles containing sparse olivine phenocrysts
-393	to -398	1,375	to 1,380	Dark gray rock with angular vesicles containing sparse olivine phenocrysts
-398	to -403	1,380	to 1,385	Dark gray rock with angular vesicles
-403	to -408	1,385	to 1,390	Slightly vesicular to gray-brown rock with angular vesicles containing sparse plagioclase phenocrysts
-408	to -413	1,390	to 1,395	Slightly vesicular to gray-brown rock with angular vesicles
-413	to -418	1,395	to 1,400	Slightly vesicular to gray-brown rock with angular vesicles containing sparse olivine phenocrysts
-418	to -423	1,400	to 1,405	Slightly vesicular to gray-brown rock with angular vesicles containing sparse olivine and plagioclase phenocrysts
-423	to -428	1,405	to 1,410	Mixture of brown rock with angular vesicles and slightly vesicular rock with angular vesicles containing olivine phenocrysts representing about 5 percent of sample
-428	to -433	1,410	to 1,415	Mixture of brown rock with angular vesicles and slightly vesicular rock with angular vesicles containing olivine phenocrysts
-433	to -438	1,415	to 1,420	Mixture of brown rock with angular vesicles and slightly vesicular rock with angular vesicles
-438	to -443	1,420	to 1,425	Mixture of brown rock with angular vesicles and slightly vesicular rock with angular vesicles; some olivine present
-443	to -448	1,425	to 1,430	Mixture of brown rock with angular vesicles and slightly vesicular rock with angular vesicles; some olivine present
-448	to -453	1,430	to 1,435	Mixture of aphyric dark gray rock with round vesicles and dense dark gray aphyric rock with sparse angular vesicles
-453	to -458	1,435	to 1,440	Mixture of aphyric dark gray rock with round vesicles and dense dark gray aphyric rock with sparse angular vesicles
-458	to -463	1,440	to 1,445	Mixture of aphyric dark gray rock with numerous round vesicles and dense dark gray aphyric rock with sparse angular vesicles
-463	to -468	1,445	to 1,450	Mixture of glassy dark rock with angular vesicles and dense slightly vesicular aphyric rock with angular vesicles
-468	to -473	1,450	to 1,455	Dark gray rock with angular vesicles
-473	to -478	1,455	to 1,460	Dark gray rock with angular vesicles containing sparse olivine and plagioclase phenocrysts
-478	to -483	1,460	to 1,465	Dark gray rock with angular vesicles
-483	to -488	1,465	to 1,470	Mixture of dark gray vesicular aphyric rock with round vesicles and dark gray vesicular and dense aphyric rock with angular vesicles
-488	to -493	1,470	to 1,475	Dark gray aphyric rock with angular vesicles
-493	to -498	1,475	to 1,480	Dark gray aphyric rock with angular vesicles
-498	to -503	1,480	to 1,485	Dark gray aphyric rock with angular vesicles containing sparse plagioclase phenocrysts
-503	to -508	1,485	to 1,490	Mixture of red porphyritic rock with angular vesicles containing plagioclase laths up to 2.0 mm long and dense and vesicular rock with angular vesicles containing sparse plagioclase phenocrysts
-508	to -513	1,490	to 1,495	Vesicular and non-vesicular gray aphyric rock with angular vesicles
-513	to -518	1,495	to 1,500	Mixture of scoriaceous gray rock with round vesicles and dark gray aphyric rock with angular vesicles

**Table 3.** Lithologic descriptions of rock cuttings from the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii--Continued  
 [Datum is mean sea level; depth measured from 982 feet above sea level; mm, millimeter; <, less than; <<, much less than; ~, about; samples were collected every 5 feet, but the actual depth from which the samples originated is not well known; many of the samples contain a mixture of several volcanic-rock morphologies]

Elevation (feet)		Depth (feet)		Sample description
-518	to -523	1,500	to 1,505	Mixture of vesicular and non-vesicular dark gray rock with angular vesicles containing sparse olivine phenocrysts
-523	to -528	1,505	to 1,510	Mixture of vesicular and non-vesicular dark gray rock with angular vesicles containing sparse olivine and possibly pyroxene phenocrysts
-528	to -533	1,510	to 1,515	Mixture of dense gray rock with few round vesicles and vesicular to non-vesicular dark gray rock with angular vesicles containing sparse plagioclase and olivine phenocrysts
-533	to -538	1,515	to 1,520	Mixture of brown rock with angular vesicles and dense gray rock with angular vesicles containing a minor amount of olivine and plagioclase phenocrysts
-538	to -543	1,520	to 1,525	Mixture of brown rock with angular vesicles and dense gray rock with angular vesicles containing minor amount of olivine and plagioclase phenocrysts
-543	to -548	1,525	to 1,530	Mixture of dark gray glassy rock with round vesicles and dark gray rock with angular vesicles containing sparse microphenocrysts of olivine
-548	to -553	1,530	to 1,535	Vesicular and non-vesicular gray aphyric rock with angular vesicles containing olivine phenocrysts
-553	to -558	1,535	to 1,540	Vesicular and non-vesicular gray aphyric rock with angular vesicles containing olivine phenocrysts
-558	to -563	1,540	to 1,545	Vesicular and non-vesicular gray aphyric rock with angular vesicles containing olivine phenocrysts and sparse pyroxene phenocrysts
-563	to -568	1,545	to 1,550	Dense dark gray rock with round vesicles containing sparse olivine phenocrysts
-568	to -573	1,550	to 1,555	Mixture of dark gray rock with few round vesicles and dense gray rock containing sparse olivine and plagioclase phenocrysts
-573	to -578	1,555	to 1,560	Dark gray rock with angular vesicles containing sparse phenocrysts of olivine
-578	to -583	1,560	to 1,565	Dark gray rock with angular vesicles containing sparse phenocrysts of olivine and plagioclase
-583	to -588	1,565	to 1,570	Mixture of vesicular and non-vesicular dark gray rock with angular vesicles containing sparse olivine phenocrysts and black glass
-588	to -603	1,570	to 1,585	No cuttings collected