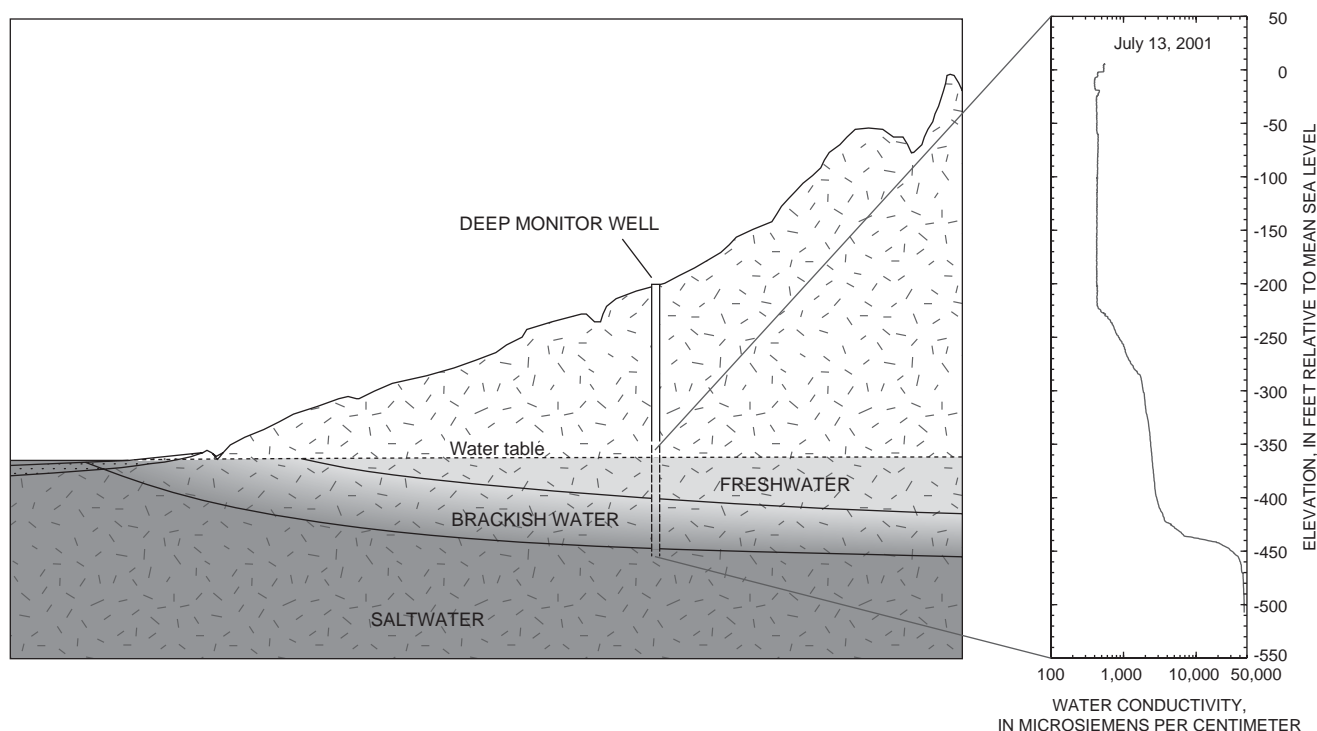


Drilling, Construction, Water-Level, and Water-Quality Information for the Kualapuu Deep Monitor Well 4-0800-01, Molokai, Hawaii

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

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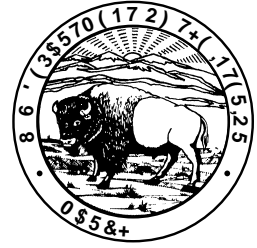
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Honolulu, Hawaii
2001

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



U.S. GEOLOGICAL SURVEY
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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
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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.

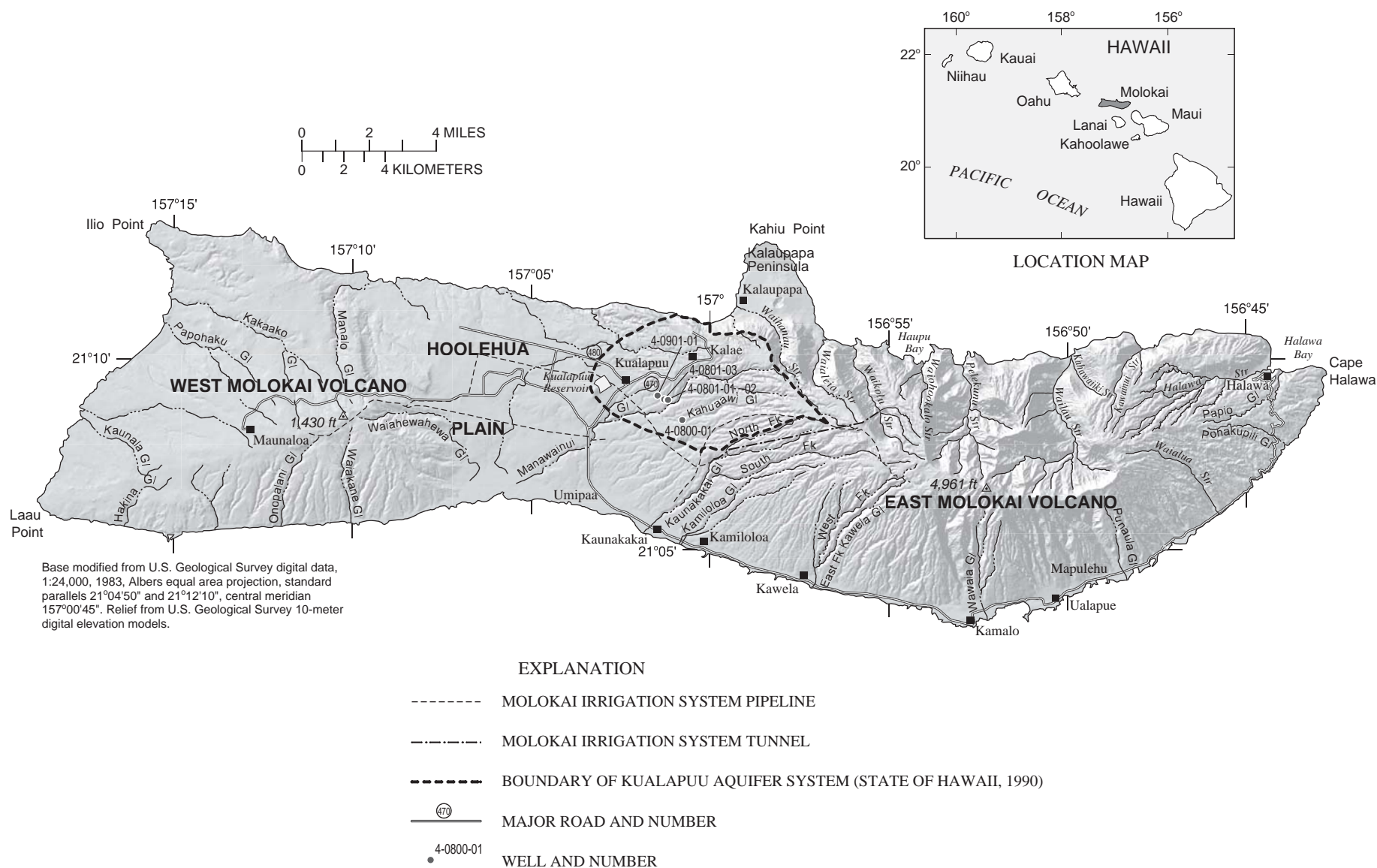


Figure 1. Geographic features, island of Molokai, Hawaii, and locations of the Kualapuu area and the Kualapuu deep monitor well (4-0800-01).

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 ± 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.

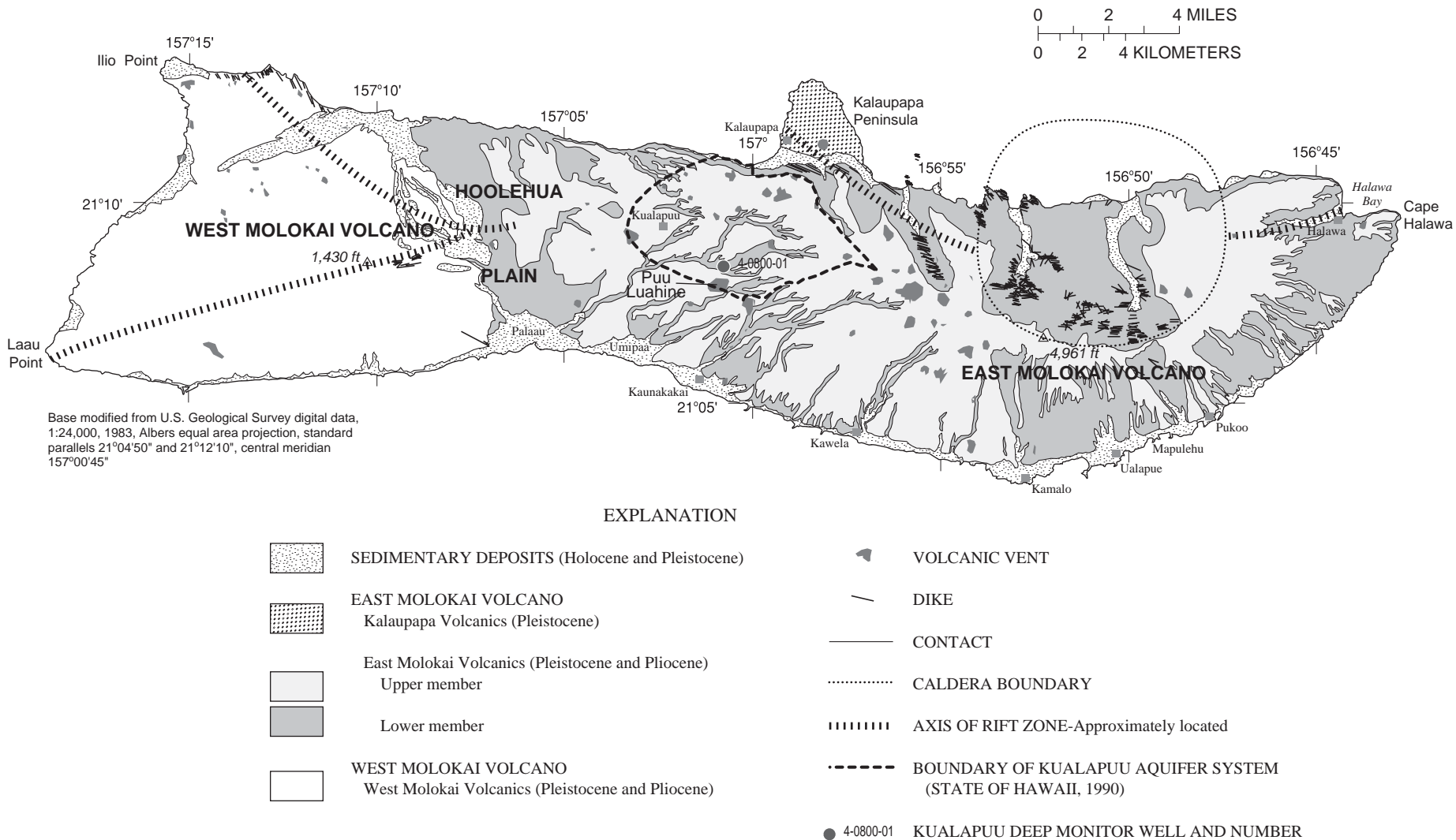


Figure 2. Generalized surficial geology of Molokai, Hawaii (from Stearns and Macdonald, 1947; and Langenheim and Clague, 1987).

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

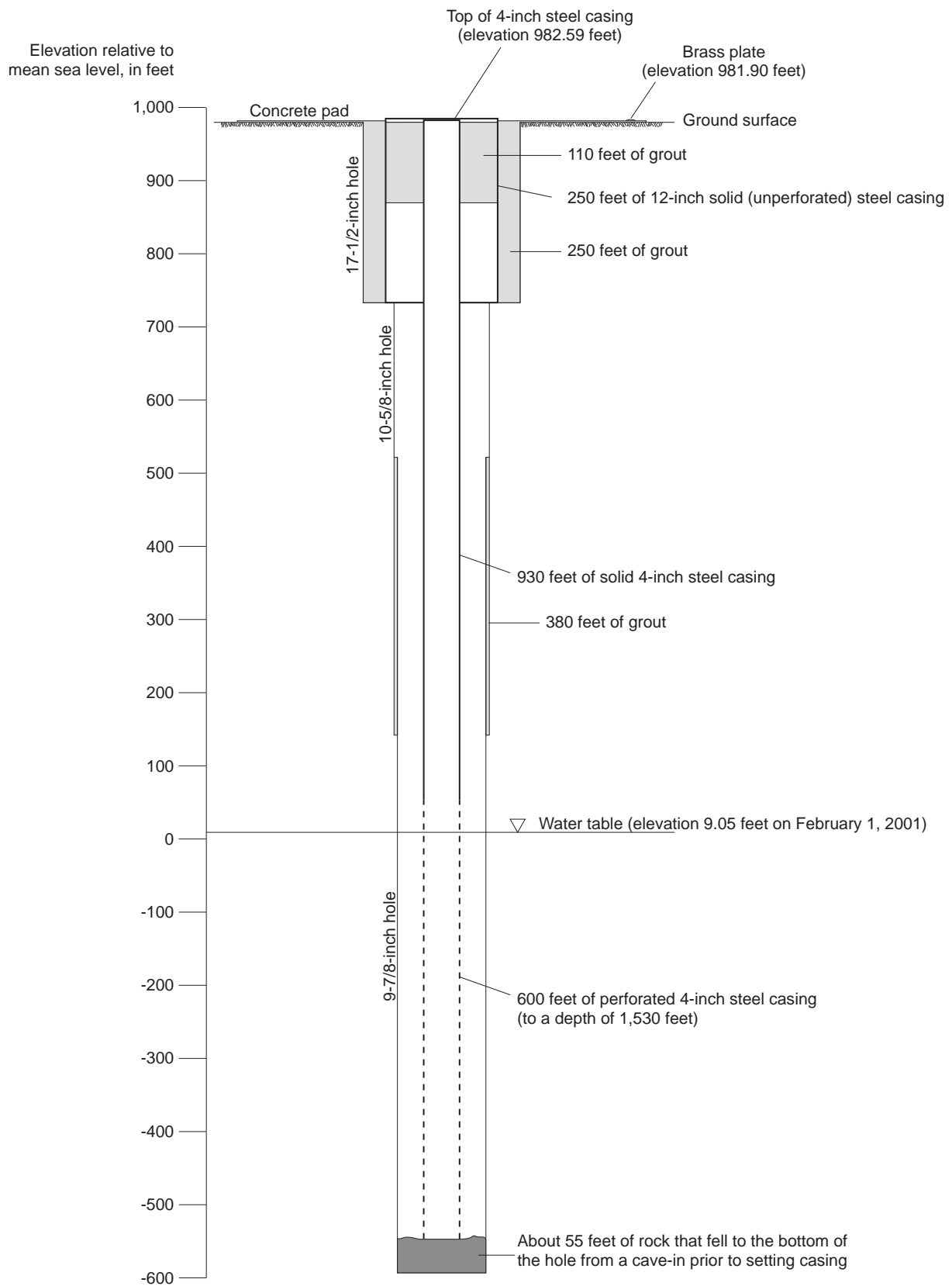


Figure 3. Construction details for the Kualapuu deep monitor well (4-0800-01), Molokai, Hawaii.

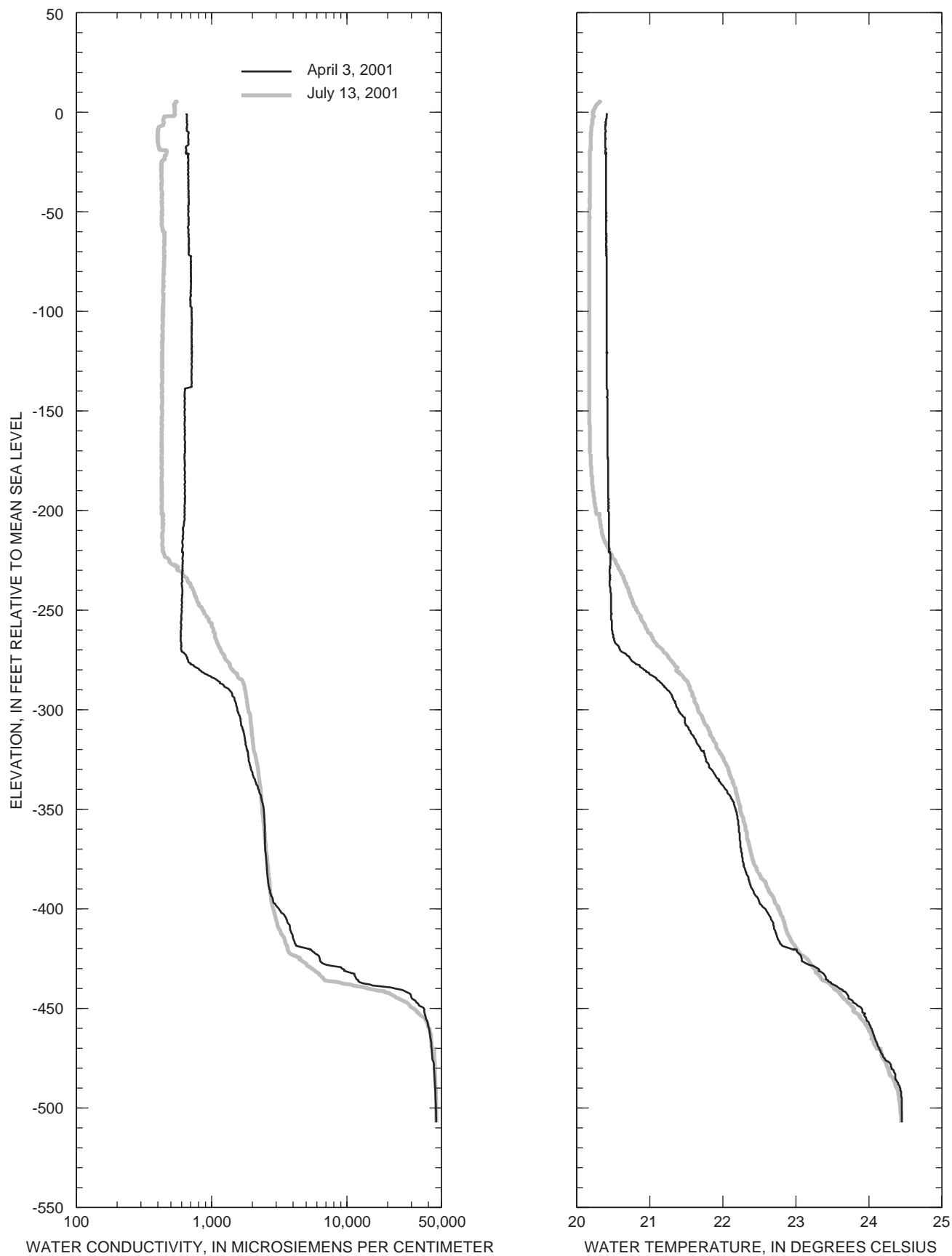


Figure 4. Water-conductivity and -temperature profiles measured in the Kualapuu deep monitor well (4-0800-01) on April 3 and July 13, 2001, Molokai, Hawaii. Data available from the USGS Hawaii District log archive.

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 tachylite cuttings
647	to	642	335	to	340	Mixture of dark gray vesicular and gray nonvesicular rock with iron oxide lining surfaces, minor amount of tachylite 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
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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
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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

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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

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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
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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