

CONSTRUCTION, GEOLOGIC LOG, AND AQUIFER
TESTS OF THE PUKAKI RESERVOIR MONITOR WELL
(STATE WELL 2-0023-01), LIHUE, KAUAI, HAWAII

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

	Multiply	By	To obtain
	inch (in.)	2.54	centimeter
	foot (ft)	0.3048	meter
	cubic foot per minute (ft ³ /min)	0.02832	cubic meter per minute
	gallon per minute (gal/min)	3.785	liter per minute
	mile, statute (mi)	1.609	kilometer

Other Useful Conversions

1 ft³/s = 448.8 gal/min

1 ft³/s = 0.6463 Mgal/d

Vertical datum

All elevations in this report are referenced relative to mean sea level.

Abbreviation:

μS/cm, microsiemens per centimeter at 25 degrees Celsius.

Construction, Geologic Log, and Aquifer Tests of the Pukaki Reservoir Monitor Well (State Well 2-0023-01), Lihue, Kauai, Hawaii

By Scot K. Izuka and Stephen B. Gingerich

Abstract

The Pukaki Reservoir monitor well, located in the center of the Lihue basin on the northeast slope of Kilohana Crater, was drilled in 1996 and tested to study the hydrology and geology in an area where no other well information is available. The well was drilled from a ground elevation of about 319 feet above sea level and penetrated a 1,147-foot section of mafic lava flows (which may include nephelinite, melilitite, basanite, and alkalic basalt), marine sediments, alluvium, and ash.

Step-drawdown and 4-day sustained-rate pumping tests were done to test aquifer properties. The maximum drawdown measured in the well during 4 days of sustained pumping at an average rate of 284 gallons per minute was 145.51 feet from an initial water-level elevation of 147.4 feet above sea level. Well loss, analyzed from the step-drawdown data, could not be determined. The temperature of the pumped water increased from 24.9 to 27.0 degrees Celsius and the specific conductance increased from 302 to 1,001 microsiemens per centimeter after 4 days of pumping.

INTRODUCTION

The Lihue basin is the center of population, government, and industry for Kauai. Recent population growth in the basin has greatly increased the demand for water in the area. The economic setback caused by Hurricane Iniki in 1993 slowed growth on Kauai and may have kept the water supply from reaching a critical

stage; however, an ample water supply is needed for the island's economic recovery. Pre-Iniki studies placed Lihue's supply at the highest priority in Kauai's water plans (Commission on Water Resources Management, 1990).

The Pukaki Reservoir monitor well is one of six monitor wells drilled in the period from April 1995 to April 1996 by the U.S. Geological Survey (USGS) in cooperation with the County of Kauai Department of Water to study the availability of ground water in the southern Lihue basin (fig. 1). The six monitor wells were sited in areas where no wells had been drilled and no subsurface information was available. Five of the six monitor wells were drilled in the central part of the Lihue basin. The sixth well was drilled in the southern part of the basin. The Pukaki Reservoir monitor well is about 0.9 mi from the nearest pumping wells and provides data for defining the regional ground-water system of the Lihue basin. The Department of Water considers the Pukaki Reservoir area as a potential site for future ground-water exploration and development.

The objectives of this study were met by analysis of data collected during and after the drilling. These data included (1) the driller's description of the drilling history and well construction, (2) water levels monitored as the well was deepened, (3) a caliper log of the uncased well boring, (4) a description of the geology from rock chips (cuttings) brought to the surface during drilling, and (5) the step-drawdown and 4-day aquifer tests. This report documents the location, drilling history, construction details, geologic log, and aquifer-test results of the Pukaki Reservoir monitor well (State well 2-0023-01).

Setting

The Pukaki Reservoir monitor well (State well 2-0023-01) is located in the Lihue basin, a large depression bounded on the west by the high mountains of central Kauai, on the south by Haupu Ridge, and on the north by the Makaleha Mountains (fig. 1). The area has undergone substantial stream erosion, weathering, and faulting followed by rejuvenated, sporadic, scattered volcanism. Two major stratigraphic units are found in the Lihue basin (fig. 2): (1) the Waimea Canyon Basalt of Pliocene and Miocene (?) age, which was erupted during the main shield-volcano-building stage of Kauai and forms the bulk of the island, including the mountains surrounding the Lihue basin, and (2) the Koloa Volcanics of Pleistocene and Pliocene age which include the rejuvenated-stage lava flows and sedimentary units that partly cover and fill the floor of the basin (Hinds, 1930; Stearns, 1946; Macdonald and others, 1960). Both the Waimea Canyon Basalt and the Koloa Volcanics have been given formational rank (Langenheim and Clague, 1987).

Kilohana Volcano in the center of the Lihue basin is a prominent edifice of the Koloa Volcanics. Macdonald and others (1960) described the Lihue basin as a subsidiary caldera that formed to the east of a central main caldera of the Kauai shield volcano. Stearns (1946) described the basin as the result of advanced stream erosion and the coalescing of many amphitheater-headed valleys. Numerous subsequent geologic investigations include a gravity survey (Kivroy and others, 1965), petrologic and geochemical analyses (Macdonald, 1968; Feigenson, 1984; Clague and Dalrymple, 1988; Maaloe and others, 1992), and radiometric dating (Clague and Dalrymple, 1988). These studies have advanced the understanding of the geology of Kauai, yet the origin of the Lihue basin remains an enigma.

Ground-water exploration in the Lihue basin has been only moderately successful, owing in part to the basin's complex ground-water hydrology. Most of the ground water in the Lihue basin is developed from wells in the Koloa Volcanics, which cover almost the entire basin floor. The Koloa Volcanics are generally considered to have low to moderate permeabilities (Macdonald and others, 1960), but specific capacities of wells in this unit are highly variable. Water levels during drilling in many of these wells declined with depth in the aquifer, indicating substantial vertical head gradients. At the base of the Koloa Volcanics and resting

unconformably on the underlying Waimea Canyon Basalt, are the weathered rocks and sedimentary deposits that formed during the period of erosion between the shield-volcano eruptions and the rejuvenated volcanism. These deposits probably have very low permeabilities and may retard the flow of water between the Koloa Volcanics and the Waimea Canyon Basalt.

The Waimea Canyon Basalt in the Lihue basin is represented by the Napali Member, the thick accumulations of thin lava flows that formed on the flank of the Kauai shield volcano. In western Kauai, the Napali Member is extensive and forms the most permeable aquifers on Kauai, but in the Lihue basin, the Napali Member crops out only in the mountains encircling the basin. It is not certain whether any of the wells drilled thus far in the center of the basin have passed through the Koloa Volcanics and into the underlying Napali Member. Therefore, the thickness of the Koloa Volcanics and the hydrologic properties of the underlying Napali Member are unknown.

Location

The Pukaki Reservoir monitor well is located in the center of the Lihue basin between sugarcane fields on the northeast slope of Kilohana Crater (table 1). The site is on the western shoulder of a sugar plantation road, about 0.2 mi west of the intersection with Maalo Road. The well was assigned the well number 2-0023-01 by the State of Hawaii Commission on Water Resources Management using the State well numbering system.

Table 1. Location, elevation, and State number of the Pukaki Reservoir monitor well, Kauai, Hawaii [Datum is mean sea level]

Latitude	22°00'54"N
Longitude	159°23'19"W
Ground elevation at brass plate in concrete pad	319.28 feet
Measuring-point elevation at top of 4-inch well casing	319.88 feet
Distance and direction from Lihue	2.5 miles northwest
Distance and direction from nearest shoreline	2.8 miles west
State well number	2-0023-01

The area within a 1 mi radius of the well is covered by a network of artificial and natural surface-water bodies. Pukaki Reservoir (part of Hanamaulu Stream) lies 0.1 mi to the east, Aii Reservoir lies 0.5 mi to the north,

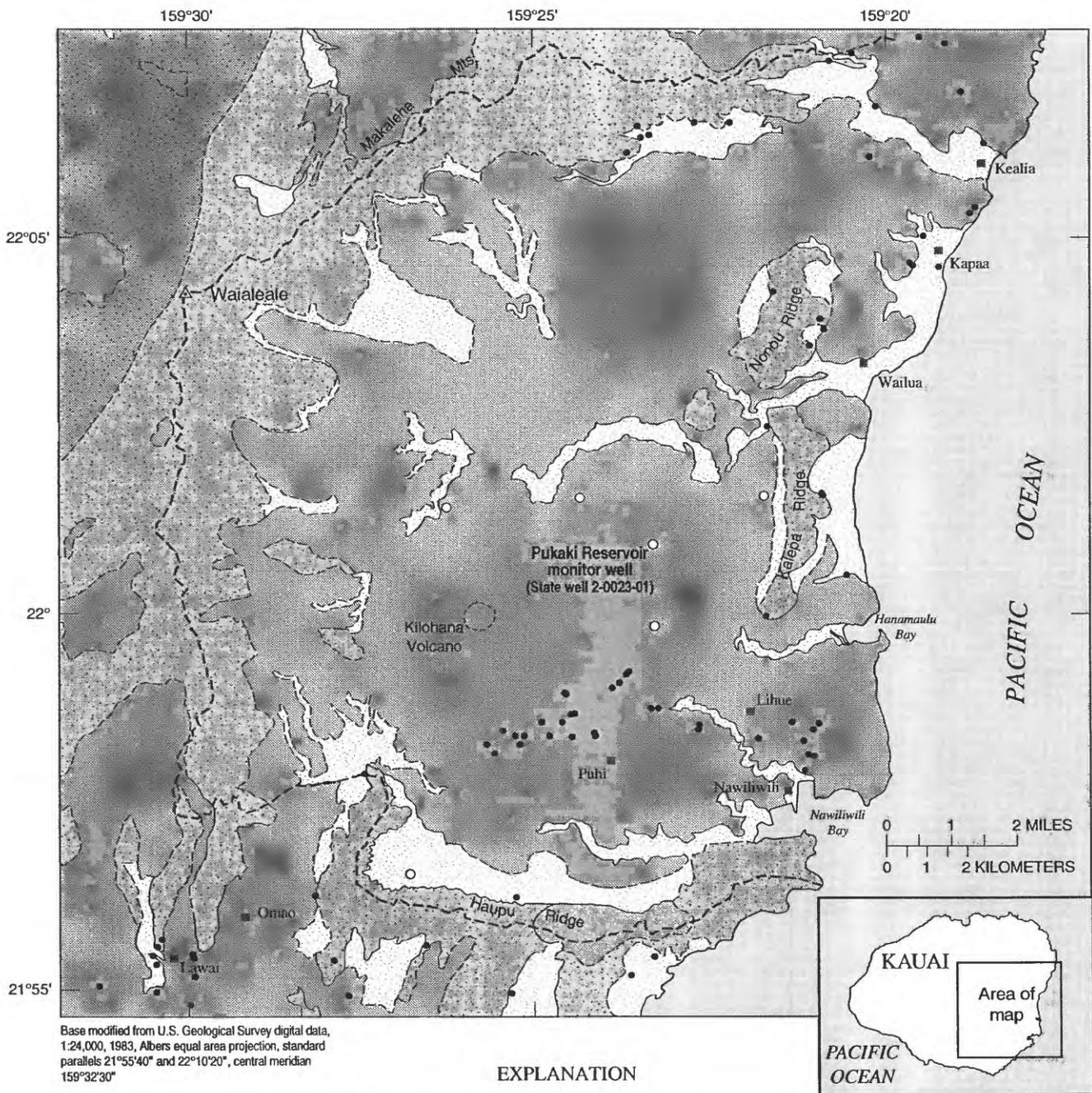


Figure 2. Geology of the Lihue basin area, Kauai, Hawaii (modified from Macdonald and others, 1960).

Table 2. Summary of construction of the Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii
 [Datum for water-level and bottom-of-hole elevations is mean sea level. Land surface elevation is about 319 ft above mean sea level; ft, feet]

Date	Significant events
February 1996	22 Drilling began, water encountered between 252 and 222 ft elevation
	25 Surface casing installed to 163 ft elevation
March 1996	6 Continued drilling from 163 ft elevation; increase in water lifted out of well at 124 to 92 ft elevation; continued drilling to -3 ft elevation
	7 Water level before drilling about 254 ft elevation and bottom-of-hole -3 ft elevation; possible increase in water lifted out of well at -38 to -48 ft elevation; continued drilling to -143 ft elevation
	8 Water level before drilling about 206 ft elevation and bottom-of-hole -143 ft elevation; continued drilling to -363 ft elevation
	10 Water level before drilling about 210 ft elevation and bottom-of-hole -363 ft elevation; increase in water lifted out of well at -419 to -428 ft and -463 ft elevation; continued drilling to -648 ft elevation
	11 Water level before drilling about 154 ft elevation and bottom-of-hole -648 ft elevation; drilling terminated at -828 ft elevation (total depth of 1,147 ft)
	12 Water level 151.9 ft elevation; logged upper 1,060 ft of hole with caliper, mud in hole obstructing caliper
	20 Water level 148 ft elevation; performed step-drawdown test
April 1996	2 Water level 147.4 ft elevation; began sustained-rate aquifer test at 284 gallons per minute
	6 Terminated sustained pumping test, drawdown of 146 ft, began recovery monitoring; cascading water noted at about 150 ft elevation
	8 Installed polyvinyl-chloride casing; well completed

Kapaia Reservoir lies 0.7 mi to the northwest, and the south fork of the Wailua River is within 1.2 mi northeast of the well. The well is located about 2.8 mi inland from the eastern coast of Kauai.

Acknowledgments

The construction, data collection, and testing of the Pukaki Reservoir monitor well was made possible with the cooperation and assistance of Mr. Murl Nielsen, Manager and Chief Engineer, and the staff of the County of Kauai Department of Water. We are grateful to Mr. Michael Furukawa for permitting the construction of the well on Amfac/JMB Hawaii, Lihue Plantation land. Drilling, aquifer-test, and elevation information were drawn extensively from the notes of G. Wayne Heck of the U.S. Geological Survey.

DRILLING METHODS AND HISTORY

The well was bored by rotary drilling with a 9-7/8-in. diameter tungsten-carbide bit. Air and foam were injected down through the hollow drill stem and circulated back up the space between the stem and the well boring to remove water and cuttings from the hole. Greater lifting power was needed as the drilling penetrated deeper below the water table. The depth of drilling was thus limited by the capacity of the air

compressor to provide the circulation. Table 2 summarizes the construction of the well.

The Pukaki Reservoir monitor well was drilled to a depth of 1,147 ft from a ground elevation of about 319 ft above sea level. Water was first found between 252 and 222 ft elevation but the water levels decreased as the well was deepened. The water level was at 148 ft elevation when the bottom of the hole was at -828 ft elevation at the completion of drilling. The drillers noted increases in water lifted out of the hole at 124 to 92 ft elevation; -38 to -48 ft elevation; at -419 to -428 ft elevation, and at -463 ft elevation.

A caliper tool was lowered down the hole to record the caliper-arm extension, an indication of the variation in hole diameter with depth, and a blockage was discovered at -741 ft elevation. A step-drawdown test was conducted on March 20 and an aquifer test at a sustained rate of 284 gal/min was conducted on April 2-6, 1995 in the open, uncased hole. Cascading water was noted in the borehole at about 150 ft elevation during the test.

A 20-ft solid polyvinyl-chloride (PVC) casing with a 4-in. inner-diameter was installed and the well was completed on April 8, 1996. The elevation of a brass plate in a concrete pad surrounding the well is 319.28 ft and the elevation of the measuring point is 319.88 ft. Construction details of the finished well are shown in figure 3.

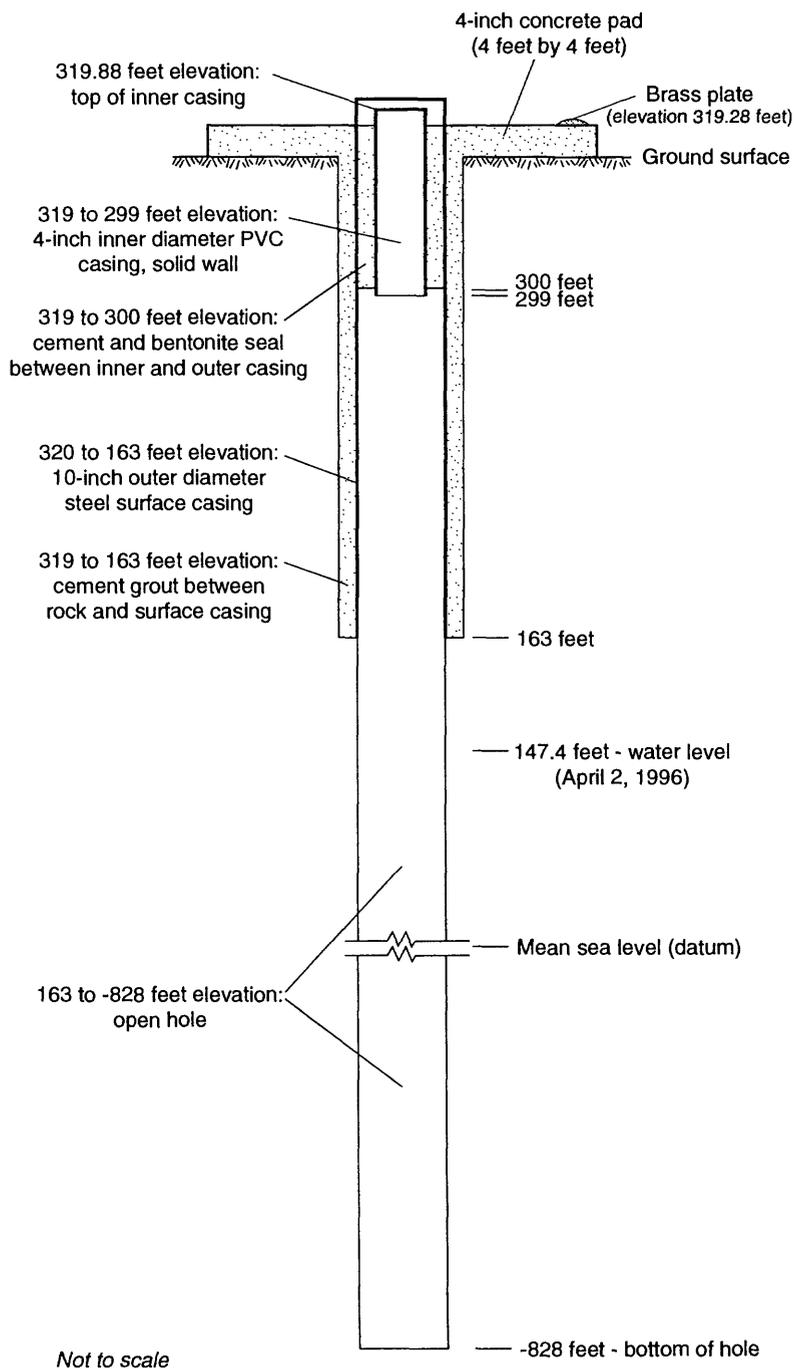


Figure 3. Construction details of the Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii.

GEOLOGIC LOG

The geologic log of the Pukaki Reservoir monitor well was compiled by examination of cuttings brought to the surface by the air and foam circulated through the well bore. Samples were collected at 5-ft depth intervals and air dried before being examined macroscopically. The complete lithologic descriptions appear in appendix 1; the geologic log is shown in figure 4.

The Pukaki Reservoir monitor well penetrated a 1,147-ft section of mafic lava flows, marine sediments, alluvium, and ash (in this report, "mafic rock" includes nephelinite, melilitite, and basanite all of which are dark, fine-grained, igneous rocks but have specific compositions that are not distinguishable in hand specimen). The uppermost part of the section consists of a 110-ft section of surface soil and highly weathered rock. Underlying the weathered rock is a 500-ft section composed predominantly of dense, mafic lava flows. Ash and breccia layers occur about midway through the section of mafic rock between 69 and 9 ft elevation. Below this thick section of mafic ash and breccia is a 35-ft layer of sandy mud with fragments of marine mollusk shells, underlain by another 105 ft of mafic lava flows. Below this section is a 150-ft layer of marine mud and gravel with fossils of mollusk shells, foraminifera, and wood. Below the marine layer is a 75-ft-thick section of mafic lava flows underlain by a 100-ft-thick layer of sediments. The base of the section penetrated by the well is composed of 70 ft of mafic lava flows and 10 ft of clay.

The caliper log of the Pukaki Reservoir monitor well (fig. 4) shows intervals where the hole deviates from the diameter of drill-bit used to make the boring. Rock layers that are unconsolidated or thin tend to crumble and cave to produce enlargements in the well boring. In contrast, rocks that are hard, massive, and thick tend to hold the shape of the boring, and thus give a smoother, unvarying log. Caliper arm extension less than the drill-bit diameter indicates sections of the well where the rock has slumped into the hole. Below the surface casing (which shows as the smooth upper 160 ft of the caliper log), the log shows a few small enlargements that may have been caused by the caving of clinker zones or unconsolidated sediment. A prominent enlargement occurs at -431 ft elevation, which corresponds approximately to the top of the lower marine layer. The log also shows decreases in hole diameter at

about -500 ft and -700 ft elevation which are probably the result of slumping of material from above.

AQUIFER TESTS

Two aquifer tests were performed using the Pukaki Reservoir monitor well (State well 2-0023-01); a step-drawdown test to determine well efficiency; and a sustained-rate test, which can be used to estimate aquifer properties in the vicinity of the well. The tests were conducted using a 50-horsepower, 6-in. diameter submersible pump with the intake elevation set at -21 ft for the step-drawdown test and -84 ft for the sustained-rate test. Measurements of the depth to water in the pumping well were made using an electric tape. The flow rate was measured using a totalizing flow meter.

The step-drawdown test, conducted on March 20, 1996 consisted of four 60-min steps at average withdrawal rates of 39, 97, 176, and 298 gal/min followed by 4,080 min of recovery monitoring (fig. 5 and appendix 2). The elevation of static water level at the start of the test was 148 ft. The data were analyzed to estimate the two components of drawdown in the pumped well: (1) the hydraulic head loss in the aquifer, and (2) the hydraulic head losses from water entering the well. The methods of Hantush and Bierschenk, and Eden and Hazel (in Kruseman and de Ridder, 1994) were attempted using the step-drawdown data, but neither method produced realistic results. The measurements of depth to water appear to be affected by the presence of cascading water in the well bore at about 150 ft elevation. Therefore, well loss could not be calculated for this well.

The sustained-rate aquifer test was conducted from April 2-6, 1996 for 5,700 min (about 4 days) at an average rate of 284 gal/min; recovery was monitored for 270 min at the end of the test (appendix 3). Flow rates during most of the sustained test fluctuated between 308 and 298 gal/min with the higher flow rates occurring in the first 60 min. At about 4,100 min into the test, the pumping rate fell to 0 gal/min for about 120 min due to a generator malfunction. The pump was restarted at 4,208 min at a rate of 302 gal/min. The maximum drawdown measured in the pumped well was 145.51 ft after 5,700 min into the test. The elevation of static water level at the start of the test was 147.4 ft. Depth-to-water mea-

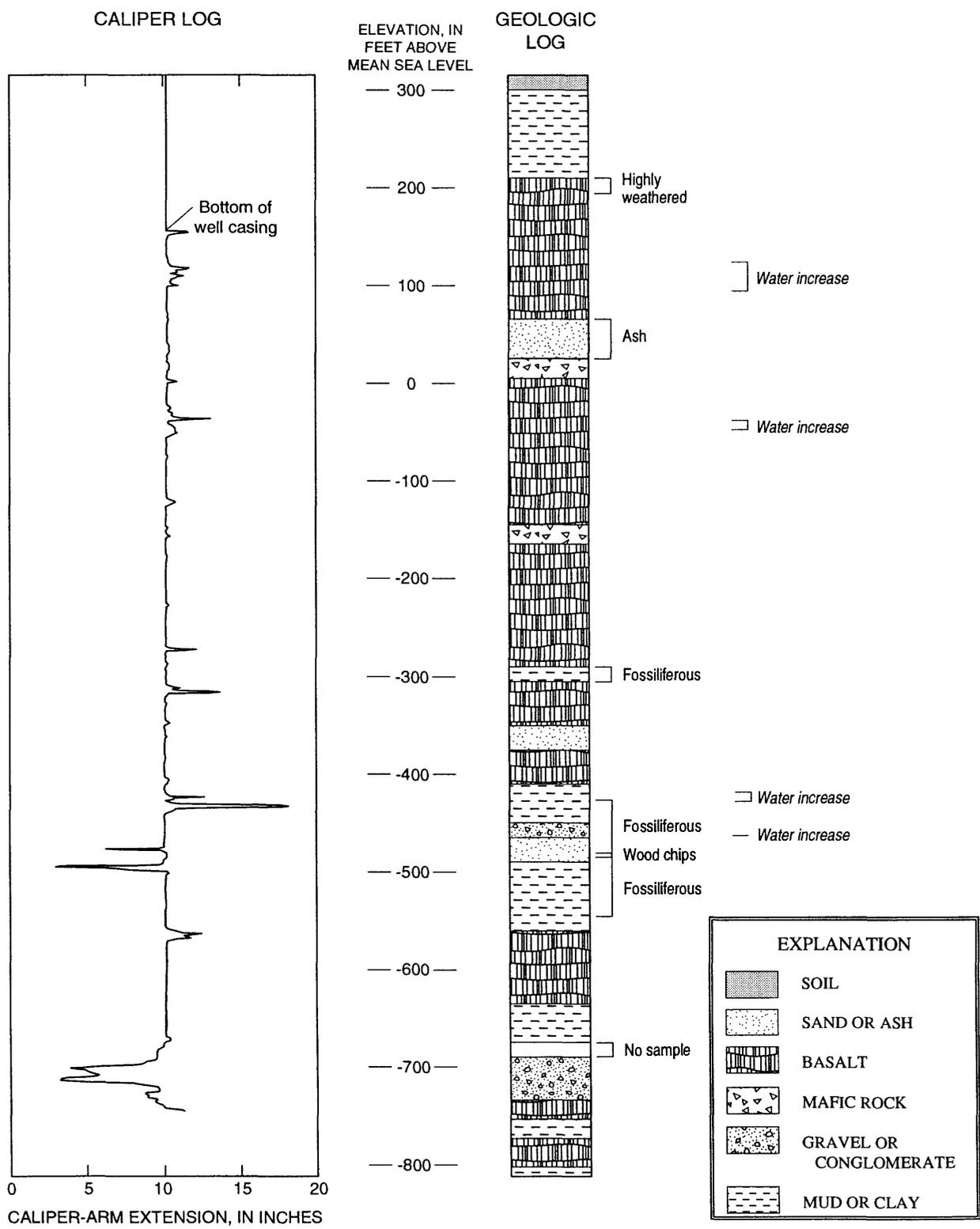


Figure 4. Geologic log and caliper-arm extension with depth in the Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii.

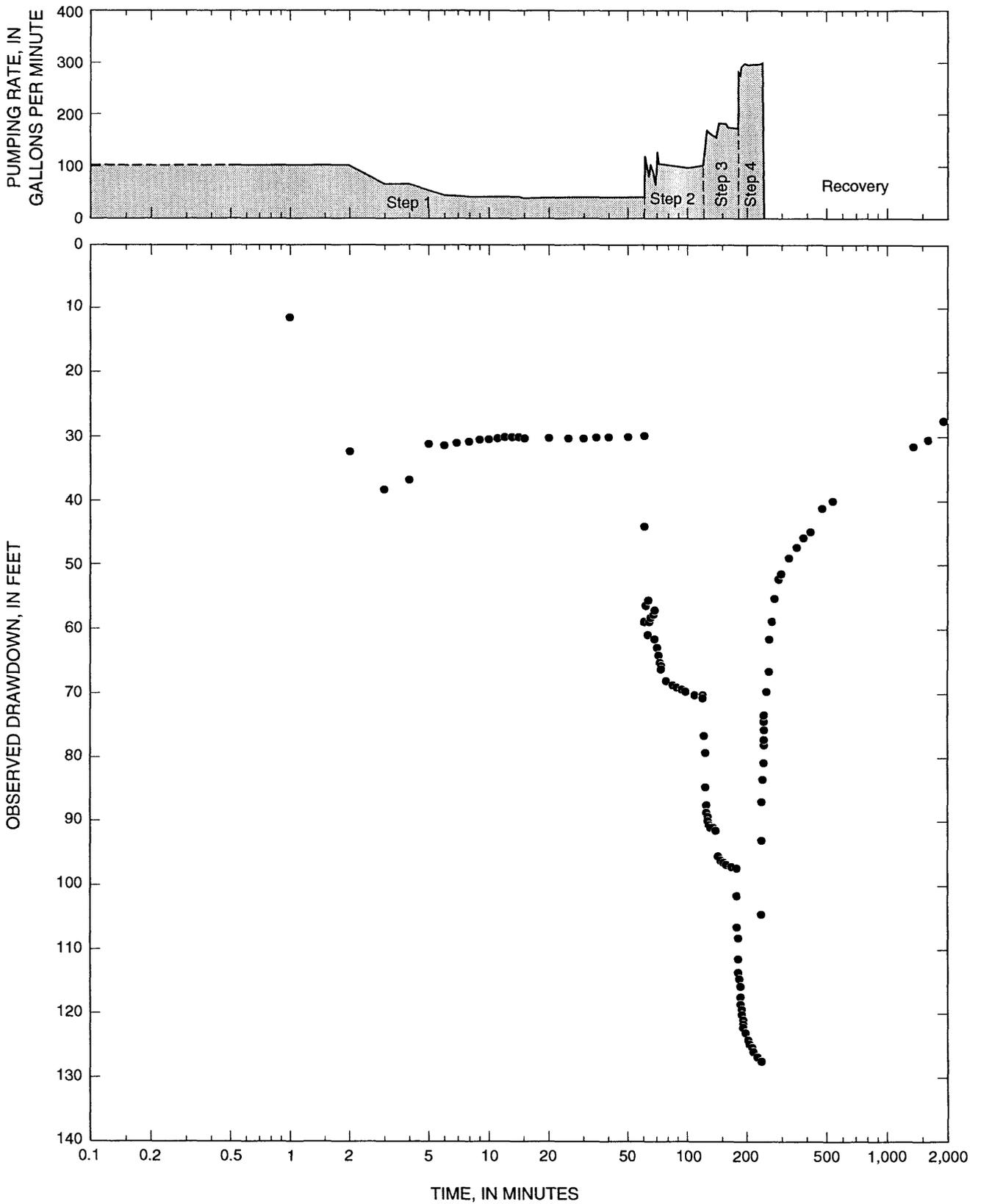


Figure 5. Drawdown with time during step-drawdown aquifer test (March 20, 1996), Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii.

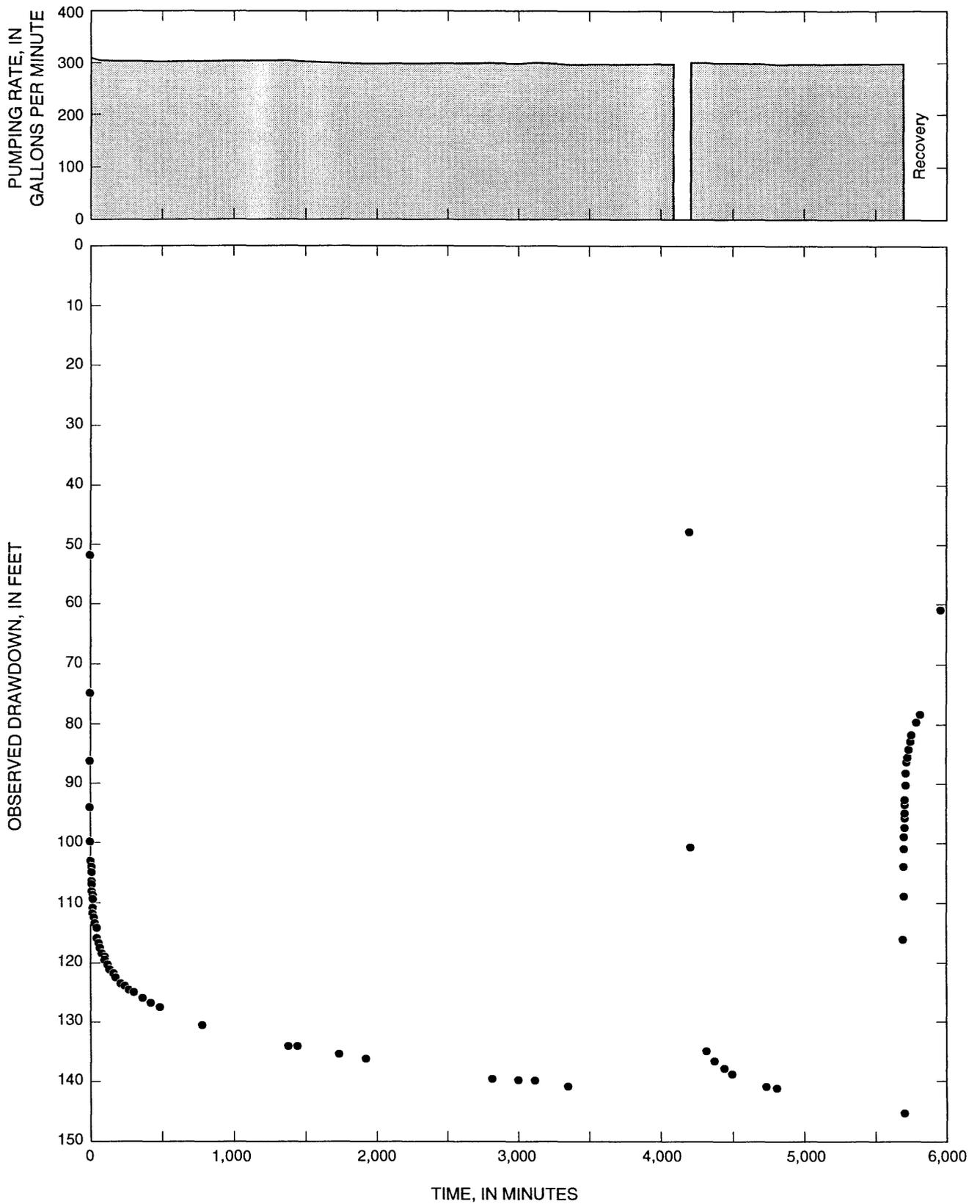


Figure 6. Drawdown with time during 4-day sustained-rate aquifer test (April 2–6, 1996), Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii.

surements were made through a 1-in. PVC pipe inserted in the well to avoid the effects of the cascading water. The pumped water was discharged into a flowing tributary of Hanamaulu Stream about 200 ft away from the pumping well.

A marked change in drawdown at 3,400 min into the sustained-rate (fig. 6) is apparent in the plot due to the 120-min failure in the generator powering the pump.

Samples of the pumped water were collected during the sustained-rate test and analyzed for temperature and specific conductance. The temperature and specific conductance of the pumped water increased steadily during the test. The temperature rose 2.1°C; from 24.9°C after 14 min of pumping to 27.0°C after 4,500 min of pumping. The specific conductance of the water increased from 302 to 1,001 $\mu\text{S}/\text{cm}$ by the end of the test.

SUMMARY

The Pukaki Reservoir monitor well (State well number 2-0023-01) is located in the Lihue basin between sugarcane fields on the northeast slope of Kilo-hana Crater. The well was constructed during the period from February 22 to April 8, 1996 to study the hydrology and geology in an area where no other well information is available. The elevation of a brass plate embedded in the concrete pad at the well is 319.28 feet and the well is 1,147 feet deep (bottom is at -828 feet elevation) and has a boring diameter of 10 inches. Twenty feet of flush-jointed 4-inch (outside diameter) solid PVC surface casing was installed in the hole.

During drilling, water levels decreased with depth from 254 feet elevation when the hole bottom was at -3 feet elevation, to 147 feet elevation when the hole was at -828 feet elevation. The drillers reported a noticeable increase in water being circulated from the hole in the intervals between 252 and 222 feet elevation, 124 and 92 feet elevation, -38 and -48 feet elevation, -419 to -428 feet elevation, and at -463 feet elevation.

The Pukaki Reservoir monitor well penetrated a 1,147-foot section of mafic lava flows, marine sediments, alluvium, and ash. The caliper log of the well shows a few intervals where caving and slumping of clinker or unconsolidated sediment occurred.

Step-drawdown and 4-day sustained-pumping-rate tests were conducted to test aquifer properties. The step-

drawdown test results were unacceptable due to probable erroneous readings. The maximum drawdown measured in the pumped well was 145.51 feet (initial water level elevation was 147.4 feet) during 4 days of sustained pumping at an average rate of 284 gallons per minute. The temperature increased from 24.9°C to 27.0°C and the specific conductance increased from 302 to 1,001 microsiemens per centimeter at 25°C after 4 days of pumping.

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Appendix 1. Lithologic descriptions of drill cuttings from Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii
 [Datum is mean sea level; depth measured from 319 feet above sea level]

Elevation (feet)	Depth (feet)	Sample description¹
319 to 314	0 to 5	dark-brown soil
314 to 309	5 to 10	dark-brown soil
309 to 304	10 to 15	dark-brown soil
304 to 299	15 to 20	brown, sticky clay with few pieces of highly weathered mafic rock
299 to 294	20 to 25	brown, sticky clay with few pieces of highly weathered mafic rock
294 to 289	25 to 30	brown, sticky clay with few pieces of highly weathered mafic rock
289 to 284	30 to 35	brown, sticky clay with few pieces of highly weathered mafic rock
284 to 279	35 to 40	brown, sticky clay with few pieces of highly weathered mafic rock
279 to 742	40 to 45	brown, sticky clay with few pieces of highly weathered mafic rock
742 to 269	45 to 50	brown, sticky clay with few pieces of highly weathered mafic rock
269 to 264	50 to 55	brown, sticky clay with few pieces of highly weathered mafic rock
264 to 259	55 to 60	brown, sticky clay with few pieces of highly weathered mafic rock
259 to 254	60 to 65	brown, sticky clay with few pieces of highly weathered mafic rock
254 to 249	65 to 70	brown clay and dense mafic rock
249 to 244	70 to 75	brown clay and dense mafic rock
244 to 239	75 to 80	sticky red-brown clay
239 to 234	80 to 85	sticky red-brown clay
234 to 229	85 to 90	sticky red-brown clay
229 to 224	90 to 95	sticky red-brown clay
224 to 219	95 to 100	sticky red-brown clay
219 to 214	100 to 105	sticky red-brown clay
214 to 209	105 to 110	orange-brown, highly weathered mafic rock
209 to 204	110 to 115	orange-brown, highly weathered mafic rock
204 to 199	115 to 120	orange-brown, highly weathered mafic rock
199 to 194	120 to 125	orange-brown, highly weathered mafic rock
194 to 189	125 to 130	light-brown, highly weathered mafic rock with dark-gray moderately vesicular mafic rock
189 to 184	130 to 135	light-brown, highly weathered mafic rock with dark-gray moderately vesicular mafic rock
184 to 179	135 to 140	light-brown, highly weathered mafic rock with dark-gray moderately vesicular mafic rock
179 to 174	140 to 145	dark-gray, moderately vesicular mafic rock with some highly weathered pieces
174 to 169	145 to 150	dark-gray, moderately vesicular mafic rock with some highly weathered pieces
169 to 164	150 to 155	dark-gray, moderately vesicular mafic rock with some highly weathered pieces
164 to 159	155 to 160	dark-gray, moderately vesicular mafic rock with some highly weathered pieces
159 to 154	160 to 165	dark-gray, moderately vesicular mafic rock with some highly weathered pieces
154 to 149	165 to 170	light-gray, dense, aphyric mafic rock with few amygdules
149 to 144	170 to 175	light-gray, dense, aphyric mafic rock with few amygdules
144 to 139	175 to 180	light-gray, dense, aphyric mafic rock with few amygdules
139 to 134	180 to 185	light-gray, dense, aphyric mafic rock with few amygdules
134 to 129	185 to 190	light- to medium-gray, very dense, aphyric mafic rock
129 to 124	190 to 195	light- to medium-gray, very dense, aphyric mafic rock
124 to 119	195 to 200	light- to medium-gray, very dense, aphyric mafic rock
119 to 114	200 to 205	brownish-gray, partially weathered, dense mafic rock
114 to 109	205 to 210	brown sand
109 to 104	210 to 215	brown, highly weathered mafic rock
104 to 99	215 to 220	brown, highly weathered mafic rock
99 to 94	220 to 225	brown, highly weathered mafic rock
94 to 89	225 to 230	brown, highly weathered mafic rock mixed with gray, unweathered mafic rock
89 to 84	230 to 235	brown, highly weathered mafic rock mixed with gray, unweathered mafic rock
84 to 79	235 to 240	brown, highly weathered mafic rock mixed with gray, unweathered mafic rock
79 to 74	240 to 245	brown, highly weathered mafic rock mixed with gray, unweathered mafic rock
74 to 69	245 to 250	brown, highly weathered mafic rock mixed with gray, unweathered mafic rock

Appendix 1. Lithologic descriptions of drill cuttings from Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii
--Continued

[Datum is mean sea level; depth measured from 319 feet above sea level]

Elevation (feet)	Depth (feet)	Sample description¹
69 to 64	250 to 255	dark-brown, weathered sand
64 to 59	255 to 260	dark-brown, weathered sand
59 to 54	260 to 265	dark-brown, weathered sand
54 to 49	265 to 270	dark-brown, weathered sand with some dense mafic rock and peridotite
49 to 44	270 to 275	dark-brown, indurated breccia
44 to 39	275 to 280	dark-brown, indurated breccia
39 to 34	280 to 285	dark-brown, indurated breccia
34 to 29	285 to 290	dark-brown, weathered sand
29 to 24	290 to 295	mix of brown breccia, black dense mafic rock, and partially weathered mafic rock
24 to 19	295 to 300	mix of brown breccia, black dense mafic rock, and partially weathered mafic rock
19 to 14	300 to 305	mix of brown breccia, black dense mafic rock, and partially weathered mafic rock
14 to 9	305 to 310	mix of brown breccia, black dense mafic rock, and partially weathered mafic rock
9 to 4	310 to 315	brownish-gray, slightly weathered, dense, aphyric mafic rock
4 to -1	315 to 320	brownish-gray, slightly weathered, dense, aphyric mafic rock
-1 to -6	320 to 325	brownish-gray, slightly weathered, dense, aphyric mafic rock
-6 to -11	325 to 330	brownish-gray, slightly weathered, dense, aphyric mafic rock
-11 to -16	330 to 335	light-gray, dense, aphyric mafic rock
-16 to -21	335 to 340	light-gray, dense, aphyric mafic rock
-21 to -26	340 to 345	light-gray, dense, aphyric mafic rock
-26 to -31	345 to 350	medium-gray, dense mafic rock with brown, highly weathered mafic rock
-31 to -36	350 to 355	medium-gray, dense mafic rock with brown, highly weathered mafic rock
-36 to -41	355 to 360	medium-gray, dense mafic rock with brown, highly weathered mafic rock
-41 to -46	360 to 365	medium-gray, dense mafic rock with brown, highly weathered mafic rock
-46 to -51	365 to 370	brown, highly weathered mafic rock
-51 to -56	370 to 375	brownish-gray, slightly weathered, dense mafic rock
-56 to -61	375 to 380	brownish-gray, slightly weathered, dense mafic rock
-61 to -66	380 to 385	brownish-gray, slightly weathered, dense mafic rock
-66 to -71	385 to 390	brownish-gray, slightly weathered, dense mafic rock
-71 to -76	390 to 395	brownish-gray, slightly weathered, dense mafic rock
-76 to -81	395 to 400	brownish-gray, slightly weathered, dense mafic rock
-81 to -86	400 to 405	brownish-gray, slightly weathered, dense mafic rock
-86 to -91	405 to 410	brownish-gray, slightly weathered, dense mafic rock
-91 to -96	410 to 415	gray, dense, aphyric mafic rock
-96 to -101	415 to 420	gray, dense, aphyric mafic rock
-101 to -106	420 to 425	gray, dense, aphyric mafic rock
-106 to -111	425 to 430	gray, dense, aphyric mafic rock
-111 to -116	430 to 435	gray, dense, aphyric mafic rock
-116 to -121	435 to 440	gray, dense, aphyric mafic rock
-121 to -126	440 to 445	gray, dense, aphyric mafic rock
-126 to -131	445 to 450	gray, dense, aphyric mafic rock
-131 to -136	450 to 455	gray, dense, aphyric mafic rock
-136 to -141	455 to 460	gray, dense, aphyric mafic rock
-141 to -146	460 to 465	gray, dense, aphyric mafic rock
-146 to -151	465 to 470	gray, dense, aphyric mafic rock
-151 to -156	470 to 475	gray, dense, aphyric mafic rock
-156 to -161	475 to 480	gray, dense, aphyric mafic rock with some brown weathered pieces
-161 to -166	480 to 485	gray, dense, aphyric mafic rock with some brown weathered pieces
-166 to -171	485 to 490	gray, dense, aphyric mafic rock with some brown weathered pieces
-171 to -176	490 to 495	medium-gray, dense aphyric mafic rock
-176 to -181	495 to 500	medium-gray, dense aphyric mafic rock

Appendix 1. Lithologic descriptions of drill cuttings from Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii

--Continued

[Datum is mean sea level; depth measured from 319 feet above sea level]

Elevation (feet)	Depth (feet)	Sample description ¹
-181 to -186	500 to 505	medium-gray, dense aphyric mafic rock
-186 to -191	505 to 510	medium-gray, dense aphyric mafic rock
-191 to -196	510 to 515	medium-gray, dense aphyric mafic rock
-196 to -201	515 to 520	medium-gray, dense aphyric mafic rock
-201 to -206	520 to 525	medium-gray, dense aphyric mafic rock
-206 to -211	525 to 530	medium-gray, dense aphyric mafic rock
-211 to -216	530 to 535	medium-gray, dense aphyric mafic rock
-216 to -221	535 to 540	medium-gray, dense aphyric mafic rock
-221 to -226	540 to 545	medium-gray, dense aphyric mafic rock
-226 to -231	545 to 550	medium-gray, dense aphyric mafic rock
-231 to -236	550 to 555	medium-gray, dense aphyric mafic rock
-236 to -241	555 to 560	medium-gray, dense aphyric mafic rock
-241 to -246	560 to 565	medium-gray, dense aphyric mafic rock
-246 to -251	565 to 570	medium-gray, dense aphyric mafic rock
-251 to -256	570 to 575	medium-gray, dense aphyric mafic rock
-256 to -261	575 to 580	medium-gray, dense aphyric mafic rock
-261 to -266	580 to 585	medium-gray, dense aphyric mafic rock
-266 to -271	585 to 590	medium-gray, dense aphyric mafic rock
-271 to -276	590 to 595	medium-gray, dense aphyric mafic rock
-276 to -281	595 to 600	medium-gray, dense aphyric mafic rock
-281 to -286	600 to 605	medium-gray, dense aphyric mafic rock
-286 to -291	605 to 610	dark-brown, sandy mud with mollusk shell fragments
-291 to -296	610 to 615	dark-brown, sandy mud with mollusk shell fragments
-296 to -301	615 to 620	dark-brown, sandy mud with mollusk shell fragments
-301 to -306	620 to 625	dark-brown, sandy mud with mollusk shell fragments
-306 to -311	625 to 630	brown, sandy mud with mollusk shell fragments
-311 to -316	630 to 635	brown, sandy mud with mollusk shell fragments
-316 to -321	636 to 640	brown, sandy mud with mollusk shell fragments
-321 to -326	640 to 645	medium brownish gray, partly weathered, dense, aphyric mafic rock
-326 to -331	645 to 650	medium brownish gray, partly weathered, dense, aphyric mafic rock
-331 to -336	650 to 655	medium brownish gray, partly weathered, dense, aphyric mafic rock
-336 to -341	655 to 660	medium brownish gray, partly weathered, dense, aphyric mafic rock
-341 to -346	660 to 665	medium brownish gray, partly weathered, dense, aphyric mafic rock
-346 to -351	665 to 670	medium brownish gray, partly weathered, dense, aphyric mafic rock
-351 to -356	670 to 675	dark-gray, dense, aphyric mafic rock
-356 to -361	675 to 680	dark-gray, dense, aphyric mafic rock
-361 to -366	680 to 685	dark-gray, dense, aphyric mafic rock
-366 to -371	685 to 690	brown sand
-371 to -376	690 to 695	brown sand with dark-gray, dense mafic rock
-376 to -381	695 to 700	brown sand with dark-gray, dense mafic rock
-381 to -386	700 to 705	brown sand with dark-gray, dense mafic rock
-386 to -391	705 to 710	brown sand with dark-gray, dense mafic rock
-391 to -396	710 to 715	gray, slightly weathered, dense aphyric mafic rock
-396 to -401	715 to 720	gray, slightly weathered, dense aphyric mafic rock
-401 to -406	720 to 725	gray, slightly weathered, dense aphyric mafic rock
-406 to -411	725 to 730	greenish-gray, dense aphyric mafic rock
-411 to -416	730 to 735	greenish-gray, dense aphyric mafic rock
-416 to -421	735 to 740	greenish-gray, dense aphyric mafic rock
-421 to -426	740 to 745	greenish-gray, dense aphyric mafic rock
-426 to -431	745 to 750	dark gray mud with gravel and foraminifera

Appendix 1. Lithologic descriptions of drill cuttings from Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii

--Continued

[Datum is mean sea level; depth measured from 319 feet above sea level]

Elevation (feet)	Depth (feet)	Sample description ¹
-431 to -436	750 to 755	dark gray mud with gravel and mollusk shells
-436 to -441	755 to 760	dark gray mud with gravel and mollusk shells
-441 to -446	760 to 765	dark gray mud with gravel and mollusk shells
-446 to -451	765 to 770	dark gray mud with gravel and mollusk shells
-451 to -456	770 to 775	dark gray mud with gravel and mollusk shells
-456 to -461	775 to 780	dark gray mud with gravel and mollusk shells
-461 to -466	780 to 785	dark gray mud with gravel and mollusk shells
-466 to -471	785 to 790	light gray gravel and sand with mollusk shells
-471 to -476	790 to 795	dark-brown to light-gray gravel
-476 to -481	795 to 800	dark-brown to light-gray gravel
-481 to -486	800 to 805	wood chips with gray sandy mud and gravel
-486 to -491	805 to 810	light brownish-gray sand with mollusk shells
-491 to -496	810 to 815	light brownish-gray sand with mollusk shells
-496 to -501	815 to 820	light brownish-gray sand with mollusk shells
-501 to -506	820 to 825	light brownish-gray sand with mollusk shells
-506 to -511	825 to 830	light gray indurated mudstone with shell fragments
-511 to -516	830 to 835	light gray indurated mudstone with shell fragments
-516 to -521	835 to 840	light gray indurated mudstone with shell fragments
-521 to -526	840 to 845	light gray indurated mudstone with shell fragments
-526 to -531	845 to 850	light gray indurated mudstone with shell fragments
-531 to -536	850 to 855	light gray indurated mudstone with shell fragments
-536 to -541	855 to 860	light gray indurated mudstone with shell fragments
-541 to -546	860 to 865	light gray indurated mudstone with shell fragments
-546 to -551	865 to 870	gray mud and mudstone
-551 to -556	870 to 875	gray mud and mudstone
-556 to -561	875 to 880	gray mud and mudstone
-561 to -566	880 to 885	gray mud and mudstone
-566 to -571	885 to 890	gray mud and mudstone
-571 to -576	890 to 895	gray mud and mudstone
-576 to -581	895 to 900	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-581 to -586	900 to 905	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-586 to -591	905 to 910	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-591 to -596	910 to 915	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-596 to -601	915 to 920	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-601 to -606	920 to 925	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-606 to -611	925 to 930	medium greenish-gray, slightly weathered, dense, aphyric mafic rock
-611 to -616	930 to 935	yellowish-gray, slightly weathered, dense aphyric mafic rock
-616 to -621	935 to 940	yellowish-gray, slightly weathered, dense aphyric mafic rock
-621 to -626	940 to 945	yellowish-gray, slightly weathered, dense aphyric mafic rock
-626 to -631	945 to 950	yellowish-gray, slightly weathered, dense aphyric mafic rock
-631 to -636	950 to 955	dark gray, dense aphyric mafic rock
-636 to -641	955 to 960	dark gray, dense aphyric mafic rock
-641 to -646	960 to 965	dark gray, dense aphyric mafic rock
-646 to -651	965 to 970	dark gray, dense aphyric mafic rock
-651 to -656	970 to 975	greenish-brown mudstone mixed with dense dark-gray aphyric mafic rock
-656 to -661	975 to 980	greenish-brown mudstone mixed with dense dark-gray aphyric mafic rock
-661 to -666	980 to 985	greenish-brown mudstone mixed with dense dark-gray aphyric mafic rock
-666 to -671	985 to 990	greenish-brown mudstone mixed with dense dark-gray aphyric mafic rock
-671 to -676	990 to 995	greenish-brown mudstone mixed with dense dark-gray aphyric mafic rock
-676 to -681	995 to 1,000	greenish-brown mudstone

Appendix 1. Lithologic descriptions of drill cuttings from Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii
 --Continued

[Datum is mean sea level; depth measured from 319 feet above sea level]

Elevation (feet)	Depth (feet)	Sample description ¹
-681 to -686	1,000 to 1,005	greenish-brown mudstone with dark gray, dense, aphyric mafic rock
-686 to -691	1,005 to 1,010	greenish-brown mudstone with dark gray, dense, aphyric mafic rock
-691 to -696	1,010 to 1,015	no sample
-696 to -701	1,015 to 1,020	no sample
-701 to -706	1,020 to 1,025	no sample
-706 to -711	1,025 to 1,030	mafic rock gravel
-711 to -716	1,030 to 1,035	mafic rock gravel with brown clay
-716 to -721	1,035 to 1,040	mafic rock gravel with brown clay
-721 to -726	1,040 to 1,045	mafic rock gravel
-726 to -731	1,045 to 1,050	mafic rock gravel
-731 to -736	1,050 to 1,055	mafic rock gravel
-736 to -741	1,055 to 1,060	mafic rock gravel
-741 to -746	1,060 to 1,065	mafic rock gravel
-746 to -751	1,065 to 1,070	mafic rock gravel
-751 to -756	1,070 to 1,075	dark gray, dense, aphyric mafic rock
-756 to -761	1,075 to 1,080	dark gray, dense, aphyric mafic rock
-761 to -766	1,080 to 1,085	dark gray, dense, aphyric mafic rock
-766 to -771	1,085 to 1,090	dark gray, dense, aphyric mafic rock
-771 to -776	1,090 to 1,095	pinkish-brown mud with partly weathered dense mafic rock
-776 to -781	1,095 to 1,100	pinkish-brown mud with partly weathered dense mafic rock
-781 to -786	1,100 to 1,105	pinkish-brown mud with partly weathered dense mafic rock
-786 to -791	1,105 to 1,110	pinkish-brown mud with partly weathered dense mafic rock
-791 to -796	1,110 to 1,115	dark-gray, dense aphyric mafic rock with pinkish-brown mud
-796 to -801	1,115 to 1,120	dark-gray, dense aphyric mafic rock with pinkish-brown mud
-801 to -806	1,120 to 1,125	dark-gray, dense aphyric mafic rock with pinkish-brown mud
-806 to -811	1,125 to 1,130	dark-gray, dense aphyric mafic rock
-811 to -816	1,130 to 1,135	dark-gray, dense aphyric mafic rock
-816 to -821	1,135 to 1,140	dense mafic rock with some red-brown mud
-821 to -826	1,140 to 1,145	red-brown, sticky mud with mafic rock
-826 to -831	1,145 to 1,150	red-brown, sticky mud

¹rotary-drilling cuttings lifted with air, foam, and polymer. Sample repository: U.S. Geological Survey, Hawaii District office. Date of logging: May, 1996.

Appendix 2. Data from step-drawdown aquifer test, March 20, 1996, Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii
 [min, minutes; ft, feet; gal/min, gallons per minute; depth to water measured from 320.12 ft above mean sea level; -, no measurement made]

Time (min)	Depth to water (ft)	Drawdown (ft)	Pumping rate (gal/min)
0	171.98	0	-
1	183.51	11.53	-
2	204.25	32.27	100
3	210.34	38.36	65
4	208.79	36.81	65
5	203.14	31.16	-
6	203.13	31.15	43
7	203.02	31.04	-
8	202.81	30.83	40
9	202.51	30.53	-
10	202.47	30.49	40
11	202.29	30.31	-
12	202.15	30.17	40
13	202.11	30.13	-
14	202.12	30.14	40
15	202.09	30.11	38
20	202.07	30.09	39
25	202.26	30.28	40
30	202.30	30.32	39
35	202.20	30.22	39
40	202.08	30.10	39
50	201.90	29.92	39
60	201.85	29.87	40
61	215.84	43.86	118
62	230.93	58.95	-
63	228.38	56.40	85
64	227.51	55.53	80
65	232.81	60.83	100
66	230.96	58.98	94
67	230.06	58.08	87
68	229.75	57.77	-
69	229.25	57.27	65
70	233.53	61.55	125
71	234.78	62.80	103
72	236.04	64.06	-
73	237.14	65.16	-
74	237.65	65.67	-
75	238.27	66.29	101
80	240.05	68.07	101
85	240.71	68.73	100
90	241.09	69.11	99
95	241.33	69.35	98
100	241.76	69.78	97
110	242.19	70.21	97
120	242.32	70.34	97
121	242.45	70.47	100
122	242.51	70.53	100
123	248.43	76.45	140
124	251.17	79.19	160
125	256.73	84.75	160
126	259.53	87.55	167
127	260.59	88.61	-

Appendix 2. Data from step-drawdown aquifer test, March 20, 1996, Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii--Continued
 [min, minutes; ft, feet; gal/min, gallons per minute; depth to water measured from 320.12 ft above mean sea level; -, no measurement made]

Time (min)	Depth to water (ft)	Drawdown (ft)	Pumping rate (gal/min)
128	261.22	89.24	167
129	261.87	89.89	-
130	262.12	90.14	-
131	262.42	90.44	160
132	262.68	90.70	-
133	262.82	90.84	-
134	262.91	90.93	160
135	262.96	90.98	-
140	263.38	91.40	155
145	267.48	95.50	180
150	268.19	96.21	180
155	268.53	96.55	180
160	268.8	96.82	173
170	269.16	97.18	174
180	269.38	97.40	174
181	273.49	101.51	200
182	278.42	106.44	280
183	280.13	108.15	260
184	283.38	111.40	275
185	285.52	113.54	290
186	286.56	114.58	-
187	287.76	115.78	280
188	289.55	117.57	290
189	290.54	118.56	292
190	291.49	119.51	297
191	292.32	120.34	-
192	293.07	121.09	-
193	293.74	121.76	297
194	293.99	122.01	-
195	294.16	122.18	-
200	295.07	123.09	297
205	296.32	124.34	-
210	296.98	125.00	296
215	297.45	125.47	297
220	297.96	125.98	-
230	298.83	126.85	297
240	299.55	127.57	300
241	276.48	104.50	0
242	264.97	92.99	0
243	258.92	86.94	0
244	255.38	83.40	0
245	252.63	80.65	0
246	250.00	78.02	0
247	249.18	77.2	0
248	247.69	75.71	0
249	246.41	74.43	0
250	245.42	73.44	0
255	241.73	69.75	0
260	238.53	66.55	0
265	233.52	61.54	0
270	230.85	58.87	0
280	227.07	55.09	0
290	224.21	52.23	0
300	223.52	51.54	0

Appendix 2. Data from step-drawdown aquifer test, March 20, 1996, Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii--Continued
 [min, minutes; ft, feet; gal/min, gallons per minute; depth to water measured from 320.12 ft above mean sea level; -, no measurement made]

Time (min)	Depth to water (ft)	Drawdown (ft)	Pumping rate (gal/min)
330	220.82	48.84	0
360	219.18	47.20	0
390	217.91	45.93	0
420	216.94	44.96	0
480	213.03	41.05	0
540	211.87	39.89	0
1,380	203.45	31.47	0
1,620	202.52	30.54	0
1,920	199.61	27.63	0
2,880	194.03	22.05	0
4,320	188.14	16.16	0

Appendix 3. Data from 4-day sustained-rate aquifer test, April 2–6, 1996, Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii

[min, minutes; ft, feet; gal/min, gallons per minute; °C, degrees Celsius; μS/cm, microsiemens per centimeter at 25°C; static water level at start of test was 147.41 feet above mean sea level; depth to water measured from 322.61 feet above mean sea level; -, no measurement made]

Time (min)	Depth to water (ft)	Drawdown (ft)	Pumping rate (gal/min)	Drawdown, corrected for well loss (ft)	Temperature (°C)	Specific conductance (μS/cm)
0	175.20	0	0	0	-	-
1	227.00	51.80	-	1.81	-	-
2	250.20	75.00	-	25.01	-	-
3	261.50	86.30	-	36.31	-	-
4	269.41	94.21	-	44.22	-	-
5	275.35	100.15	-	50.16	-	-
6	278.52	103.32	308	53.33	-	-
7	279.26	104.06	-	54.07	-	-
8	279.41	104.21	308	54.22	-	-
9	280.36	105.16	-	55.17	-	-
10	281.20	106.00	-	56.01	-	-
11	281.79	106.59	-	56.60	-	-
12	282.43	107.23	308	57.24	-	-
13	283.71	108.51	-	58.52	-	-
14	284.06	108.86	-	58.87	24.9	302
15	284.65	109.45	308	59.46	-	-
20	286.26	111.06	307	61.39	-	-
25	287.03	111.83	-	62.16	24.9	304
30	287.72	112.52	306	63.17	-	-
35	288.64	113.44	-	64.09	-	-
40	289.60	114.40	-	65.05	-	-
50	291.39	116.19	-	66.84	-	-
60	292.16	116.96	305	67.94	-	-
70	293.00	117.80	-	68.78	-	-
80	293.73	118.53	-	69.51	-	-
90	294.44	119.24	305	70.22	25.0	308
100	294.79	119.59	-	70.57	-	-
120	295.78	120.58	-	71.56	-	-
140	296.44	121.24	305	72.22	25.2	313
160	297.23	122.03	-	73.01	25.3	313
180	297.84	122.64	304	73.94	-	-
210	298.75	123.55	-	74.85	-	-
240	299.27	124.07	-	75.37	25.2	322
270	300.01	124.81	304	76.11	-	-
300	300.42	125.22	-	76.52	25.1	328
360	301.27	126.07	303	77.69	25.3	333
420	302.21	127.01	-	78.63	-	-
480	302.90	127.70	302	79.64	25.1	328
780	305.84	130.64	303	82.26	25.3	371
1,380	309.43	134.23	305	85.21	24.9	434
1,440	309.51	134.31	303	85.93	25.4	444
1,740	310.77	135.57	300	88.14	-	-
1,920	311.42	136.22	298	89.42	26.1	496
2,820	314.64	139.44	300	92.01	25.9	658
3,000	315.04	139.84	298	93.04	-	-
3,120	315.29	140.09	300	92.66	26.8	731

Appendix 3. Data from 4-day sustained-rate aquifer test, April 2–6, 1996, Pukaki Reservoir monitor well (State well 2-0023-01), Kauai, Hawaii--Continued

[min, minutes; ft, feet; gal/min, gallons per minute; °C, degrees Celsius; μS/cm, microsiemens per centimeter at 25°C; static water level at start of test was 147.41 feet above mean sea level; depth to water measured from 322.61 feet above mean sea level; -, no measurement made]

Time (min)	Depth to water (ft)	Drawdown (ft)	Pumping rate (gal/min)	Drawdown, corrected for well loss (ft)	Temperature (°C)	Specific conductance (μS/cm)
3,360	316.12	140.92	298	94.12	26.8	800
4,200	223.00	47.80	0	47.80	-	-
4,208	276.00	100.80	302	52.74	-	-
4,320	310.24	135.04	302	86.98	25.9	602
4,380	312.02	136.82	300	89.39	26.6	874
4,440	313.20	138.00	300	90.57	26.9	908
4,500	313.98	138.78	299	91.67	27.0	919
4,740	316.19	140.99	298	94.19	-	-
4,800	316.52	141.32	298	94.52	26.8	955
5,700	320.71	145.51	298	98.71	26.6	1,001
5,701	291.42	116.22	0	116.22	-	-
5,702	284.19	108.99	0	108.99	-	-
5,703	279.18	103.98	0	103.98	-	-
5,704	276.22	101.02	0	101.02	-	-
5,705	274.09	98.89	0	98.89	-	-
5,706	272.62	97.42	0	97.42	-	-
5,707	271.01	95.81	0	95.81	-	-
5,708	270.10	94.90	0	94.90	-	-
5,709	268.88	93.68	0	93.68	-	-
5,710	268.21	93.01	0	93.01	-	-
5,715	265.35	90.15	0	90.15	-	-
5,720	263.42	88.22	0	88.22	-	-
5,725	261.68	86.48	0	86.48	-	-
5,730	260.63	85.43	0	85.43	-	-
5,740	259.20	84.00	0	84.00	-	-
5,750	257.96	82.76	0	82.76	-	-
5,760	257.00	81.80	0	81.80	-	-
5,790	254.79	79.59	0	79.59	-	-
5,820	253.46	78.26	0	78.26	-	-
5,970	236.05	60.85	0	60.85	-	-