USGS
science for a changing world

Construction, Geologic, and Hydrologic Data from Five Exploratory Wells on Rota, Commonwealth of the Northern Mariana Islands, 1999

Prepared in cooperation with the
COMMONWEALTH UTILITIES CORPORATION,
COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

Open-File Report 2005-1042

U.S. Department of the Interior
U.S. Geological Survey

Construction, Geologic, and Hydrologic Data from Five Exploratory Wells on Rota, Commonwealth of the Northern Mariana Islands, 1999

By Robert L. Carruth

Prepared in cooperation with the
COMMONWEALTH UTILITIES CORPORATION,
COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

Open-File Report 2005-1042

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2005
For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225

For more information about the USGS and its products:
Telephone: 1-888-ASK-USGS
World Wide Web: http://www.usgs.gov/

Suggested citation: Carruth, R.L., 2005, Construction, geologic, and hydrologic data from five exploratory wells on Rota, Commonwealth of the Northern Mariana Islands, 1999 : U.S. Geological Survey Open-File Report 2005-1042, 40 p.

Contents

Figures

Tables

Appendices Provided in Excel Format

Conversion Factors and Datum

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometers (km)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	1,461	cubic meter per day per square kilometer [$(m^3/d)/km^2$]

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F = (1.8 x °C) + 32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (°F - 32) / 1.8

Vertical coordinate information is referenced relative to mean sea level.

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Construction, Geologic, and Hydrologic Data from Five Exploratory Wells on Rota, Commonwealth of the Northern Mariana Islands, 1999

By Robert L. Carruth

Abstract

Rota is the southernmost of the 14 small islands that make up the Commonwealth of the Northern Mariana Islands. Reduced springflow at Matan Hanom and As Onan springs occurred during a drought associated with the 1997-98 El Niño. Water from the two developed springs constituted the only municipal water source for the island at that time. In April 1998, reduced water supplies forced the Commonwealth Utilities Corporation to restrict water service in the principal villages of Songsong and Sinapalu for the duration of the dry season.

In 1999, Five exploratory wells, EX-1 through EX-5 (CUC wells SP-MW1, SP-1, -2, -3, and SP-MW2), were drilled in the Sinapalu region of Rota to (1) assess the availability of fresh ground-water resources in an area where no other well information were available, and (2) to provide a new water source to help mitigate the impacts of drought associated with recurring El Niño weather events. The wells penetrated mainly light colored (dirty white to brownish), fragmental limestones containing abundant coral remains.

Sustained-rate, recovery, and step-drawdown aquifer tests were attempted at each of the five exploratory wells to estimate aquifer properties in the vicinity of the wells and to assess the potential for new water sources. At wells EX-1 (CUC well SP-MW1) and EX-5 (CUC well SP-MW2), attempts to conduct sustained-rate aquifer tests resulted in excessive drawdown to the pump intakes in the vicinity of the wells. At well EX-2 (CUC well SP-1), the maximum drawdown measured in the pumped well was 3.93 ft during 8 days of sustained pumping at an average rate of 187 gal/min. At well EX-3 (CUC well SP-2), the maximum drawdown measured in the pumped well was 2.31 ft during 8 days of sustained pumping at an average rate of 108 gal/min, and at well EX-4 (CUC well SP-3), the maximum drawdown measured in the pumped well was 3.27 ft during 8 days of sustained pumping at an average rate of 139 gal/min. Specific conductance at the end of 8 days of pumping was 403, 358, and 445 µS/cm at well EX-2, EX-3, and EX-4 (CUC wells SP-1, -2, and -3), respectively.

Introduction

The island of Rota is about 45 mi north-northeast of Guam in the western Pacific and lies between 14°06’ and 14°12’ north latitude and between 145°07’ and 145°17’ east longitude (fig. 1). The island is oriented on an east-west axial direction and is approximately 11.5 mi long and 3 mi wide. Including two small islets along the west shore, the land area of Rota is about 33 mi^2 or about 15 percent of the land area of Guam. Rota is the southernmost of the 14 small islands that make up the Commonwealth of the Northern Mariana Islands.

Water-supply shortages occur on Rota during extended dry periods, which are often attributed to the El Niño. The 1997–98 El Niño in the Northern Mariana Islands was marked by four destructive typhoons (Wynne, Joan, Keith, and Paka) followed by a drought. Rainfall at the Rota Airport in 1998 was 58 in., which is about 40 percent below the annual average of 95 in. (Chip Guard, National Weather Service, pers. commun.). Flows from the Matan Hanom and As Onan springs, the only municipal water-supply source for the island, also were below normal in 1998. From April through June 1998, the Commonwealth Utilities Corporation (CUC) was forced for the first time to restrict water service in the principal villages of Songsong and Sinapalu.

In March 1998, the Federal Emergency Management Agency (FEMA) approved a grant application from the CUC for Hazard Mitigation Grant Program (HMGP) funding. Part of the federal funding was for water-supply augmentation projects on Rota to help mitigate the impacts of future droughts. As a result, the U.S. Geological Survey (USGS), in cooperation with the CUC, (1) selected locations for five exploratory wells and provided oversight during drilling operations, (2) collected aquifer-test data to determine the availability of fresh ground water at the five exploratory wells, and (3) and reviewed water-quality data. The five exploratory wells (EX-1 through EX-5) were sited in the Sinapalu region (fig. 2), an area where no wells had been drilled and no subsurface information were available.

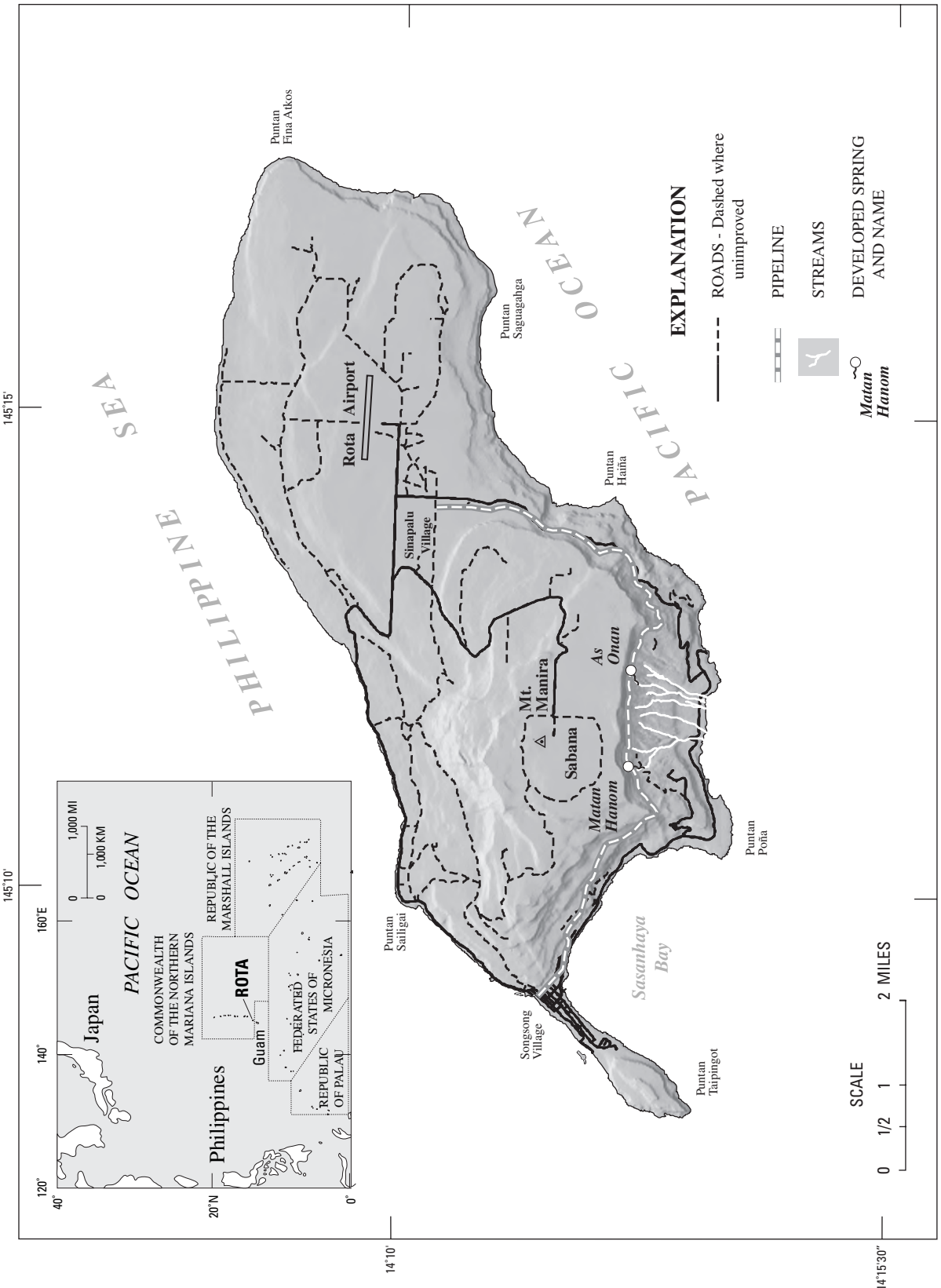

Figure 1. Location and shaded relief of Rota, Comonwealth of the Northern Mariana islands.

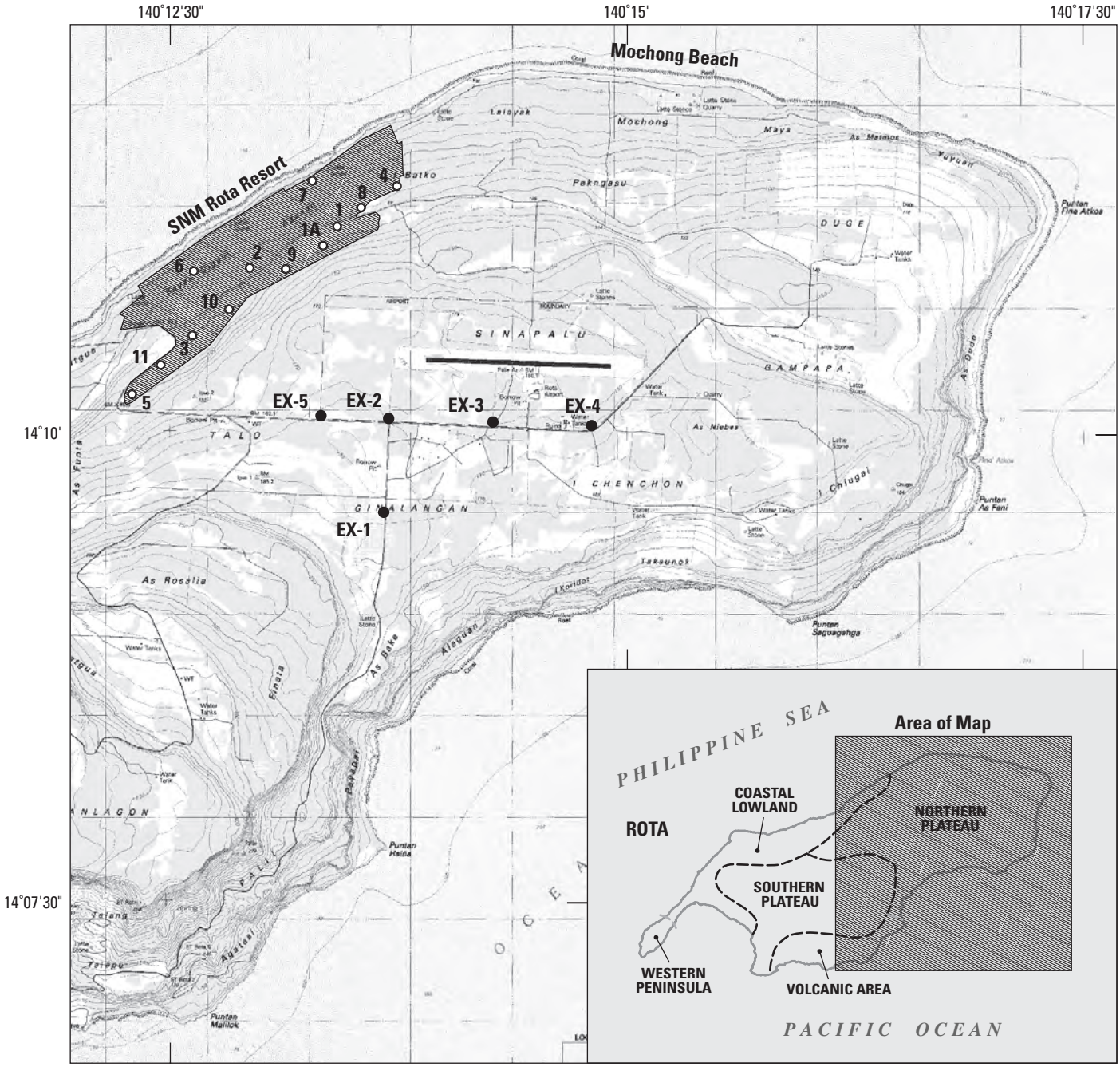

Figure 2. Location of the five exploratory wells drilled in 1999 and pre-existing wells in the northern plateau, Rota. (Inset map modified from Bridge, 1947)

The objectives of this project were met by analysis of data collected during and after the drilling operations. These data included (1) the driller's description of well-construction details and the drilling history, (2) a description of the geology from the rock chips (drill cuttings) brought to the surface during drilling, (3) sustained-rate, recovery, and step-drawdown tests at wells EX-2, -3, and -4, (4) a review of water-quality data at wells EX-2, -3, and -4, and (5) a review of water-level data collected at wells EX-1 through EX-5. This report documents the location, drilling history, construction details, geology, aquifer-test, water-level, and water-quality data of the five exploratory wells on Rota.

Physical Setting

Rota is a subareal peak on the Mariana Island Arc and consists of a volcanic core overlain by younger limestones (fig. 3). Mt. Manira is the highest point on the island at an elevation of 1,612 ft above sea level. Undifferentiated, coralline limestone rocks cover most of the surface area above sea level, occurring as a series of plateaus separated by steep scarps. Less than 10 percent of the exposed area is volcanic rock. Younger beach deposits mantle the older longshore limestone benches and the entire island is surrounded by a fringing reef in a relatively young stage of development (Piper, 1947).

The five exploratory wells are located in the Sinapalu region of Rota, a coralline limestone plateau in the northeastern section of the island that contains the Sinapalu Village and the Rota Airport (fig. 2). This limestone plateau, referred to as the northern plateau by Bridge (1946), ranges in large part between 500 and 625 ft above sea level, and is part of a large plateau that roughly comprises the eastern half of the island. The southern and eastern sides of the plateau are discontinuously terraced and terminate in pronounced cliffs that lead to a rocky shoreline. In the north, the plateau gradually slopes in an unterraced ramp toward the sea, terminating at the Mochon Beach area.

The corralline limestones which make up the northern plateau have been described by Piper (1947) as largely compact, massive or indistinctly bedded, and locally including moderately consolidated reef rubble. The surface of the northern plateau is thinly mantled by residual soil, lacks surface streams, and has subdued epikarst features. The features of the limestone rocks of the northern plateau are consistent with other Pleistocene limestones in the Mariana Islands whose properties include moderate to high transmission of ground water.

Prior to 1999, ground-water exploration on the northern plateau was limited to the site of the SNM Rota Resort located east-northeast of the Sinapalu area (fig. 2). In 1991 and 1992, 11 exploratory wells were drilled to investigate the availability of ground-water resources beneath the SNM Rota Resort site. The borings, ranging from 120 to 400 ft below land surface, encountered medium-hard to hard, pure to argillaceous coralline limestone of varying color (white, yellow, and tan) throughout the drilled depths. Cavities of various sizes were encountered in most of the test holes. Static (non-pumping) ground-water levels at wells along the inland boundary of the resort's property are between 2 and 4 ft, and range from about 1 to 2 ft at wells along the seaward boundary. Nance (1993) reported that results of the drilling and testing indicate the presence of an exploitable freshwater lens and recommended further study to characterize the hydrologic properties of the aquifer beneath the site. Eight of the original 11 exploratory wells were converted to water-supply wells in 1993 and are operated intermittently for a water source for the golf course and resort. Of the remaining three wells, the two drilled near the seaward boundary of the resort were converted to monitor wells and one well was abandoned due to low yield.

Ground-water exploration in the northern plateau has been moderately successful within the limited area of drilling and testing (SNM Rota Resort), owing in part to the generally moderate-to-high permeabilities of the limestones. However, low permeability zones in the limestones occur, evidenced in part by a wide range of specific capacities of exploratory wells at the resort (Nance, 1993). The thickness and structure of the limestones of the northern plateau is unknown and thus far, none of the exploratory wells have encountered the volcanic basement rock. The limited information available indicate that a freshwater lens of significant thickness and aerial extent may exist in the limestones that make up the northern plateau; however, the occurrence and movement of ground water within the plateau remain largely unknown.

Location and Name of Wells

The five exploratory wells (EX-1 through EX-5) are located in the Sinapalu area of the northern plateau of Rota (fig. 2 and table 1). Four of the wells (EX-2 through EX-5) are located along the road that makes up the southern boundary of the Rota Airport. Well EX-1 is located within the Sinapalu Village inside the fenced area that contains the 0.5 Mgal Sinapalu water-storage reservoir. All five wells are located on land that is administered by the government of the Commonwealth of the Northern Mariana Islands (CNMI).

Well EX-4 is located 0.5 mi east of the intersection of the road leading north into the Rota Airport with the road heading east towards Gampapa and west towards the entrance to Sinapalu Village and further west towards the entrance to the SNM Rota Resort (herein referred to as the airport intersection). Well EX-3 is located 0.2 mi west of the airport intersection, and wells EX-2 and EX-5 are located 0.9 mi west and 1.3 mi west of the airport intersection, respectively. Well EX-1 is located 0.5 mi south of well EX-2 along the road leading into the Sinapalu Village.

Upon completion of drilling and testing, the CUC assigned well names according to their well-naming system for water-supply wells and monitor wells. The well-naming system uses a two-letter abbreviation for the place name on the island (SP for Sinapalu) with sequential numbering for water-supply wells (SP-1, for example). Similarly, monitor wells are assigned the two-letter place name abbreviation, a two-letter abbreviation for monitor well, and a sequential number (SP-MW1, for example).

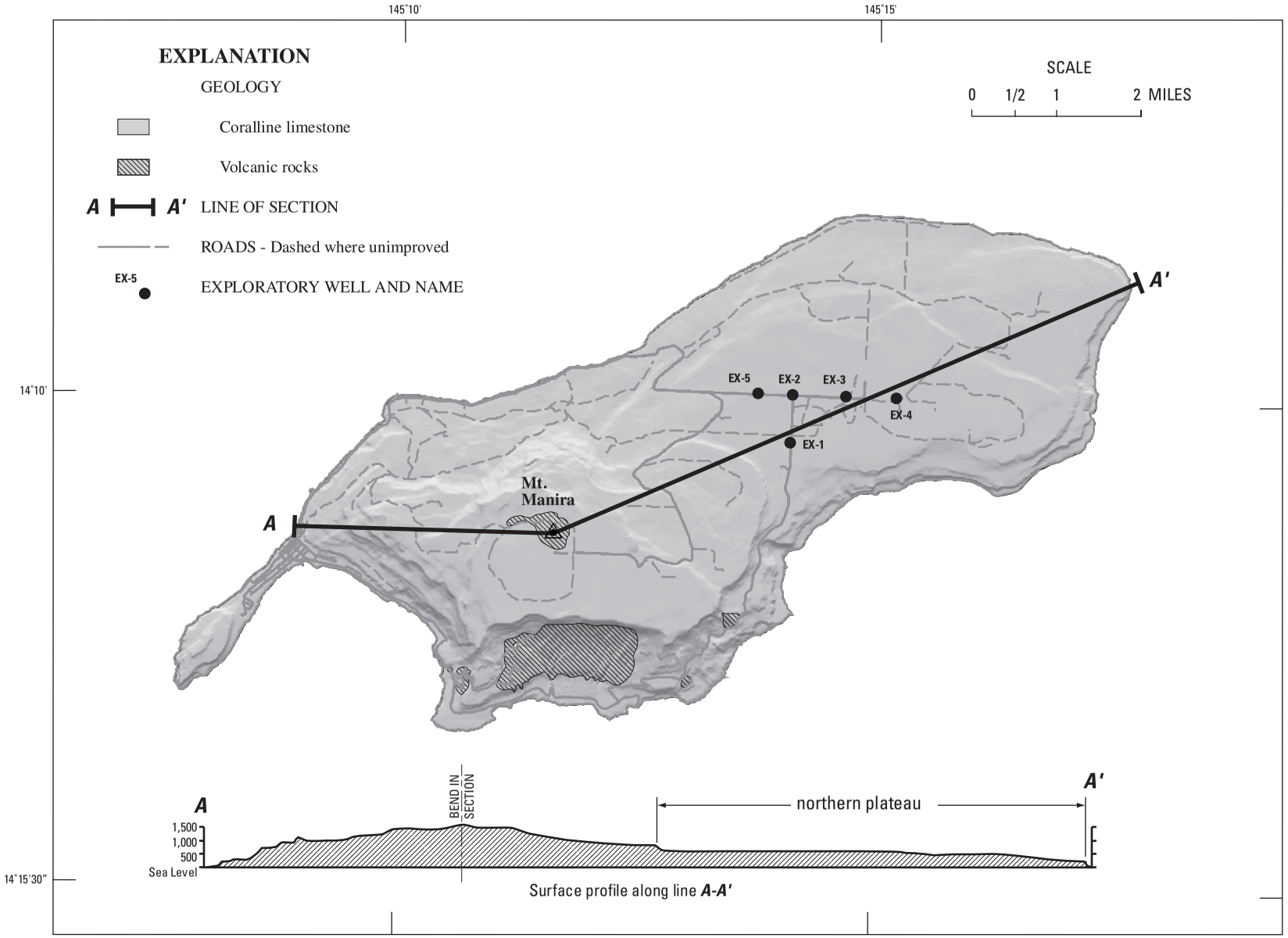

Figure 3. Generalized surficial geology of Rota (modified from Piper, 1947).

Table 1. Exploratory well name, CUC well name, location, and elevation of the five exploratory wells on Rota

[datum is mean sea level]

Exploratory well name	CUC well name	Latitude[1]	Longitude[1]	Approximate elevation of land surface, (feet)	Elevation of brass monument in concrete well pad, (feet)	Elevation of measuring point, (feet)	Location of measuring point
EX-1	SP-MW 1	14 09 37	145 13 40	602	603.16	603.98	Top of casing
EX-2	SP-1	14 10 03	145 13 42	593	594.06	594.53	Top of sounding tube
EX-3	SP-2	14 10 03	145 14 16	573	575.91	576.38	Top of sounding tube
EX-4	SP-3	14 10 02	145 14 48	570	570.19	570.71	Top of sounding tube
EX-5	SP-MW 2	14 10 05	145 13 20	590	591.07	591.52 (592.16)	Top of sounding tube (top of casing)

[1]Estimated from 1:25,000 USGS topographic map, revised in 1999. North American Datum of 1983.

Acknowledgments

The construction, data collection, and testing of the five exploratory wells were made possible with the cooperation and assistance of Mr. Rodel Alvidera, Drilling Project Engineer for Geotesting Inc., and Mr. Danny Barrion, Drilling Project Manager for the CUC. I am grateful to Mr. Don Smith, Technical Assistance Engineer for the CUC, for his technical input and drilling contract oversight. Drilling, aquifer-test, and elevation information were drawn extensively from the notes of Mr. Charles Ewart of the U.S. Geological Survey (retired).

Data were compiled from the following agencies:

Commonwealth Utilities Corporation (CUC)

Geotesting Inc.

Permits or permission were obtained from the following agencies:

Commonwealth Ports Authority (CPA)

Commonwealth Department of Environmental Quality (DEQ)

Commonwealth Historical Preservation Office (HPO)

Commonwealth Department of Land and Natural Resources (DLNR)

Assistance from these agencies in support of the exploratory drilling and testing program is gratefully acknowledged. Field and office support from the staff of CUC is also appreciated.

Drilling Methods and History

The wells were initially bored by rotary drilling with a 9-7/8-in. diameter tungsten-carbide tri-cone bit. Air and drilling foam were injected down through the hollow drill stem and circulated back up the annular space between the drill stem and the well boring to remove cuttings from the hole. When the initial pilot borings neared the target depth of -15 ft relative to mean sea level, the drill stem and bit were removed and the holes were reamed to 13-in. diameter by rotary drilling with a 13-in. hole-opening tool down to the target depth of -15 ft. Tables 2–6 and figures 4–8 summarize the construction of the five wells.

The elevation of the brass plate in the concrete pad at well EX-1 (SP-MW1) is 603.16 ft and the well is 745 ft deep (bottom is at -143 ft elevation). The well was initially drilled to -15 ft elevation, the target depth for initial testing. The initial water level was about 3.95 ft elevation. An aquifer test was attempted but had to be terminated due to rapid drawdown and low yield. A decision was made to install 8-in. steel casing, with perforations between the water table and the initial bottom at -15 ft, and to deepen the well from the elevation of -15 ft to -143 ft (total depth of 745 ft from land surface). The well was deepened by lowering a 7 7/8-in. diameter bit through the 8-in. steel casing to continue drilling beyond -15 ft. Flush-threaded 6-in. polyvinyl-chloride (PVC) casing, with perforations between the water table and the bottom, was installed. The well was designated as a monitor well and renamed by the CUC to SP-MW1. CUC well SP-MW1 will be used as a vertical-profiling well to monitor the thickness of the freshwater lens and the movement of the transition zone. Table 2 summarizes the construction history of the well. A drawing of the construction details of the finished well is shown in figure 4.

The elevation of the brass plate in the concrete pad at well EX-2 (SP-1) is 594.06 ft and the well is 608 ft deep (bottom is at -15 ft elevation). A void in the limestone was encountered at 3 ft elevation and drilling fluid circulation was lost as the drill bit penetrated from 3 ft (590 ft deep) to -8 ft elevation (601 ft), where drilling fluid circulation to the surface resumed. The ini-

tial water-level elevation was 3.75 ft. Two aquifer tests were conducted in the open hole before the casing was installed, an 8-day sustained-rate test and a step-drawdown test. During the 8-day sustained-rate test, the well was pumped at an average rate of 187 gal/min. Upon completion of the aquifer tests, the well was cased with 8-in. solid steel casing, with a 20-ft section of stainless steel well screen at the bottom. The bottom of the screen is at -12 ft elevation. A 30-HP submersible pump was installed and the pump intake set at about -7 ft elevation. The well was designated as a CUC water-supply well and renamed to SP-1. Table 3 summarizes the construction history of the well. A drawing of the construction details of the finished well is shown in figure 5.

The elevation of the brass plate in the concrete pad at well EX-3 (SP-2) is 575.91 ft and the well is 588 ft deep (bottom is at -15 ft elevation). The initial water-level elevation was 4.34 ft. Sustained-rate and step-drawdown aquifer tests were conducted in the open hole before casing was installed. During the 8-day sustained-rate test, the well was pumped at an average rate of 108 gal/min. Upon completion of the aquifer tests, the well was cased with 8-in. solid steel casing, with a 20-ft section of stainless steel well screen at the bottom. The bottom of the screen is at -14 ft elevation. A 30-HP submersible pump was installed and the pump intake set at about -7 ft elevation. The well was designated as a CUC water-supply well and renamed to SP-2. Table 4 summarizes the construction history of the well. A drawing of the construction details of the finished well is shown in figure 6.

The elevation of the brass plate in the concrete pad at well EX-4 (SP-3) is 570.19 ft and the well is 585 ft deep (bottom is at -15 ft elevation). The initial water-level elevation was 3.33 ft. Sustained-rate and step-drawdown aquifer tests were conducted in the open hole before casing was installed. During the 8-day sustained-rate test, the well was pumped at an average rate of 139 gal/min. Upon completion of the aquifer tests, the well was cased with 8-in. solid steel casing, with a 20-ft section of stainless steel well screen at the bottom. The bottom of the screen is at -13 ft elevation. A 30-HP submersible pump was installed and the pump intake set at about -7 ft elevation. The well was designated as a CUC water-supply well and renamed to SP-3. Table 5 summarizes the construction history of the well. A drawing of the construction details of the finished well is shown in figure 7.

The elevation of the brass plate in the concrete pad at well EX-5 (SP-MW2) is 591.07 ft and the well is 605 ft deep (bottom is at -15 ft elevation). The initial water-level elevation was 3.17 ft. An aquifer test was attempted but had to be terminated due to rapid drawdown and low yield. A decision was made to install 8-in. steel casing, with perforations between the water table and the bottom at -15 ft. The well was designated as a monitor well and renamed by the CUC to SP-MW2. CUC well SP-MW2 will be used as a water-table monitoring well to monitor the movement of the water table in response to recharge, ocean level, and ground-water withdrawal. Table 6 summarizes the construction history of the well. A drawing of the construction details of the finished well is shown in figure 8.

Table 2. Construction summary of exploratory well EX-1 (SP-MW1), Rota

[Datum for water-level and bottom-of-hole elevation is mean sea level. Land surface elevation is about 602 ft above mean sea level; ft, feet]

Date		Significant events
July 1999	12	Drilling began. Drilled from 602 ft to 492 ft elevation (depth of 0 to 110 ft). Rupture of the control panel hydraulic hose at 10:30 AM, repaired by 2:35 PM
	13	Continued drilling from 492 ft to 332 ft elevation (depth of 110 to 270 ft). Breakdown on the starter at 3:30 PM
	15	Installed rig starter by 8:15 AM and continued drilling from 332 ft to 152 ft elevation (depth of 270 to 450 ft)
	16	Continued drilling from 152 ft to -7 ft elevation (depth of 450 to 609 ft)
	19	Began pulling out drill pipes until 3:20 PM, began reaming the hole until 4:00 PM
	27	Completed reaming the hole, pulled out drill bit
August 1999	25	Continued drilling at 1:00 PM, reached final depth of -15 ft elevation (total depth of 617 ft) at 1:30 PM
September 1999	14	Began installation of pump assembly for pumping-test
	15	Completed installation of pump assembly
	16	Attempted to conduct sustained-rate aquifer test; terminated due to high drawdown and low yield
November 1999	12	Began installation of 8" steel casing and well screen
	15	Completed installation of 8" steel casing and well screen
	16	Began to grout the hole
	17	Completed grouting the hole
	19	Began deepening of hole from -15 ft to -143 ft elevation (final depth of 745 ft)
	22	Began installation of 6" PVC casing and well screen
	23	Completed installation of 6" PVC casing and well screen
February 2000	17	Water level altitude at 3.95 ft elevation

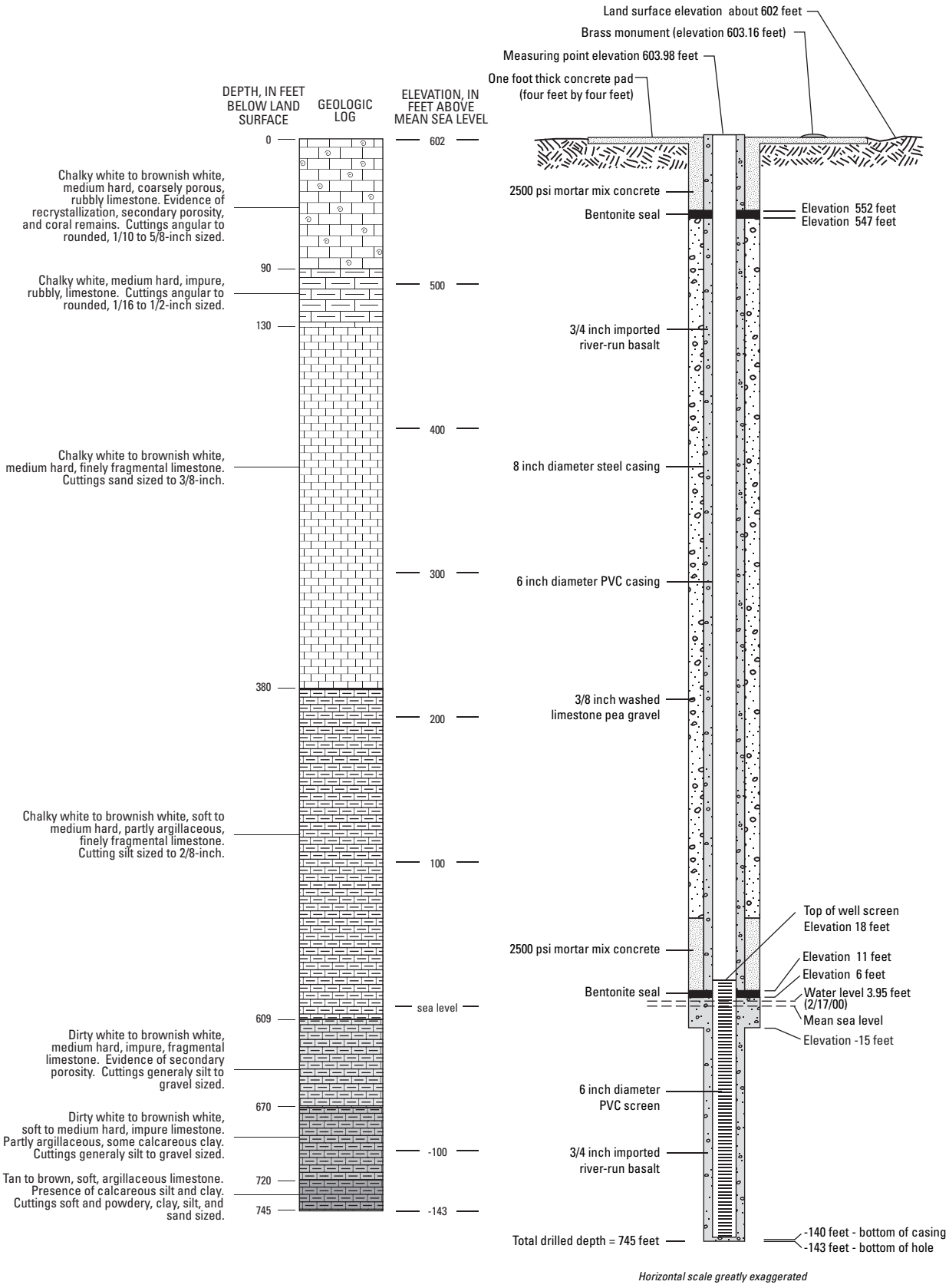

Figure 4. Geologic log and construction details of well EX-1 (CUC well SP-MW1), Rota.

Table 3. Construction summary of exploratory well EX-2 (SP-1), Rota

[Datum for water-level and bottom-of-hole elevation is mean sea level. Land surface elevation is about 593 ft above mean sea level; ft, feet; gal/min, gallons per minute]

Date		Significant events
July 1999	28	Drilling began. Drilled from 593 ft to 453 ft elevation (depth of 0 to 140 ft). Leaking hydraulic hose and head gasket, repaired by 10:30 AM. Bean pump repaired by 1:20 PM
	29	Continued drilling from 453 ft to 253 ft elevation (depth of 140 to 340 ft)
	30	Continued drilling from 253 ft to 83 ft elevation (depth of 340 to 510 ft)
August 1999	02	Continued drilling to -2 ft elevation (depth of 595 ft)
	03	Pulled out drill pipes and prepared 13 " hole opener to ream the hole. Sound the hole at 3:00 PM, no water detected
	04	Began reaming the hole. Breakdown on hydraulic motor occurred at 3:00 PM
	05	Repaired hydraulic motor. Continued reaming the hole
	11	Completed reaming the hole, pulled out the drill bit
	19	Installed 14" x 2' PVC casing in hole. Breakdown on starter motor for compressor engine
	20	Repaired starter motor by 10:00 AM. Hole deepened, using 12" bit; Void encountered at about 3 ft elevation (590 ft), circulation returned at about -8 ft elevation (601 ft); drilling terminated at -15 ft elevation (total depth of 608 ft)
	21	Began installation of pump assembly for sustained-rate aquifer test
	23	Completed installation of pump assembly for sustained-rate aquifer test, Breakdown on generator occurred.
	28	Began pre-sustained-rate aquifer test at 9:45 AM, terminated due to undeveloped well, clogged well screen, and generator problems. Conducted a second pre-sustained-rate aquifer test at 2:30 PM, water began to clear after 3 attempts of pre-sustained-rate aquifer test.
	30	Began 8-day sustained-rate aquifer test at 172 gal/min
September 1999	07	Terminated 8-day sustained-rate aquifer test at 5:44 PM; began recovery test at 5:45 PM; terminated recovery test at 8:15 PM.
	08	Performed first step-drawdown test at 10:13 AM, completed step-drawdown test at 3:15 PM.
	10	Pulled out pump assembly
November 1999	11	Prepared and completed installation of concrete pad
	16	Grout the hole, including the concrete pad
	27	Began installation of casing and well screen
	28	Completed installation of casing and well screen, bottom of screen is at -12 ft elevation (605 ft)
December 1999	10	Installed pump and motor for production well
February 2000	17	Water level altitude at 3.75 ft elevation

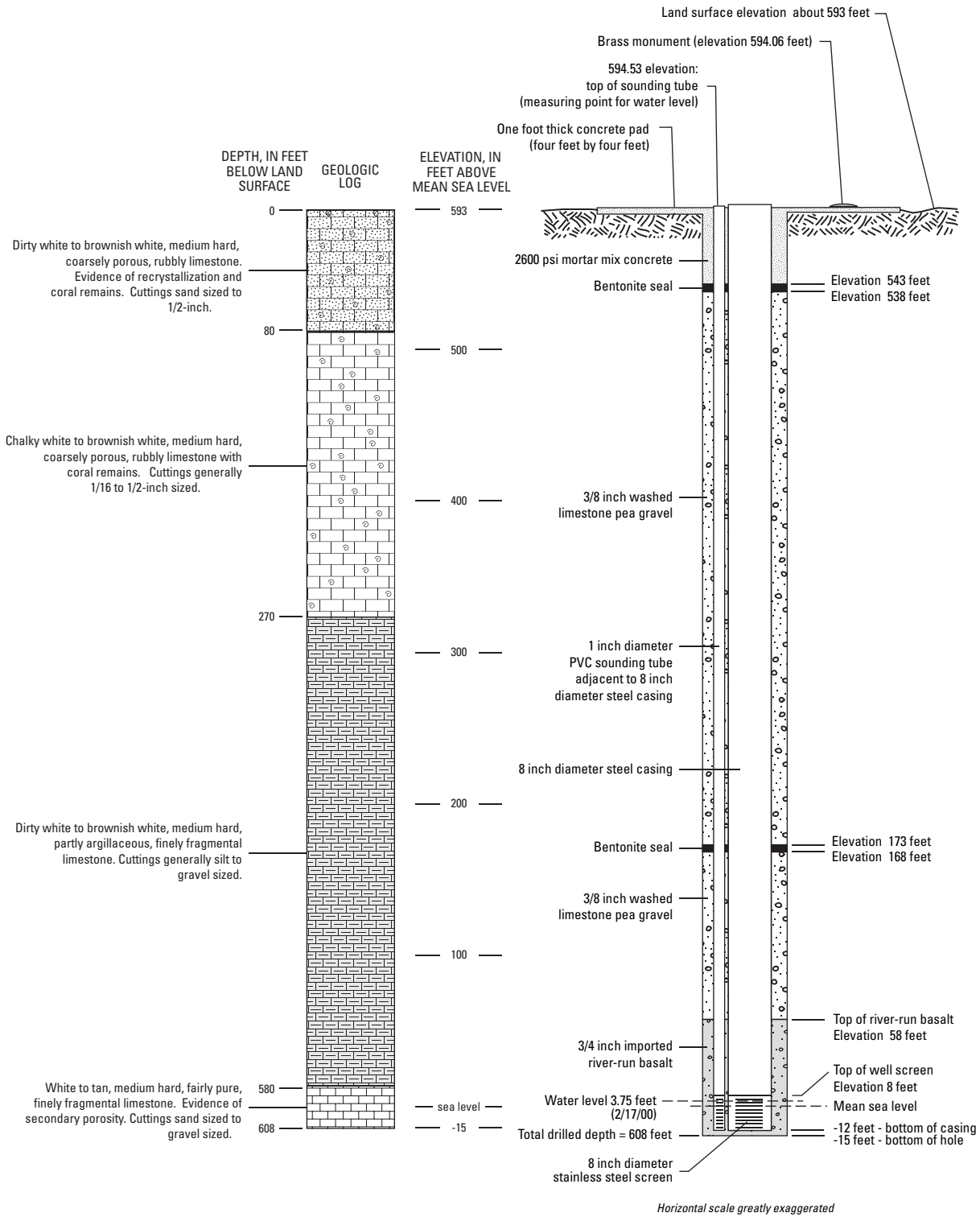

Figure 5. Geologic log and construction details of well EX-2 (CUC well SP-1), Rota.

Table 4. Construction summary of exploratory well EX-3 (SP-2), Rota

[Datum for water-level and bottom-of-hole elevation is mean sea level. Land surface elevation is about 573 ft above mean sea level; ft, feet; gal/min, gallons per minute]

Date		Significant events
October 1999	12	Set up rig and started drilling at 9:30 AM, drilled to 393 ft sea level elevation
	13	Continue drilling 7:00 AM
	14	Completed the pilot hole drilling at -15 ft sea level elevation (total depth of 588 ft), possible change of formation at bottom of hole, found light greenish-brown clay attached to the drill bit, USGS representative was present and took sample when the hole was reamed.
	15	Pulled out drill bit, installed hole opener and began reaming the hole
	19	Completed reaming the hole
	21	Began installation of pump assembly for sustained-rate aquifer test
	22	Completed installation of pump assembly. Problem encountered after 46 minutes of pump test run, motor burned out, scheduled to pull out pump
	23	Pulled out pump. Pump was burned and inoperable.
	25	Pump from Saipan office received, pump installed, encountered another problem; possible breakdown on submersible pump. Decided to pull out pipes and replace pump
	26	Installed CUC pump and motor
	27	Began 8-day sustained-rate aquifer test at 8:30 AM, 112 gal/min
November 1999	04	Terminated 8-day sustained-rate aquifer test at 8:30 AM; performed recovery test at 8:31 AM, end recovery test at 11:01 AM; start step-drawdown test at 12:00 PM, completed step-drawdown test at 4:34 PM.
	05	Pulled out pump
	09	Began installation of casing and well screen
	10	Completed installation of casing and well screen
	17	Grout the hole
December 1999	09	Installed pump and motor for production well
February 2000	17	Water level altitude at 4.34 ft elevation

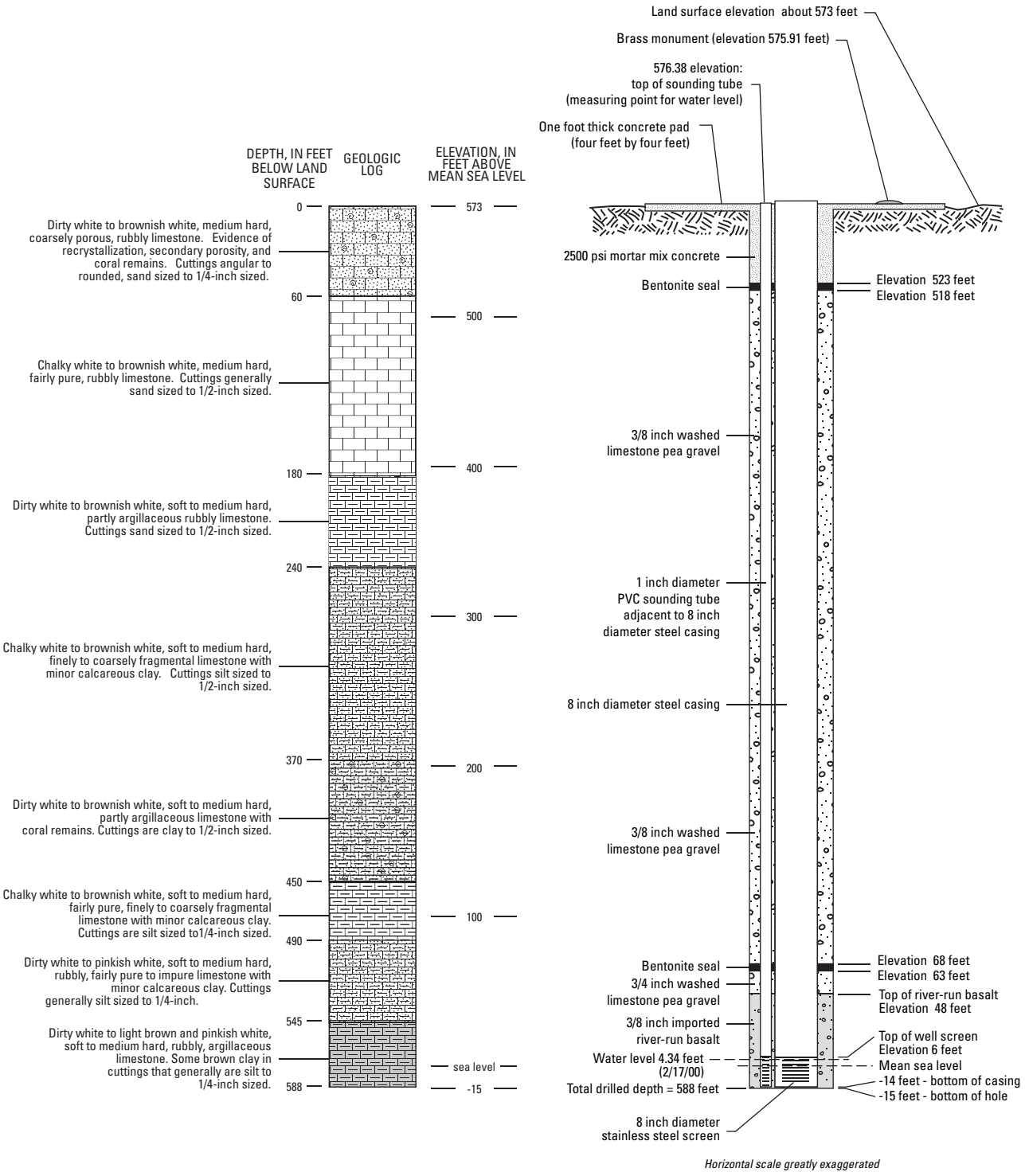

Figure 6. Geologic log and construction details of well EX-3 (CUC well SP-2), Rota.

Table 5. Construction summary of exploratory well EX-4 (SP-3), Rota

[Datum for water-level and bottom-of-hole elevation is mean sea level. Land surface elevation is about 570 ft above mean sea level; ft, feet; gal/min, gallons per minute]

Date		Significant events
August 1999	26	Spacer for pull-down chain repaired and installed on rig. Drilling began. Drilled from 570 ft to 560 ft elevation (depth of 0 to 10 ft)
	27	Drilled from 560 ft to 500 ft elevation (depth of 10 to 70 ft)
	30	Drilled from 500 ft to 420 ft elevation (depth of 70 to 155 ft)
	31	Drilled from 420 ft to 180 ft elevation, stopped drilling at 180 ft elevation
September 1999	01	Pulled out 300 feet of drill pipe to ream tight hole then drilled it back in. Encountered problem with planetary gear box, no drilling
	08	Repaired and installed planetary gear box on rig.
	09	Drilled from 180 ft to 30 ft elevation (depth of 390 to 540 ft)
	10	Drilled from 30 ft to -15 ft elevation (depth of 540 to 585 ft), completed pilot hole drilling at 10:25 AM, (total depth 585 ft)
	13	Pulled out 8" bit, installed 13" hole opener, began reaming the hole.
	16	Completed reaming the hole
	21	Pulled out drill bit and drill pipes. Installed pump assembly for sustained-rate aquifer test
	23	Began 8-day sustained-rate aquifer test at 3:00 PM, 180 gal/min
October 1999	01	Terminated 8-day sustained-rate aquifer test at 3:00 PM; start recovery test at 3:01 PM, end recovery test at 4:01 PM
	02	Start step-drawdown test at 8:10 AM, completed step-drawdown test at 1:14 PM
	22	Began Installation of casing and well screen at 7:00 AM, completed installation at 6:00 PM
November 1999	08	Installed concrete pad, fabricated bottom and top cover for casing
	16	Grout the hole, including the concrete pad
December 1999	09	Began installation of pump and motor for production well
	10	Completed installation of pump and motor for production well
February 2000	17	Water level altitude at 3.33 ft elevation

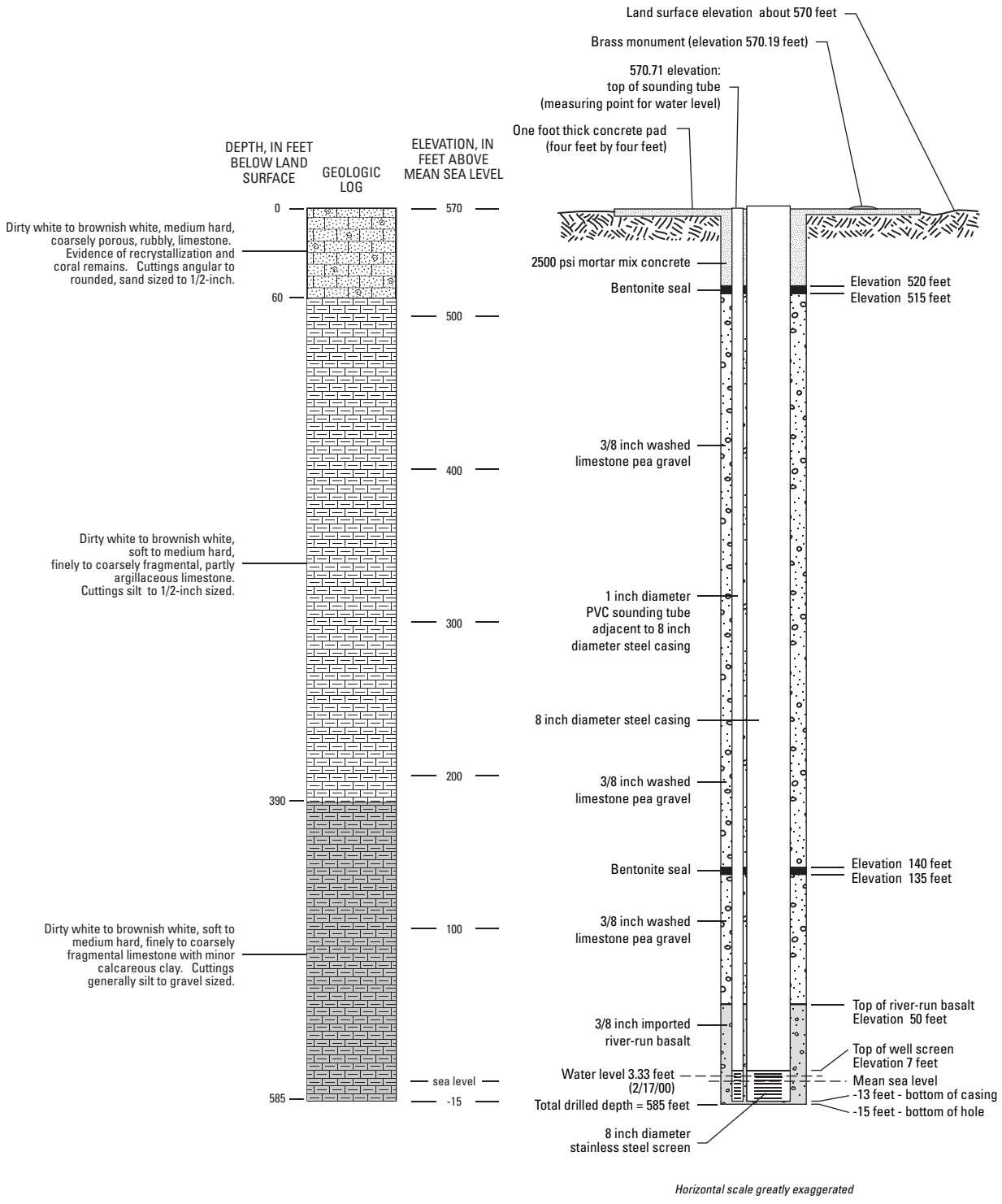

Figure 7. Geologic log and construction details of well EX-4 (CUC well SP-3), Rota.

Table 6. Construction summary of exploratory well EX-5 (SP-MW2), Rota

[Datum for water-level and bottom-of-hole elevation is mean sea level. Land surface elevation is about 590 ft above mean sea level; ft, feet]

Date		Significant events
September 1999	23	Surface casing installed
	24	Drilling began. Drilled from 590 ft to 420 ft elevation (depth of 0 to 170 ft)
	27	Drilled from 420 to 250 ft elevation (depth of 170 to 340 ft), no samples taken after 290 ft elevation due to loss of circulation. No cuttings recovered.
	28	Drilled from 250 ft to 150 ft elevation (depth of 340 to 440 ft), pulled out pipe to avoid tightness of hole over 190 ft elevation
	29	Continued drilling with no circulation. Drilled from 150 ft to 10 ft elevation (depth of 440 to 580 ft)
	30	Terminated drilling at -15 ft elevation (total depth of 605 ft), start pulling out the drill pipes, replaced 8" pilot bit with 13" hole opener, start reaming the hole.
October 1999	02	Completed reaming the hole
	11	Attempted to conduct sustained-rate aquifer test; terminated due to high drawdown and low yield
November 1999	02	Began installation of casing and well screen
	03	Completed installation of casing and well screen, bottom of well is at -15 ft elevation (605 ft), bottom of screen is at -14 ft elevation (604 ft)
	16	Grout the hole, including the concrete pad
February 2000	17	Water level altitude at 3.17 ft elevation

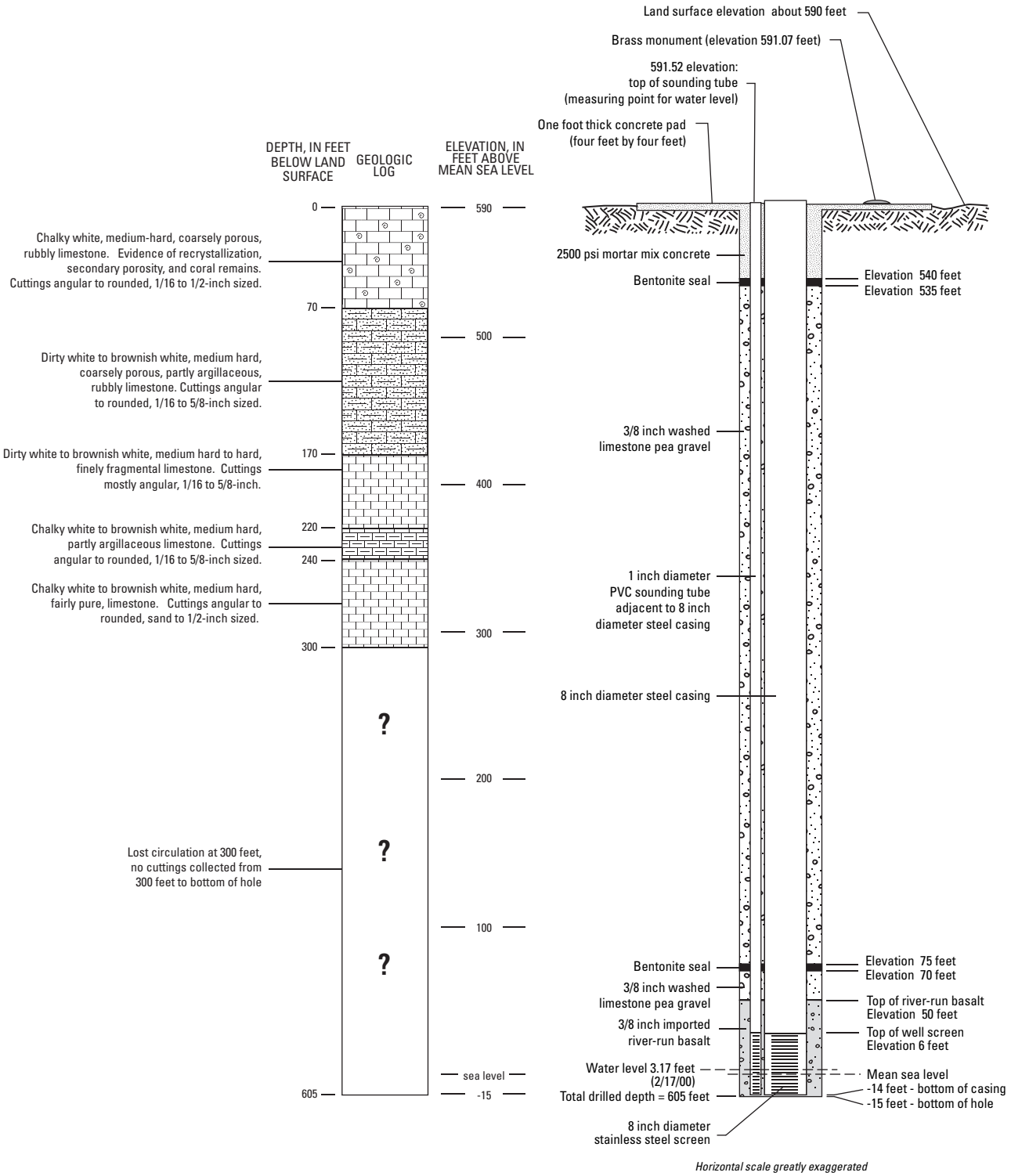

Figure 8. Geologic log and construction details of well EX-5 (CUC well SP-MW2), Rota.

Geologic Logs

The geologic logs of the five exploratory wells on Rota were compiled by examination and description 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 for each of the five wells are in appendix 1; the geologic logs are shown in figures 4–8.

All five exploratory wells penetrated mainly light colored (dirty white to brownish), coarsely porous, finely to coarsely fragmental limestone containing abundant coral remains. The limestone rocks penetrated by the wells varied from soft to medium hard and from fairly pure calcium carbonate to rocks containing fine-grained material of volcanic origin (impure). Some sections penetrated by the wells, particularly towards the bottom of the borings, contain significant amounts of calcareous silt and clay. Rocks composed of or containing clay-sized particles are know as argillaceous

Well EX-1, the deepest of the five wells, penetrated a 745 ft section of light colored (chalky white to brownish) coarsely porous, fragmental limestone. The uppermost part of the section consists of 90 ft of rubbly limestone with evidence of recrystallization. The section from 90 ft to 130 ft contains impure rubbly limestone. From 130 ft to 670 ft, the limestone mainly is finely fragmental and impure. The bottom section, from 670 to 745 ft, contains soft to medium hard impure limestone with calcareous silt and clay.

Well EX-2 penetrated a 608 ft section of limestone. The uppermost section consists of 80 ft of rubbly and coarsely porous rock with evidence of recrystallization. From 80 to 270 ft, the limestone is rubbly and has abundant coral remains. The section from 270 to 580 ft is finely fragmental and impure. From 580 ft to the bottom at 608 ft, the limestone is fine grained, mostly pure, and has evidence of solution-enhanced porosity.

Well EX-3 penetrated a 588 ft section of limestone. The uppermost section, about 60 ft, consists of rubbly limestone with evidence of solution-enhanced porosity and recrystallization. From 60 to 180 ft, the cuttings are fairly pure. Samples of the section from 180 to 545 ft are fairly pure to impure with minor amounts or calcareous clay. From 545 ft to the bottom at 588 ft, the limestone is mostly impure, rubbly and contains minor amounts of brown clay.

Well EX-4 penetrated a 585 ft section of limestone. The uppermost section consists of 60 ft of rubbly limestone with evidence of recrystallization and coral remains. From 60 to 390 ft, the limestone is partly argillaceous and finely to coarsely fragmental. From 390 ft to the bottom at 585 ft, the limestone is mostly impure and contains minor amounts of calcareous clay.

Well EX-5 was bored to 605 ft; however, no cuttings were recovered beyond 290 ft because a cavity in the limestone caused a loss of circulation of drilling fluids. The uppermost section, about 70 ft, consists of coarsely porous, rubbly limestone with evidence of recrystallization. From 70 to 170 ft, the well bore. Samples were collected at 5-ft depth intervals and air dried before being examined macroscopically. The complete lithologic descriptions for each of the five wells are in appendix 1; the geologic logs are shown in figures 4–8. limestone is partly argillaceous, rubbly, and coarsely porous. Samples of the section from 170 to 220 ft are fairly pure and finely fragmental. The section from 220 to 240 ft is partly argillaceous. From 240 ft to 290 ft the limestone is fairly pure. No cuttings were recovered beyond 290 ft; however, the drillers reported that the rotational torque and action of the drill bit from 290 ft to the bottom at 605 ft was consistent with boring to similar depths at the other exploratory wells.

Aquifer Tests

Aquifer tests were attempted at each of the five exploratory wells. At wells EX-1 (CUC well SP-MW1) and EX-5 (CUC well SP-MW2), excessive water-level drawdown to the pump intake in the vicinity of these two wells precluded sustained-rate aquifer tests. At wells EX-2, EX-3, and EX-4, (CUC wells SP-1, -2, and -3, respectively) three aquifer tests were performed; (1) a sustained-rate test, which can be used to estimate aquifer properties in the vicinity of the well, (2) a recovery test, which also can be used to estimate aquifer properties in the vicinity of the well (thereby providing a check on the results of the sustained-rate test), and (3) a step-drawdown test which can be used to determine the component of drawdown attributed to well losses. Data for the aquifer tests at the three wells are shown in appendices 2–10.

All tests were conducted before installation of casing and gravel pack. The tests were conducted using a 30-horsepower, 6-in. diameter submersible pump with the intake elevation set at about -7 ft for each test in each well. Measurements of the depth to water in the pumping wells were made using an electric tape lowered through 1-in. PVC pipe attached to the pump column to minimize the effects of turbulence near the pump intake. The flow rate was measured using a totalizing flow meter. For all tests, the pumped water was discharged through 4-in. PVC pipe about 800 ft away from the pumping well.

The sustained-rate aquifer test at well EX-2 (CUC well SP-1) was conducted from August 30-September 7, 1999 for 11,520 min (8 days) at an average rate of 187 gal/min (appendix 2). Flow rates during the test fluctuated between 168 and 205 gal/min with most of the fluctuation occurring during the first day. The period of greatest drawdown occurred during the first 720 min (12 hours) of the test as the well was developed; maximum drawdown measured in the pumped well was 3.93 ft at 720 min into the test. Depth-to-water prior to the start of the test was 590.28 ft. Following the sustained-rate test, recovery was monitored for 225 min (fig. 9 and appendix 3). The step-drawdown test, conducted on September 8, 1999, consisted of five steps at average rates of 23, 55, 103, 155, and 180 gal/min for durations of 30, 60, 60, 60, and 80 min, respectively (fig. 10 and appendix 4).

The sustained-rate aquifer test at well EX-3 (CUC well SP-2) was conducted from October 27-November 4, 1999 for 11,520 min (8 days) at an average rate of 108 gal/min (appendix 5). Flow rates during the test fluctuated between 104 and 112 gal/min with most of the fluctuation occurring during the first day (fig. 11). Drawdown continued to increase from 1.74 to 2.31 ft during the first 60 min of the test. Maximum drawdown measured in the pumped well was 2.31 ft at 60 min into the test (fig. 11 and appendix 5). Depth-to-water prior to the start of the test was 571.84 ft. Following the sustained-rate test, recovery was monitored for 150 min (fig. 11 and appendix 6). The step-drawdown test, conducted on November 4, 1999, consisted of five steps at average rates of 21, 36, 73, 94, and 103 gal/min for durations of 30 min for the first step and 60 min for steps 2–5, respectively (fig. 12 and appendix 7)

The sustained-rate aquifer test at well EX-3 (CUC well SP-2) was conducted from October 27-November 4, 1999 for 11,520 min (8 days) at an average rate of 108 gal/min (appendix 5). Flow rates during the test fluctuated between 104 and 112 gal/min with most of the fluctuation occurring during the first day (fig. 11). Drawdown continued to increase from 1.74 to 2.31 ft during the first 60 min of the test. Maximum drawdown measured in the pumped well was 2.31 ft at 60 min into the test (fig. 11 and appendix 5). Depth-to-water prior to the start of the test was 571.84 ft. Following the sustained-rate test, recovery was monitored for 150 min (fig. 11 and appendix 6). The step-drawdown test, conducted on November 4, 1999, consisted of five steps at average rates of 21, 36, 73, 94, and 103 gal/min for durations of 30 min for the first step and 60 min for steps 2–5, respectively (fig. 12 and appendix 7).

The sustained-rate aquifer test at well EX-4 (CUC well SP-3) was conducted from September 23-October 1, 1999 for 11,520 min (8 days) at an average rate of 139 gal/min (appendix 8). Flow rates during the test fluctuated between 112 and 180 gal/min, with the higher rates occurring during the first day. The discharge rate was lowered after the first day from about 175 gal/min to about 125 gal/min because the initial pumping water level had stabilized near or below sea level. A sharp decrease in drawdown occurred when the discharge rate was lowered (fig. 13). Maximum drawdown during the test was 3.30 ft, recorded 1 min into the test at a discharge rate of 180 gal/min (fig. 13 and appendix 8).

Depth-to-water prior to the start of the test was 567.40 ft. Following the sustained-rate test, recovery was monitored for 60 min (fig. 13 and appendix 9). The step-drawdown test, conducted on October 2, 1999, consisted of five 60 min steps at average rates of 27, 74, 95, 134, and 179 gal/min (fig. 14 and appendix 10).

Samples of the pumped water were collected during the sustained-rate tests and analyzed for temperature and specific conductance. At well EX-2 (CUC well SP-1), the temperature of the pumped water was 26.5°C at the start and end of the test, and ranged from a low of 26.0°C to a high of 27.5°C (appendix 2). Specific conductance at the start and end of the test was nearly the same at 400 and 403 µS/cm (appendix 2). At well EX-3 (CUC well SP-2), the temperature of the pumped water was 28°C and 27.5°C at the start and end of the test, respectively, and ranged from a low of 27.0°C to a high of 28.5°C (appendix 5). Specific conductance decreased slowly during the test from 383 µS/cm at the start to 358 µS/cm at the end (appen-

Depth-to-water prior to the start of the test was 567.40 ft. Following the sustained-rate test, recovery was monitored for 60 min (fig. 13 and appendix 9). The step-drawdown test, conducted on October 2, 1999, consisted of five 60 min steps at average rates of 27, 74, 95, 134, and 179 gal/min (fig. 14 and appendix 10).

Samples of the pumped water were collected during the sustained-rate tests and analyzed for temperature and specific conductance. At well EX-2 (CUC well SP-1), the temperature of the pumped water was 26.5°C at the start and end of the test, and ranged from a low of 26.0°C to a high of 27.5°C (appendix 2). Specific conductance at the start and end of the test was nearly the same at 400 and 403 µS/cm (appendix 2). At well EX-3 (CUC well SP-2), the temperature of the pumped water was 28°C and 27.5°C at the start and end of the test, respectively, and ranged from a low of 27.0°C to a high of 28.5°C (appendix 5). Specific conductance decreased slowly during the test from 383 µS/cm at the start to 358 µS/cm at the end (appendix 5). At well EX-4 (CUC well SP-3), the temperature of the pumped water was 28°C and 27.5°C at the start and end of the test, respectively, and ranged from a low of 26.5°C to a high of 28°C (appendix 8). Specific conductance at well EX-4 was nearly constant during the test after an initial decrease from 456 µS/cm to 445 µS/cm during the first 30 min (appendix 8).

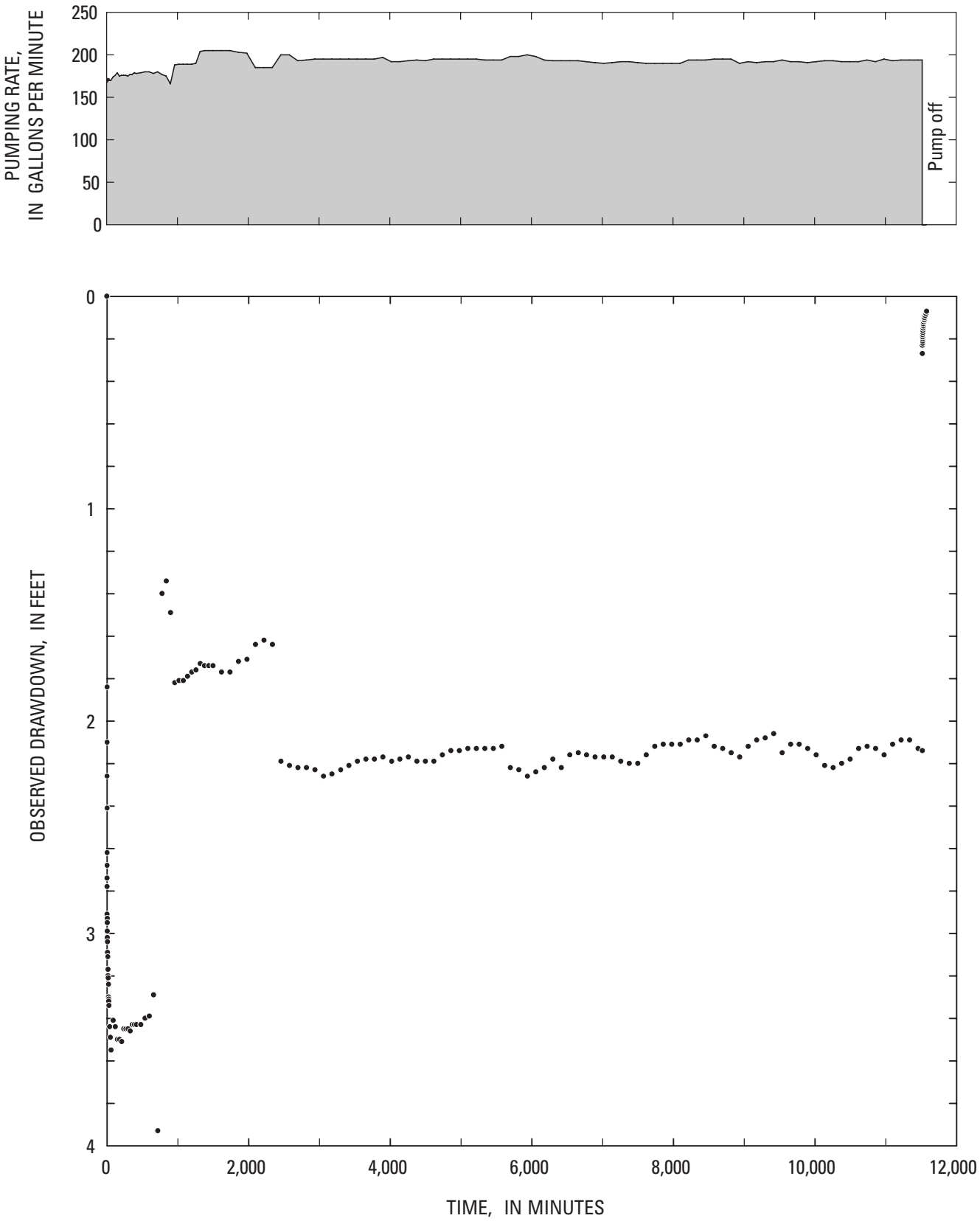

Figure 9. Drawdown and recovery with time during and after the 8-day sustained aquifer test (Aug 30 -- September 7, 1999), at well EX-2 (CUC well SP-1) Rota.

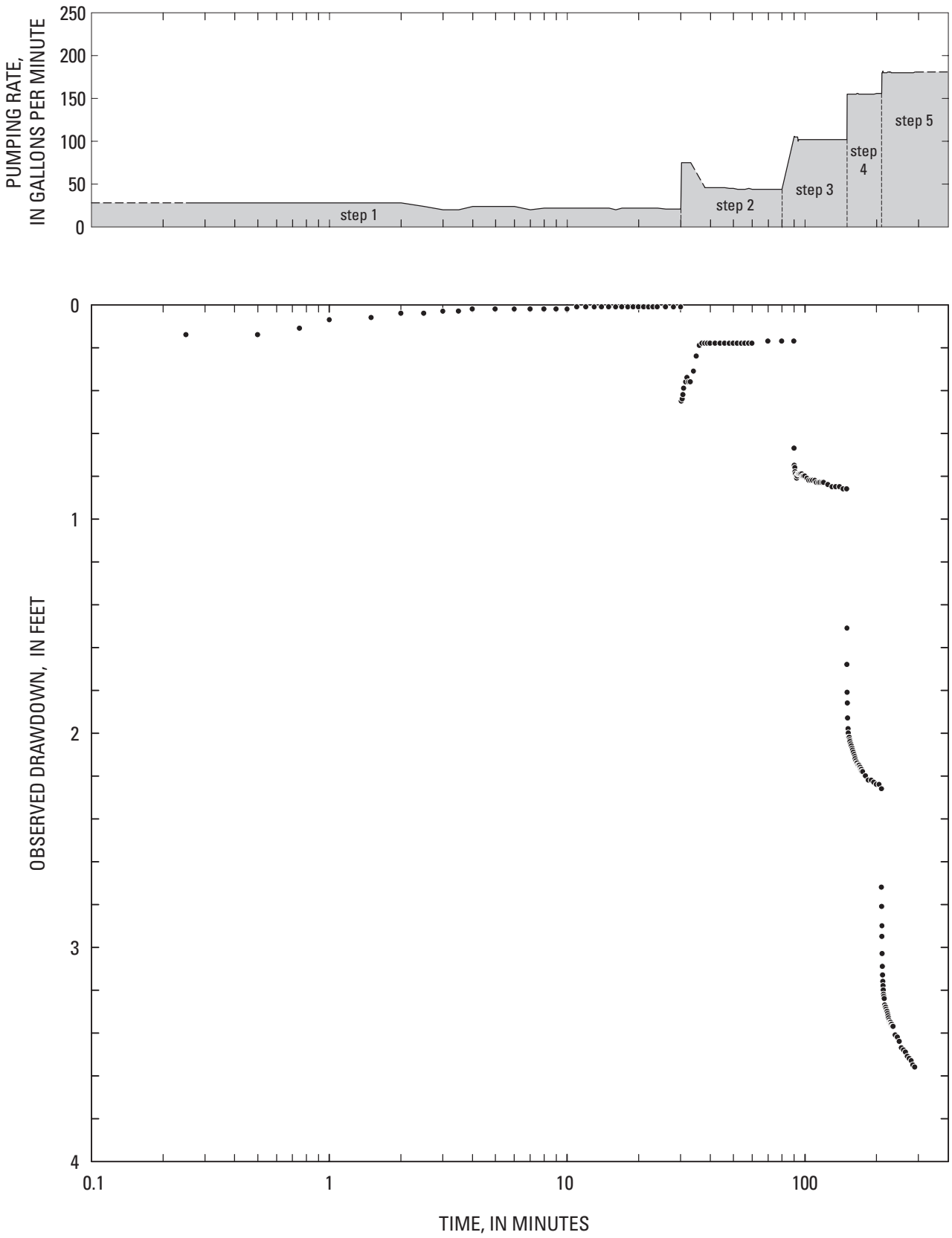

Figure 10. Drawdown with time during the step-drawdown aquifer test (September 8, 1999), at well EX-2 (CUC well SP-1) Rota

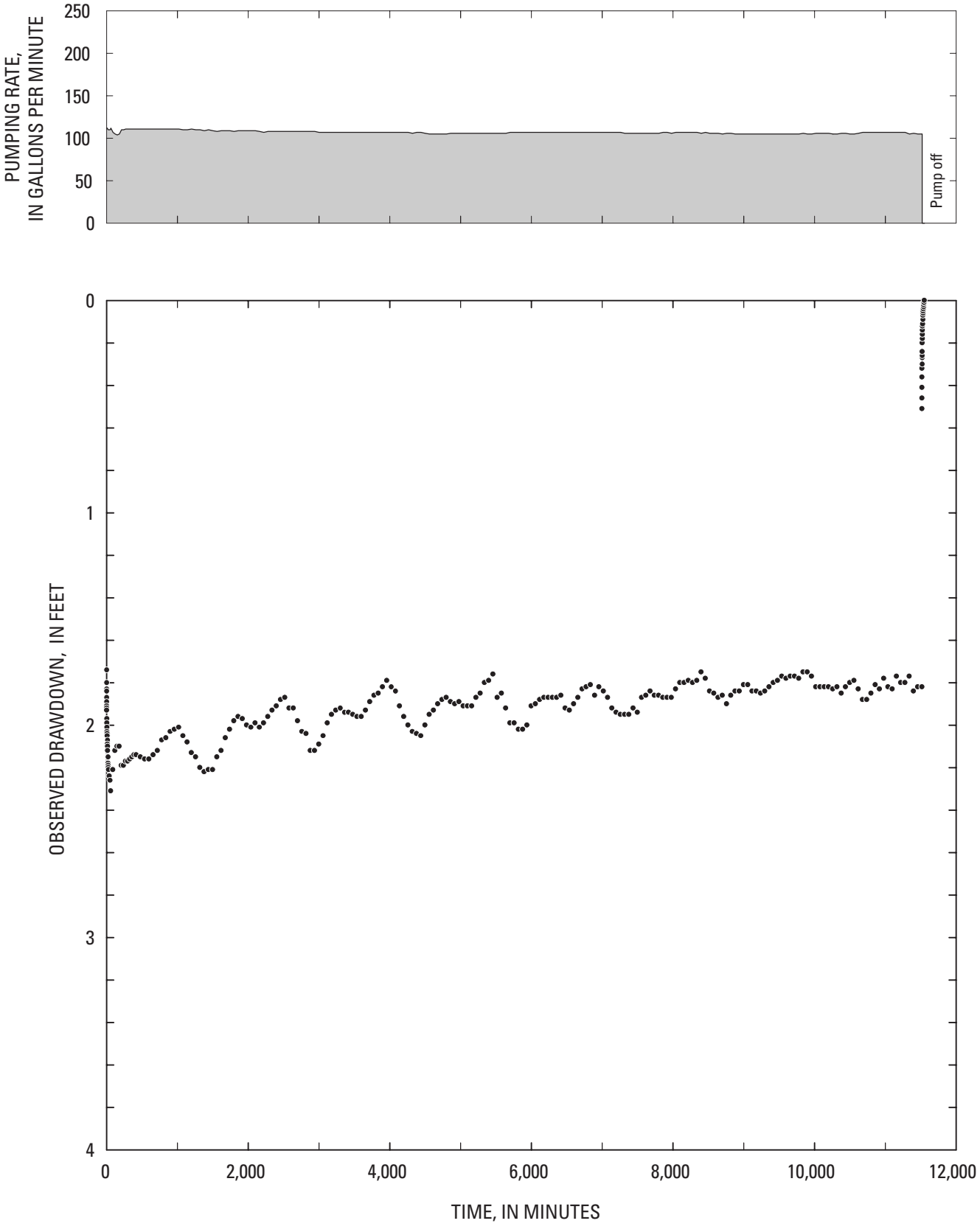

Figure 11. Drawdown and recovery with time during and after the 8-day sustained aquifer test (October 27 -- November 4, 1999), at well EX-3 (CUC well SP-2) Rota.

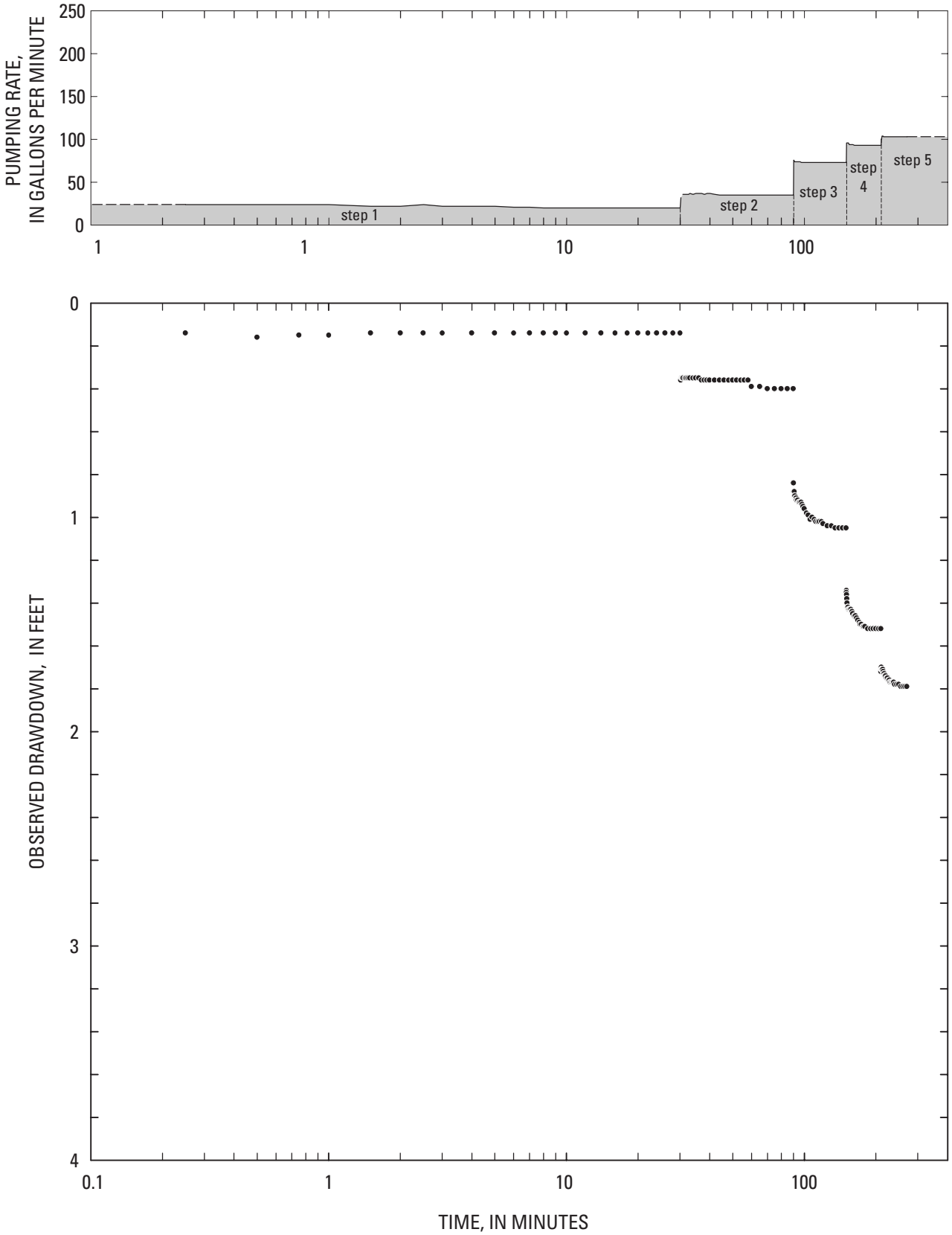

Figure 12. Drawdown with time during the step-drawdown aquifer test (November 4, 1999), at well EX-3 (CUC well SP-2) Rota.

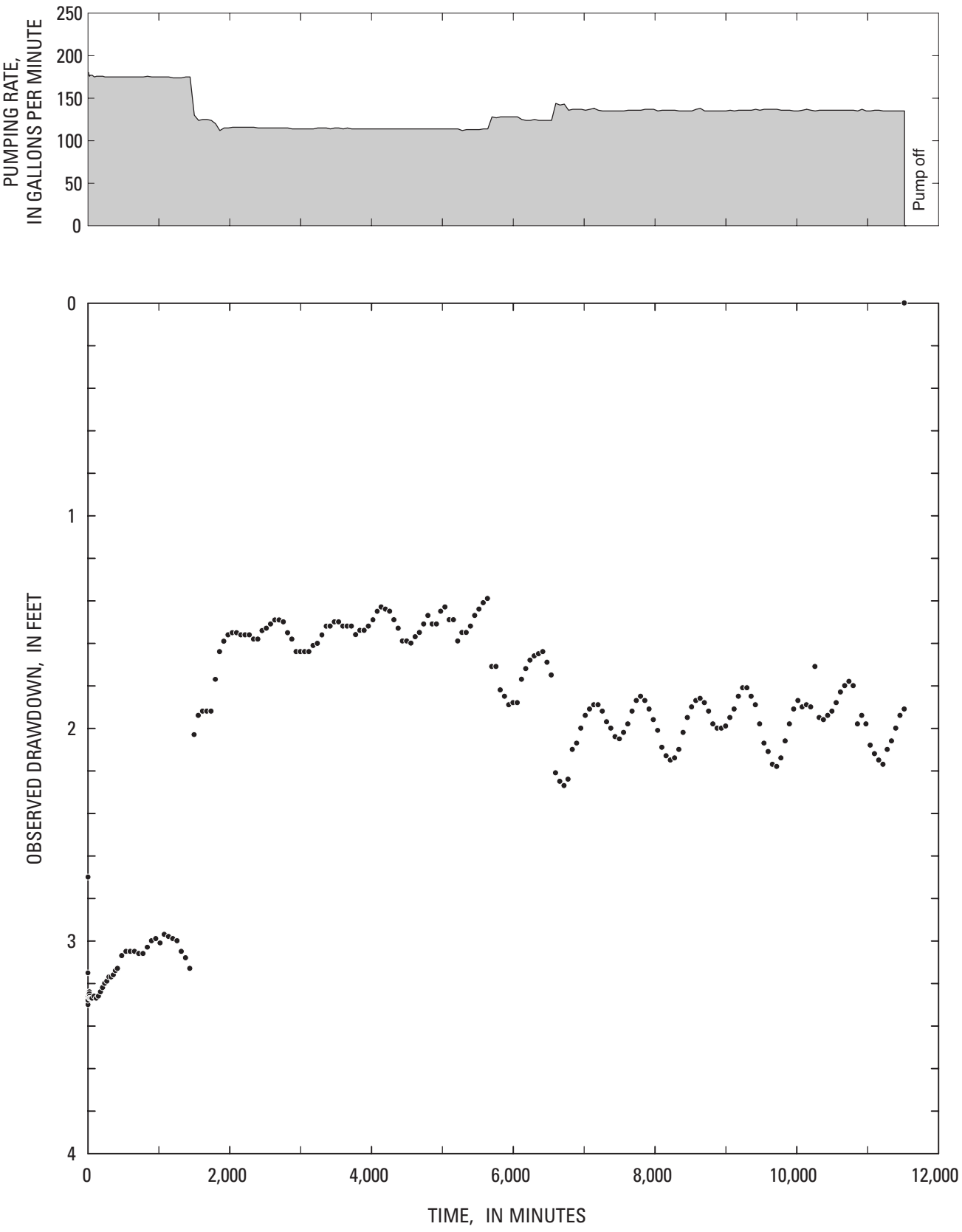

Figure 13. Drawdown and recovery with time during and after the 8-day sustained-rate aquifer test (September 23 -- October 1, 1999), at well EX-4 (CUC well SP-3) Rota.

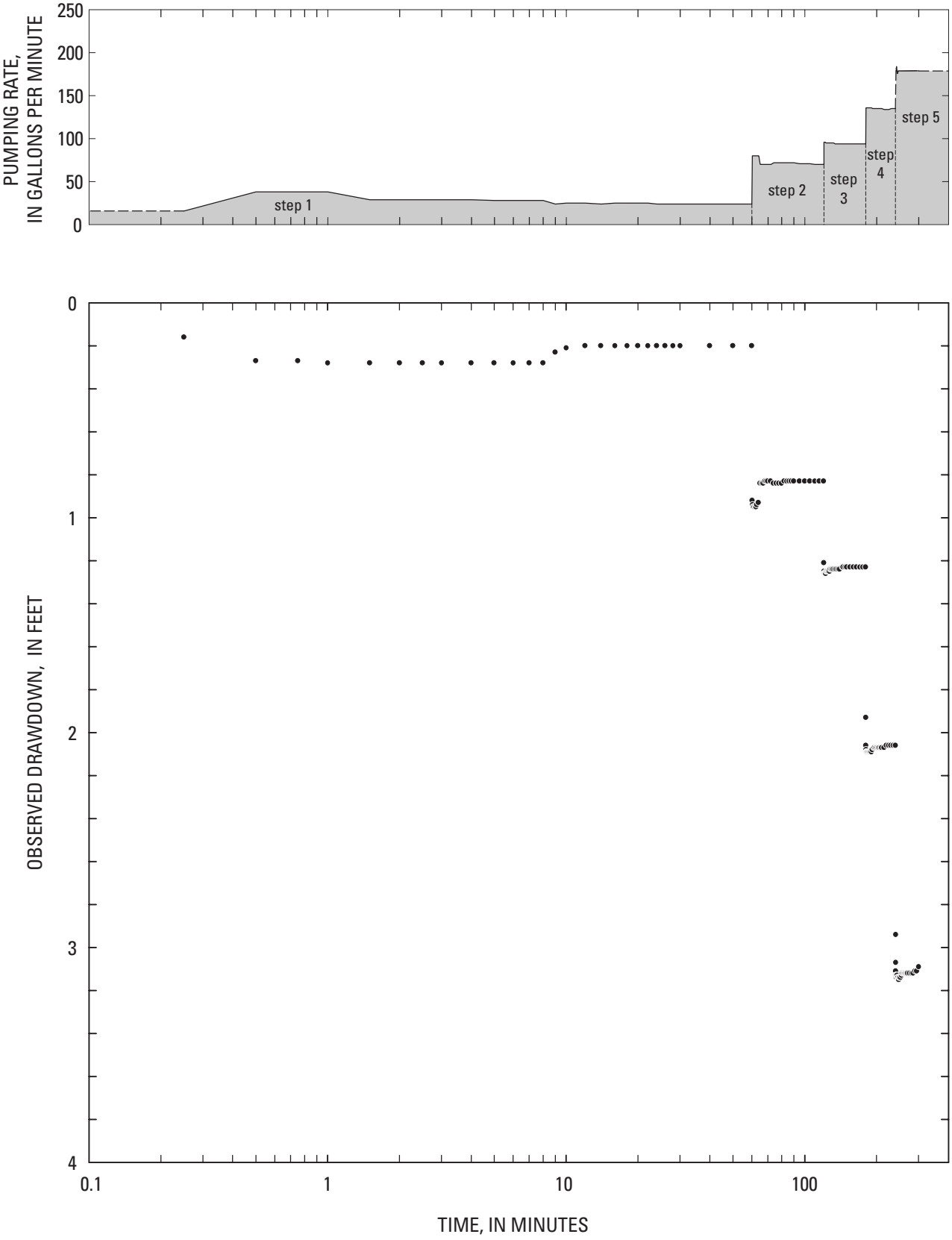

Figure 14. Drawdown with time during the step-drawdown aquifer test (October 2, 1999), at well EX-4 (CUC well SP-3) Rota.

Water Levels

Ground-water levels relative to mean sea level are measured intermittently at the five exploratory wells by the CUC (figs 15-19). Static (non-pumping) ground-water levels at all five wells were more than 2.5 ft during the period from February 17, 2000 to March 5, 2001. Static water levels at the three wells (EX-2, -3, and -4) converted to water-supply wells by the CUC (CUC wells SP-1, -2, and-3) averaged 3.54 ft, 4.15 ft, and 3.19 ft, respectively. Pumping water level at well EX-2 (CUC well SP-1), recorded on August 4, 2000 at 9:25 AM, was -3.83 ft at 123 gal/min. Three pumping water levels recorded at well EX-3 (CUC well SP-2) ranged from a low of -0.14 ft at 167 gal/min on June 7, 2000, to a high of 0.23 ft at 168 gal/min on August 4, 2000.

At the two wells (EX-1 and EX-5) designated as monitor wells by the CUC (SP-MW1 and SP-MW2), the measured water level ranged from 3.42 to 4.00 ft at well EX-1 (CUC well SP-MW1) and from 2.69 to 3.21 ft at well EX-5 (CUC well SP-MW2). Average water level for the 13 measurements made from February 17, 2000 to March 5, 2001 was 3.79 ft at well EX-1 (CUC well SP-MW1) and 3.03 ft at well EX-5 (CUC well SP-MW2).

[Measuring point elevation 603.98 feet; gpm, gallons per minute; gal, gallons]

Well EX-1 (CUC well SP-MW1)			
Date	Time	Depth to water (feet)	Water level altitude (feet)
02/17/00	1400	600.03	3.95
03/07/00	1246	600.02	3.96
03/10/00	1030	600.11	3.87
03/22/00	1405	600.05	3.93
05/23/00	1337	599.99	3.99
06/07/00	1425	599.98	4.00
08/04/00	1015	600.04	3.94
09/07/00	1345	600.07	3.91
10/20/00	1515	600.20	3.78
11/09/00	1334	600.22	3.76
12/12/00	0908	600.55	3.43
01/05/01	0930	600.56	3.42
03/05/01	1038	600.51	3.47

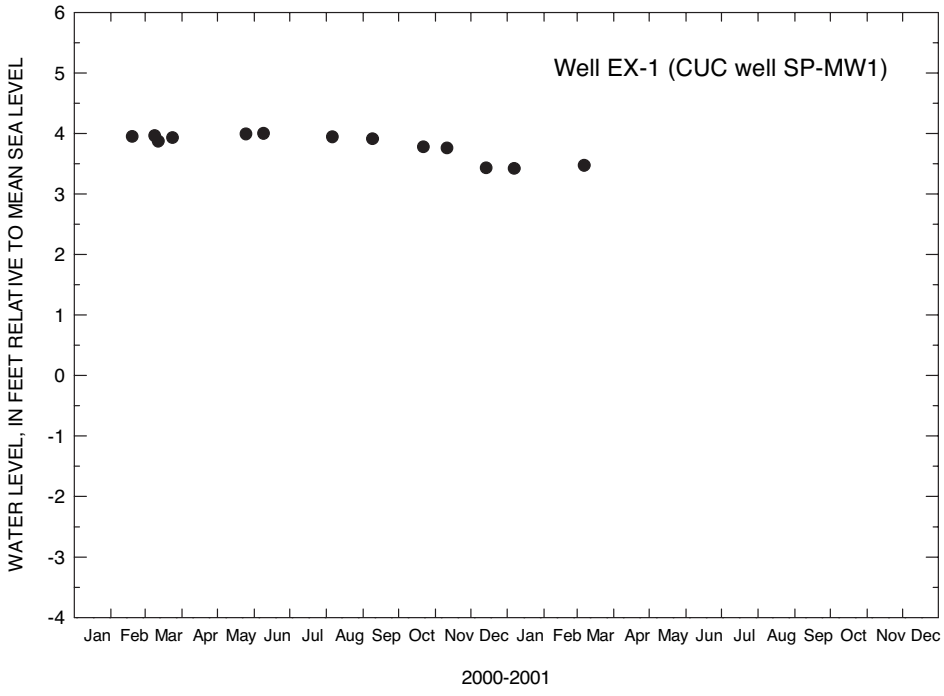

Figure 15. Intermitent ground-water data at well EX-1 (CUC well SP-MW1), 2000-2001, Rota.

[Measuring point elevation 594.53 feet; gpm, gallons per minute; gal, gallons]

Well EX-2 (CUC well SP-1)					
Date	Time	Pumping rate (gpm)	Meter reading (gal)	Depth to water (feet)	Water level altitude (feet)
02/17/00	1418	0		590.78	3.75
03/07/00	1150	0		590.85	3.68
03/22/00	1337	0		590.84	3.69
05/23/00	1324	0	1625826	590.82	3.71
06/07/00	1405	0	1636800	590.81	3.72
08/04/00	0925	123	7488900	598.36	-3.83
09/07/00	0949	0	8210137	590.78	3.75
10/11/00	0836	0	8219900	591.11	3.42
10/20/00	0730	0	8219900	591.01	3.52
11/09/00	1315	0	8228200	591.04	3.49
12/12/00	1000	0	8228200	591.26	3.27
01/05/01	0915	0	8228900	591.27	3.26
03/05/01	0949	0	8256100	591.29	3.24

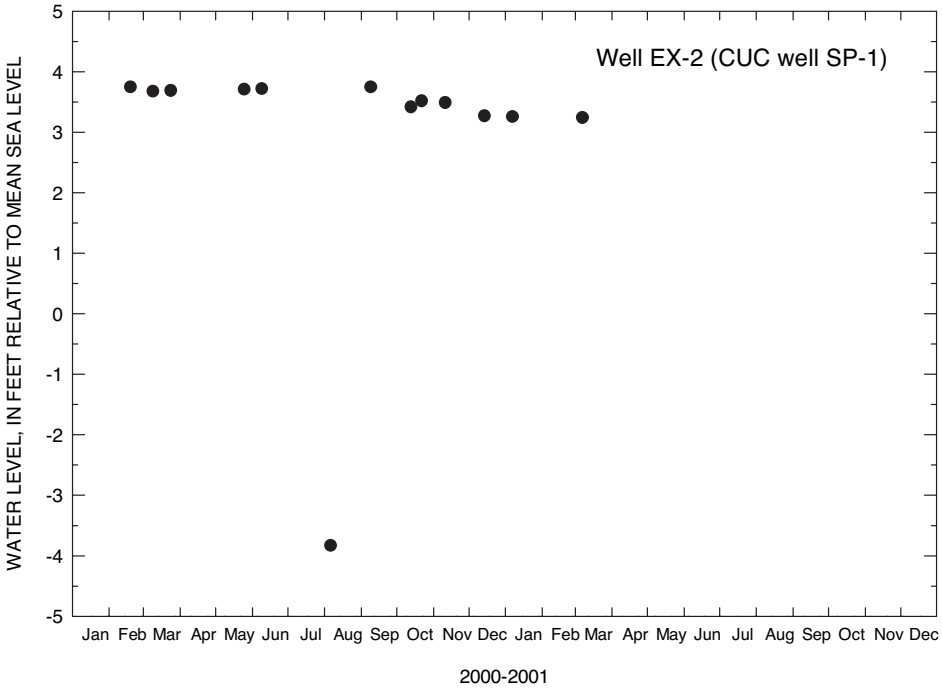

Figure 16. Intermitent ground-water data at well EX-2 (CUC well SP-1), 2000-2001, Rota.

[Measuring point elevation 576.38 feet; gpm, gallons per minute; gal, gallons]

Well EX-3 (CUC well SP-2)					
Date	Time	Pumping rate (gpm)	Meter reading (gal)	Depth to water (feet)	Water level altitude (feet)
02/17/00	1432			572.04	4.34
03/10/00	1000			572.12	4.26
03/22/00	1417			571.99	4.39
05/23/00	1305	167	7881200	576.49	-0.11
06/07/00	1334	167	11483700	576.52	-0.14
08/04/00	0945	168	2527700	576.15	0.23
09/07/00	1009	0	29434200	571.98	4.40
10/11/00	0900	0	29451600	572.26	4.12
10/20/00	0820	0	29451600	572.21	4.17
11/09/00	0832	0	29452100	572.28	4.10
12/12/00	1015	0	29452100	572.52	3.86
01/05/01	0849	0	29451600	572.47	3.91
03/05/01	0932	0	29496700	572.39	3.99

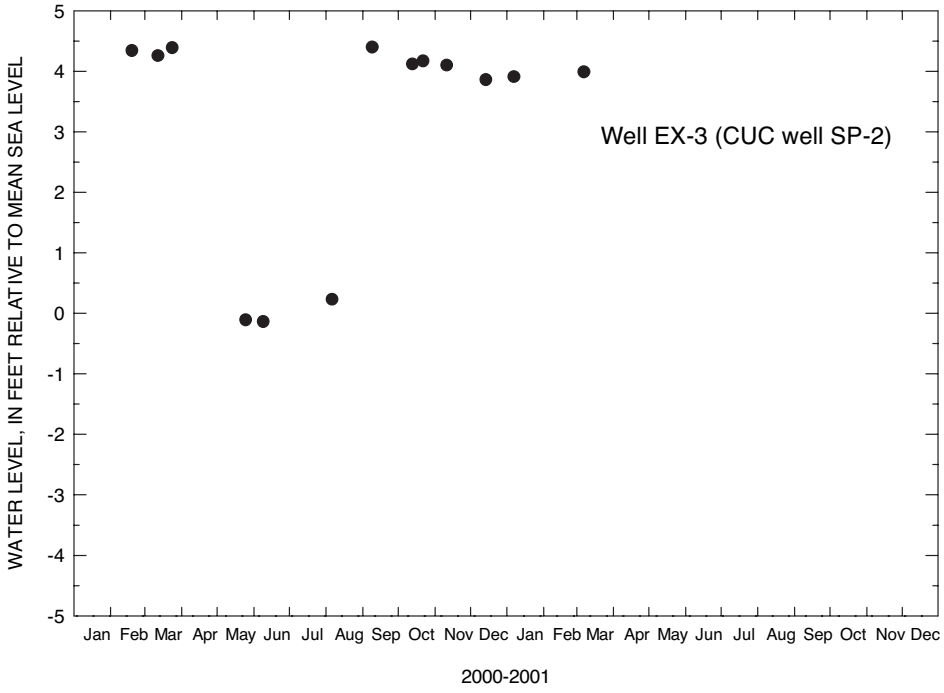

Figure 17. Intermitent ground-water data at well EX-3 (CUC well SP-2), 2000-2001, Rota.

[Measuring point elevation 570.71 feet; gpm, gallons per minute; gal, gallons; --, no data]

Well EX-4 (CUC well SP-3)					
Date	Time	Pumping rate (gpm)	Meter reading (gal)	Depth to water (feet)	Water level altitude (feet)
02/17/00	1455	0	--	567.38	3.33
03/07/00	1330	0	--	567.35	3.36
03/10/00	0937	0	--	567.60	3.11
03/22/00	1430	0	--	567.39	3.32
05/22/00	1312	0	--	567.29	3.42
06/07/00	1350	0	--	567.16	3.55
08/04/00	1005	0	--	567.22	3.49
09/07/00	1034	0	--	567.39	3.32
10/11/00	0923	0	--	567.61	3.10
11/09/00	1258	0	--	567.68	3.03
12/12/00	1030	0	--	567.92	2.79
01/05/01	0959	0	--	567.85	2.86
03/05/01	0846	0	--	567.78	2.93

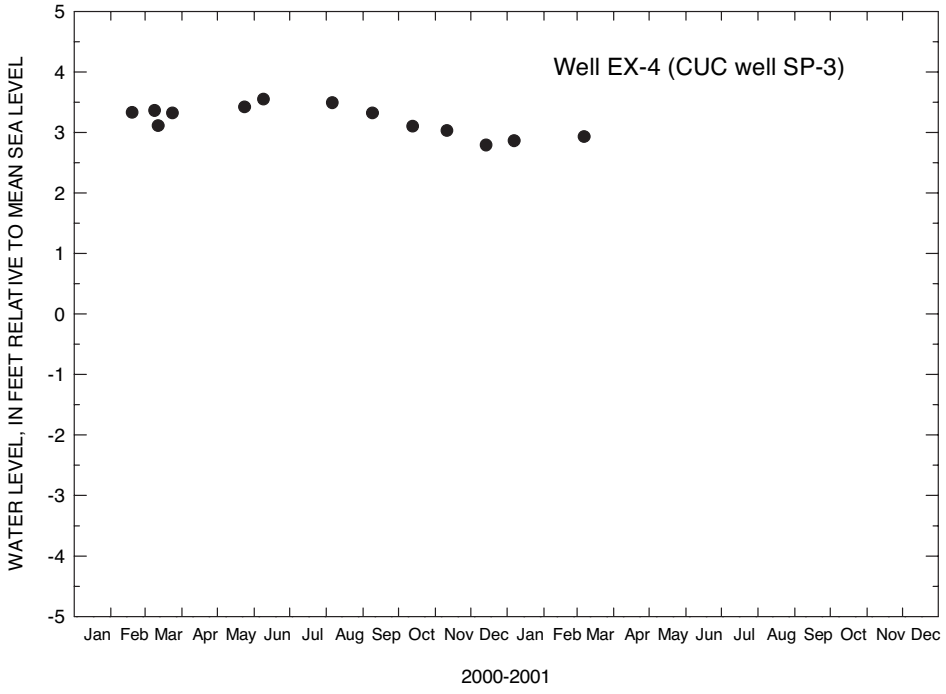

Figure 18. Intermitent ground-water data at well EX-4 (CUC well SP-3), 2000-2001, Rota.

[Measuring point elevation 591.52 feet; gpm, gallons per minute; gal, gallons]

Well EX-5 (CUC well SP-MW2)			
Date	Time	Depth to water (feet)	Water level altitude (feet)
02/17/00	1340	588.35	3.17
03/07/00	1246	588.38	3.14
03/22/00	1405	588.35	3.17
05/23/00	1352	588.33	3.19
06/06/00	1600	588.31	3.21
06/07/00	1430	588.33	3.19
08/03/00	0912	588.41	3.11
09/07/00	1315	588.32	3.20
10/11/00	1010	588.66	2.86
11/09/00	1405	588.58	2.94
12/12/00	0937	588.82	2.70
01/05/01	1020	588.83	2.69
03/05/01	1534	588.73	2.79

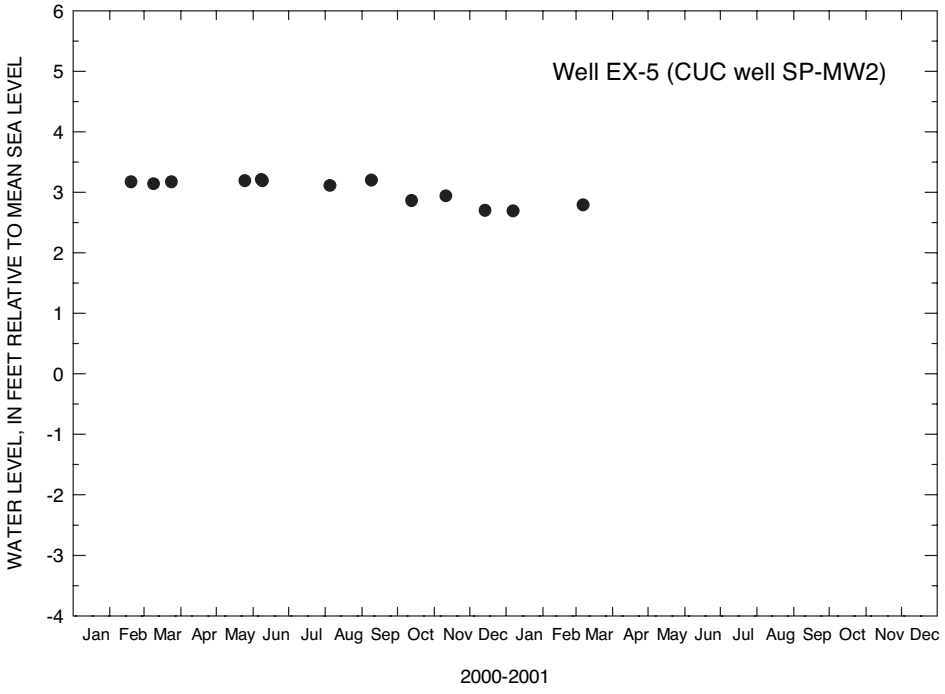

Figure 19. Intermitent ground-water data at well EX-5 (CUC well SP-MW2), 2000-2001, Rota.

Water Quality

An appraisal of water quality was made at exploratory wells that may be converted to municipal water-supply wells. The CUC installed submersible pumps for water production in wells EX-2, -3, and -4 (CUC wells SP-1, -2, and-3) based on favorable aquifer-test results. Water samples were collected on June 6, and September 25, 2000, from hose bibs located on the well heads after the pump had been running for 30 min. Before connecting the wells to the distribution system, the CUC sent the water samples for laboratory analyses to determine if any aspects of water quality might pose a threat to health. The Standard USEPA sampling procedures for quality assurance were followed and all samples were stored on ice prior to analysis. The samples were shipped to the Montgomery Watson Laboratory in California and analyzed for a suite of inorganic and organic constituents included in the primary drinking-water standards established by the U.S. Environmental Protection Agency (USEPA) in the Safe Drinking Water Act (U.S. Environmental Protection Agency, 1989).

Results of the water-quality analyses, shown in tables 7–12, indicate that the samples of water from the three wells meet the requirements set by the USEPA for a potable water source. A summary of the inorganic and organic constituents found in water from the three wells are listed in tables 7–9. Pesticides, herbicides, and other volatile organic constituents found to be less than detection limits in water from the three wells are shown in tables 10–12.

In addition to the water-quality analyses at the three proposed water-supply wells, specific conductance was measured by the USGS throughout the water column at well EX-1 (CUC well SP-MW1) using an electronic down-the-hole logging instrument on August 4, 2000. The vertical specific-conductance profile of the monitoring well is shown in figure 20.

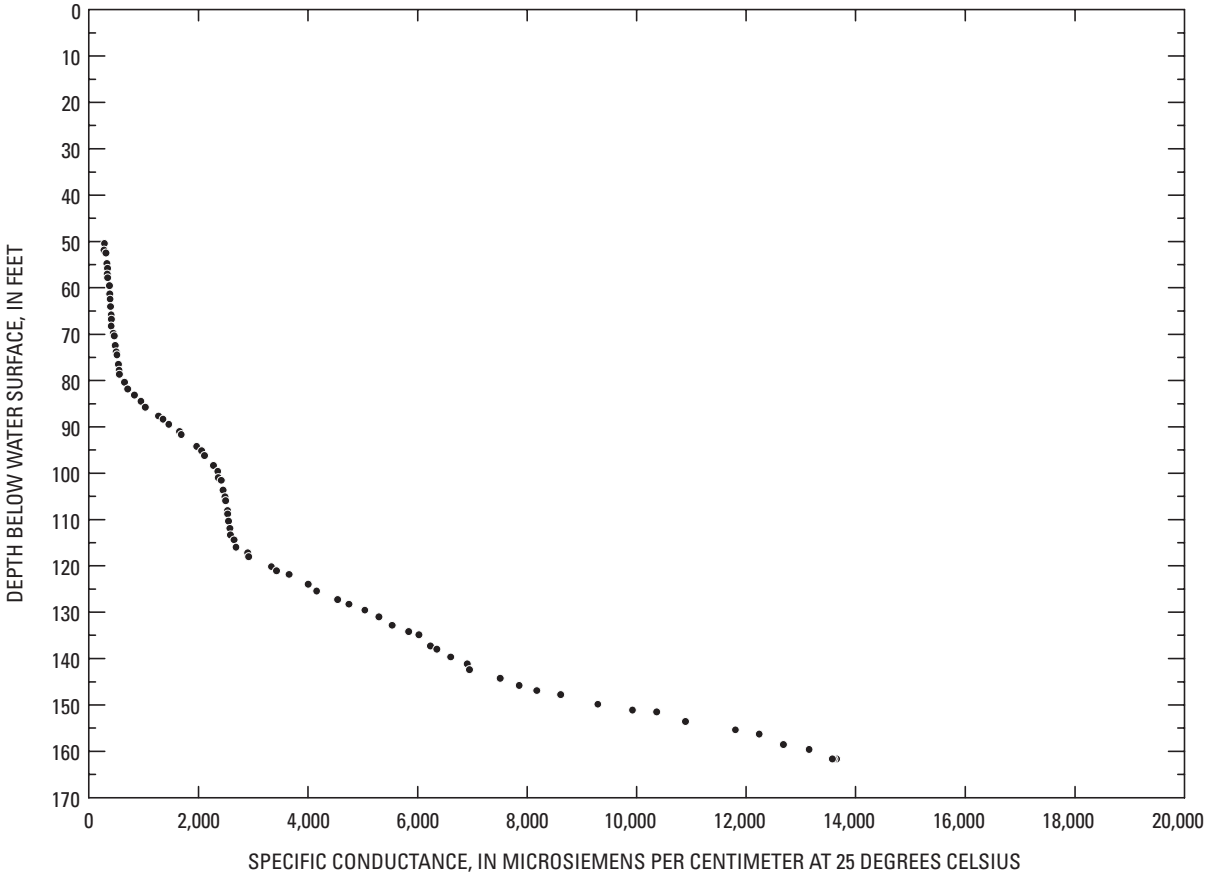

Figure 20. Specific conductance profile at well EX-1 (CUC well SP-MW1) , August 4, 2000, Rota

Table 7. Water-quality data at well EX-2 (CUC well SP-1) on June 6, 2000 and September 25, 2000, Rota

[<, actual value is less than value shown, value shown is detection limit; us/cm, microsiemens per centimeter at 26.8°C; °C, degrees Celsius; mg/L, milligrams per liter; ug/L, micrograms per liter; --, not analyzed; pg/L, picograms per liter; pCi/L, picocurie per liter; ND, no detection; analyses by Montgomery Watson Laboratories]

Property or constituent	Detection limit	June 6, 2000	September 25, 2000
INORGANIC			
Field measurements			
Specific conductance (us/cm at 26.8°C)		403[1]	
pH (units)		7.9[1]	
PHYSICAL PROPERTIES			
Temperature, water (°C)		27[1]	
Major ions, total (mg/L)			
Chloride		19[1]	
Flouride	0.05	0.12	0.12
Nutrients, total (mg/L)			
Nitrate + Nitrate as N by RFA	0.1	2.57	2.6
Metals, total recoverable (ug/L)			
Antimony, Total, ICAP/MS	1	ND	ND
Arsenic, Total, ICAP/MS	1	ND	ND
Barium, Total, ICAP/MS	2	ND	ND
Beryllium, Total, ICAP/MS	1	ND	ND
Cadmium, Total, ICAP/MS	0.5	ND	ND
Chromium, Total, ICAP/MS	2	10	3.7
Mercury	0.2	ND	ND
Nickel, Total, ICAP/MS	5	ND	ND
Selenium, Total, ICAP/MS	5	ND	ND
Thallium, Total, ICAP/MS	1	ND	ND
ORGANIC			
Cyanide, total (mg/L)	0.025	ND	ND
Pesticides and herbicides, total recoverable			
alpha-Chlordane, ug/L	0.05	ND	ND
gamma-Chlordane, ug/L	0.05	ND	ND
2,3,7,8 - TCDD, pg/L	2	ND	ND
Hexachlorobenzene, ug/L	0.05	ND	--
Radiation and Radionuclides (pCi/L)			
Gross, alpha……	1	--	2.4
Gross, beta……..	1.2	--	<1.2

[1] Measured by USGS during sustained-rate aquifer test on September 7, 1999

Table 8. Water-quality data at well EX-3 (CUC well SP-2) on June 6, 2000 and September 25, 2000, Rota

[<, actual value is less than value shown, value shown is detection limit; us/cm, microsiemens per centimeter at 27.3°C; °C, degrees Celsius; mg/L, milligrams per liter; ug/L, micrograms per liter; --, not analyzed; pg/L, picograms per liter; pCi/L, picocurie per liter; ND, no detection; analyses by Montgomery Watson Laboratories]

Property or constituent	Detection limit	June 6, 2000	September 25, 2000
INORGANIC			
Field measurements			
Specific conductance (us/cm at 27.3°C)		302[1]	
pH (units)		7.3[1]	
PHYSICAL PROPERTIES			
Temperature, water (°C)		27[1]	
Major ions, total (mg/L)			
Chloride		22[1]	
Flouride	0.05	0.17	0.17
Nutrients, total (mg/L)			
Nitrate + Nitrate as N by RFA	0.1	1.25	1.1
Metals, total recoverable (ug/L)			
Antimony, Total, ICAP/MS	1	ND	ND
Arsenic, Total, ICAP/MS	1	ND	ND
Barium, Total, ICAP/MS	2	ND	ND
Beryllium, Total, ICAP/MS	1	ND	ND
Cadmium, Total, ICAP/MS	0.5	ND	ND
Chromium, Total, ICAP/MS	2	8.3	2.8
Mercury	0.2	ND	ND
Nickel, Total, ICAP/MS	5	ND	ND
Selenium, Total, ICAP/MS	5	ND	ND
Thallium, Total, ICAP/MS	1	ND	ND
ORGANIC			
Cyanide, total (mg/L)	0.025	ND	ND
Pesticides and herbicides, total recoverable			
alpha-Chlordane, ug/L	0.05	ND	ND
gamma-Chlordane, ug/L	0.05	ND	ND
2,3,7,8 - TCDD, pg/L	2	ND	ND
Hexachlorobenzene, ug/L	0.05	ND	ND
Radiation and Radionuclides (pCi/L)			
Gross, alpha……	1	--	<1
Gross, beta……..	1.2	--	2.3

[1] Measured by USGS during sustained-rate aquifer test on November 4, 1999

Table 9. Water-quality data at well EX-4 (CUC well SP-3) on June 6, 2000 and September 25, 2000, Rota

[<, actual value is less than value shown, value shown is detection limit; us/cm, microsiemens per centimeter at 27.3°C; °C, degrees Celsius; mg/L, milligrams per liter; ug/L, micrograms per liter; --, not analyzed; pg/L, picograms per liter; pCi/L, picocurie per liter; ND, no detection; analyses by Montgomery Watson Laboratories]

Property or constituent	Detection limit	June 6, 2000	September 25, 2000
INORGANIC			
Field measurements			
Specific conductance (us/cm at 27.3°C)		445[1]	
pH (units)		8.1[1]	
PHYSICAL PROPERTIES			
Temperature, water (°C)		27[1]	
Major ions, total (mg/L)			
Chloride		27[1]	
Flouride	0.05	0.15	0.14
Nutrients, total (mg/L)			
Nitrate + Nitrate as N by RFA	0.1	2.02	2
Metals, total recoverable (ug/L)			
Antimony, Total, ICAP/MS	1	ND	ND
Arsenic, Total, ICAP/MS	1	1	1
Barium, Total, ICAP/MS	2	2	2
Beryllium, Total, ICAP/MS	1	ND	ND
Cadmium, Total, ICAP/MS	0.5	ND	ND
Chromium, Total, ICAP/MS	2	ND	4.4
Mercury	0.2	ND	ND
Nickel, Total, ICAP/MS	5	ND	ND
Selenium, Total, ICAP/MS	5	ND	ND
Thallium, Total, ICAP/MS	1	ND	ND
ORGANIC			
Cyanide, total (mg/L)	0.025	ND	ND
Pesticides and herbicides, total recoverable			
alpha-Chlordane, ug/L	0.05	ND	ND
gamma-Chlordane, ug/L	0.05	ND	ND
2,3,7,8 - TCDD, pg/L	2	ND	ND
Hexachlorobenzene, ug/L	0.05	ND	ND
Volatile organic constituents, (ug/L)			
(found to be above detection limits)			
Chloroform (Trichloromethane)	0.5	0.8	0.7
Total THM	0.5	0.8	0.7
Radiation and Radionuclides (pCi/L)			
Gross, alpha……	1	--	<1
Gross, beta……..	1.2	--	2.3

[1] Measured by USGS during sustained-rate aquifer test on October 1, 1999

Table 10. Pesticides, herbicides and other volatile organic constituents found to be less than detection limits in water samples from well EX-2 (CUC well SP-1) on June 6, 2000 and September 25, 2000, Rota

[ug/L, micrograms per liter; analyses by Montgomery Watson Laboratories]

Organic (total recoverable)	Detection limit (ug/L)	Organic (total recoverable)	Detection limit (ug/L)	Organic (total recoverable)	Detection limit (ug/L)
1,1,1,2-Tetrachloroethane	0.5	Carbon Tetrachloride	0.5	Methomyl	1
1,1,1-Trichloroethane	0.5	Chlordane	0.1	Methoxychlor	0.05
1,1,2,2-Tetrachloroethane	0.5	Chlorobenzene	0.5	Methoxychlor	0.05
1,1,2-Trichloroethane	0.5	Chlorodibromomethane	0.5	Methyl Tert-butyl ether (MTBE)	3
1,1-Dichloroethane	0.5	Chloroethane	0.5	Metolachlor	0.05
1,1-Dichloroethylene	0.5	Chloroform (Trichloromethane)	0.5	Metribuzin	0.05
1,1-Dichloropropene	0.5	Chloromethane(Methyl Chloride)	0.5	Molinate	0.2
1,2,3-Trichlorobenzene	0.5	Chlorthalonil (Draconil,Bravo)	0.01	Naphthalene	0.5
1,2,3-Trichloropropane	0.5	Chrysene	0.02	n-Butylbenzene	0.5
1,2,4-Trichlorobenzene	0.5	cis-1,2-Dichloroethylene	0.5	Nitrobenzene	10
1,2,4-Trimethylbenzene	0.5	cis-1,3-Dichloropropene	0.5	n-Propylbenzene	0.5
1,2-Dichloroethane	0.5	Dalapon (qualitative)	1	o-Chlorotoluene	0.5
1,2-Dichloropropane	0.5	Delta-BHC	0.01	o-Dichlorobenzene (1,2-DCB)	0.5
1,3,5-Trimethylbenzene	0.5	Di-(2-Ethylhexyl)adipate	0.6	Oxamyl (Vydate)	2
1,3-Dichloropropane	0.5	Di(2-Ethylhexyl)phthalate	0.6	o-Xylene	0.5
2,2-Dichloropropane	0.5	Dibenz(a,h)Anthracene	0.05	p,p' DDD	0.01
2,4,5-T	0.2	Dibromochloropropane (DBCP)	0.01	p,p' DDE	0.01
2,4,5-TP (Silvex)	0.2	Dibromomethane	0.5	p,p' DDT	0.01
2,4-D	0.1	Dicamba	0.08	Paraquat	2
2,4-DB	2	Dichlorodifluoromethane	0.5	PCB 1016 Aroclor	0.07
2,4-Dinitrotoluene	0.1	Dichloromethane	0.5	PCB 1221 Aroclor	0.1
2-Butanone (MEK)	5	Dichlorprop	0.5	PCB 1232 Aroclor	0.1
3,5-Dichlorobenzoic acid	0.5	Dieldrin	0.2	PCB 1242 Aroclor	0.1
3-Hydroxycarbofuran	2	Dieldrin	0.01	PCB 1248 Aroclor	0.1
4-Methyl-2-Pentanone (MIBK)	5	Diethylphthalate	0.5	PCB 1254 Aroclor	0.1
4-Nitrophenol (qualitative)	5	Di-isopropyl ether	5	PCB 1260 Aroclor	0.1
Acenaphthylene	0.1	Dimethoate	10	p-Chlorotoluene	0.5
Acifluorfen (qualitative)	0.2	Dimethylphthalate	0.5	p-Dichlorobenzene (1,4-DCB)	0.5
Alachlor	0.05	Di-n-Butylphthalate	0.5	Pentachlorophenol	1
Alachlor (Alanex)	0.05	Dinoseb	0.2	Pentachlorophenol	0.04
Aldicarb (Temik)	0.5	Diquat	0.4	Phenanthrene	0.02
Aldicarb sulfone	0.7	Endosulfan I (alpha)	0.01	Picloram	0.1
Aldicarb sulfoxide	0.5	Endosulfan II (beta)	0.01	p-Isopropyltoluene	0.5
Aldrin	0.05	Endosulfan sulfate	0.01	Prometryn	0.5
Aldrin	0.01	Endothall	5	Propachlor	0.05
Alpha-BHC	0.01	Endrin	0.1	Pyrene	0.05
Anthracene	0.02	Endrin	0.01	sec-Butylbenzene	0.5
Atrazine	0.05	Endrin Aldehyde	0.01	Simazine	0.05
Baygon	2	Ethyl benzene	0.5	Styrene	0.5
Bentazon	0.5	Ethylene Dibromide (EDB)	0.01	tert-amyl Methyl Ether	3
Benz(a)Anthracene	0.05	Fluoranthene	0.1	tert-Butyl Ethyl Ether	3
Benzene	0.5	Fluorene	0.05	tert-Butylbenzene	0.5
Benzo(a)pyrene	0.02	Fluorotrichloromethane-Freon11	0.5	Tetrachloroethylene (PCE)	0.5
Benzo(b)Fluoranthene	0.02	Glyphosate	6	Thiobencarb	0.2
Benzo(g,h,i)Perylene	0.05	Heptachlor	0.04	Toluene	0.5
Benzo(k)Fluoranthene	0.02	Heptachlor	0.01	Tot DCPA Mono&Diacid Degradate	0.1
Beta-BHC	0.01	Heptachlor Epoxide	0.02	Total THM	0.5
Bromacil	0.2	Heptachlor Epoxide	0.01	Total xylenes	0.5
Bromobenzene	0.5	Hexachlorobutadiene	0.5	Toxaphene	0.5
Bromochloromethane	0.5	Hexachlorocyclopentadiene	0.05	trans-1,2-Dichloroethylene	0.5
Bromodichloromethane	0.5	Indeno(1,2,3,c,d)Pyrene	0.05	trans-1,3-Dichloropropene	0.5
Bromoform	0.5	Isophorone	0.5	trans-Nonachlor	0.05
Bromomethane (Methyl Bromide)	0.5	Isopropylbenzene	0.5	Trichloroethylene (TCE)	0.5
Butachlor	0.05	Lindane	0.02	Trichlorotrifluoroethane(Freon)	0.5
Butylbenzylphthalate	0.5	Lindane (gamma-BHC)	0.01	Trifluralin	0.1
Caffeine	0.02	m,p-Xylenes	0.5	Vinyl chloride (VC)	0.3
Carbaryl	2	m-Dichlorobenzene (1,3-DCB)	0.5		
Carbofuran (Furadan)	0.9	Methiocarb	2		

Table 11. Pesticides, herbicides and other volatile organic constituents found to be less than detection limits in water samples from well EX-3 (CUC well SP-2) on June 6, 2000 and September 25, 2000, Rota

[ug/L, micrograms per liter; analyses by Montgomery Watson Laboratories]

Organic (total recoverable)	Detection limit (ug/L)	Organic (total recoverable)	Detection limit (ug/L)	Organic (total recoverable)	Detection limit (ug/L)
1,1,1,2-Tetrachloroethane	0.5	Carbon Tetrachloride	0.5	Methomyl	1
1,1,1-Trichloroethane	0.5	Chlordane	0.1	Methoxychlor	0.05
1,1,2,2-Tetrachloroethane	0.5	Chlorobenzene	0.5	Methoxychlor	0.05
1,1,2-Trichloroethane	0.5	Chlorodibromomethane	0.5	Methyl Tert-butyl ether (MTBE)	3
1,1-Dichloroethane	0.5	Chloroethane	0.5	Metolachlor	0.05
1,1-Dichloroethylene	0.5	Chloroform (Trichloromethane)	0.5	Metribuzin	0.05
1,1-Dichloropropene	0.5	Chloromethane(Methyl Chloride)	0.5	Molinate	0.2
1,2,3-Trichlorobenzene	0.5	Chlorthalonil (Draconil,Bravo)	0.01	Naphthalene	0.5
1,2,3-Trichloropropane	0.5	Chrysene	0.02	n-Butylbenzene	0.5
1,2,4-Trichlorobenzene	0.5	cis-1,2-Dichloroethylene	0.5	Nitrobenzene	10
1,2,4-Trimethylbenzene	0.5	cis-1,3-Dichloropropene	0.5	n-Propylbenzene	0.5
1,2-Dichloroethane	0.5	Dalapon (qualitative)	1	o-Chlorotoluene	0.5
1,2-Dichloropropane	0.5	Delta-BHC	0.01	o-Dichlorobenzene (1,2-DCB)	0.5
1,3,5-Trimethylbenzene	0.5	Di-(2-Ethylhexyl)adipate	0.6	Oxamyl (Vydate)	2
1,3-Dichloropropane	0.5	Di(2-Ethylhexyl)phthalate	0.6	o-Xylene	0.5
2,2-Dichloropropane	0.5	Dibenz(a,h)Anthracene	0.05	p,p' DDD	0.01
2,4,5-T	0.2	Dibromochloropropane (DBCP)	0.01	p,p' DDE	0.01
2,4,5-TP (Silvex)	0.2	Dibromomethane	0.5	p,p' DDT	0.01
2,4-D	0.1	Dicamba	0.08	Paraquat	2
2,4-DB	2	Dichlorodifluoromethane	0.5	PCB 1016 Aroclor	0.07
2,4-Dinitrotoluene	0.1	Dichloromethane	0.5	PCB 1221 Aroclor	0.1
2-Butanone (MEK)	5	Dichlorprop	0.5	PCB 1232 Aroclor	0.1
3,5-Dichlorobenzoic acid	0.5	Dieldrin	0.2	PCB 1242 Aroclor	0.1
3-Hydroxycarbofuran	2	Dieldrin	0.01	PCB 1248 Aroclor	0.1
4-Methyl-2-Pentanone (MIBK)	5	Diethylphthalate	0.5	PCB 1254 Aroclor	0.1
4-Nitrophenol (qualitative)	5	Di-isopropyl ether	5	PCB 1260 Aroclor	0.1
Acenaphthylene	0.1	Dimethoate	10	p-Chlorotoluene	0.5
Acifluorfen (qualitative)	0.2	Dimethylphthalate	0.5	p-Dichlorobenzene (1,4-DCB)	0.5
Alachlor	0.05	Di-n-Butylphthalate	0.5	Pentachlorophenol	1
Alachlor (Alanex)	0.05	Dinoseb	0.2	Pentachlorophenol	0.04
Aldicarb (Temik)	0.5	Diquat	0.4	Phenanthrene	0.02
Aldicarb sulfone	0.7	Endosulfan I (alpha)	0.01	Picloram	0.1
Aldicarb sulfoxide	0.5	Endosulfan II (beta)	0.01	p-Isopropyltoluene	0.5
Aldrin	0.05	Endosulfan sulfate	0.01	Prometryn	0.5
Aldrin	0.01	Endothall	5	Propachlor	0.05
Alpha-BHC	0.01	Endrin	0.1	Pyrene	0.05
Anthracene	0.02	Endrin	0.01	sec-Butylbenzene	0.5
Atrazine	0.05	Endrin Aldehyde	0.01	Simazine	0.05
Baygon	2	Ethyl benzene	0.5	Styrene	0.5
Bentazon	0.5	Ethylene Dibromide (EDB)	0.01	tert-amyl Methyl Ether	3
Benz(a)Anthracene	0.05	Fluoranthene	0.1	tert-Butyl Ethyl Ether	3
Benzene	0.5	Fluorene	0.05	tert-Butylbenzene	0.5
Benzo(a)pyrene	0.02	Fluorotrichloromethane-Freon11	0.5	Tetrachloroethylene (PCE)	0.5
Benzo(b)Fluoranthene	0.02	Glyphosate	6	Thiobencarb	0.2
Benzo(g,h,i)Perylene	0.05	Heptachlor	0.04	Toluene	0.5
Benzo(k)Fluoranthene	0.02	Heptachlor	0.01	Tot DCPA Mono&Diacid Degradate	0.1
Beta-BHC	0.01	Heptachlor Epoxide	0.02	Total THM	0.5
Bromacil	0.2	Heptachlor Epoxide	0.01	Total xylenes	0.5
Bromobenzene	0.5	Hexachlorobutadiene	0.5	Toxaphene	0.5
Bromochloromethane	0.5	Hexachlorocyclopentadiene	0.05	trans-1,2-Dichloroethylene	0.5
Bromodichloromethane	0.5	Indeno(1,2,3,c,d)Pyrene	0.05	trans-1,3-Dichloropropene	0.5
Bromoform	0.5	Isophorone	0.5	trans-Nonachlor	0.05
Bromomethane (Methyl Bromide)	0.5	Isopropylbenzene	0.5	Trichloroethylene (TCE)	0.5
Butachlor	0.05	Lindane	0.02	Trichlorotrifluoroethane(Freon)	0.5
Butylbenzylphthalate	0.5	Lindane (gamma-BHC)	0.01	Trifluralin	0.1
Caffeine	0.02	m,p-Xylenes	0.5	Vinyl chloride (VC)	0.3
Carbaryl	2	m-Dichlorobenzene (1,3-DCB)	0.5		
Carbofuran (Furadan)	0.9	Methiocarb	2		

Table 12. Pesticides, herbicides and other volatile organic constituents found to be less than detection limits in water samples from well EX-4 (CUC well SP-3) on June 6, 2000 and September 25, 2000, Rota

[ug/L, micrograms per liter; analyses by Montgomery Watson Laboratories]

Organic (total recoverable)	Detection limit (ug/L)	Organic (total recoverable)	Detection limit (ug/L)	Organic (total recoverable)	Detection limit (ug/L)
1,1,1,2-Tetrachloroethane	0.5	Carbon Tetrachloride	0.5	Methomyl	1
1,1,1-Trichloroethane	0.5	Chlordane	0.1	Methoxychlor	0.05
1,1,2,2-Tetrachloroethane	0.5	Chlorobenzene	0.5	Methoxychlor	0.05
1,1,2-Trichloroethane	0.5	Chlorodibromomethane	0.5	Methyl Tert-butyl ether (MTBE)	3
1,1-Dichloroethane	0.5	Chloroethane	0.5	Metolachlor	0.05
1,1-Dichloroethylene	0.5	Chloromethane(Methyl Chloride)	0.5	Metribuzin	0.05
1,1-Dichloropropene	0.5	Chlorthalonil (Draconil,Bravo)	0.01	Molinate	0.2
1,2,3-Trichlorobenzene	0.5	Chrysene	0.02	Naphthalene	0.5
1,2,3-Trichloropropane	0.5	cis-1,2-Dichloroethylene	0.5	n-Butylbenzene	0.5
1,2,4-Trichlorobenzene	0.5	cis-1,3-Dichloropropene	0.5	Nitrobenzene	10
1,2,4-Trimethylbenzene	0.5	Dalapon (qualitative)	1	n-Propylbenzene	0.5
1,2-Dichloroethane	0.5	Delta-BHC	0.01	o-Chlorotoluene	0.5
1,2-Dichloropropane	0.5	Di-(2-Ethylhexyl)adipate	0.6	o-Dichlorobenzene (1,2-DCB)	0.5
1,3,5-Trimethylbenzene	0.5	Di(2-Ethylhexyl)phthalate	0.6	Oxamyl (Vydate)	2
1,3-Dichloropropane	0.5	Dibenz(a,h)Anthracene	0.05	o-Xylene	0.5
2,2-Dichloropropane	0.5	Dibromochloropropane (DBCP)	0.01	p,p' DDD	0.01
2,4,5-T	0.2	Dibromomethane	0.5	p,p' DDE	0.01
2,4,5-TP (Silvex)	0.2	Dicamba	0.08	p,p' DDT	0.01
2,4-D	0.1	Dichlorodifluoromethane	0.5	Paraquat	2
2,4-DB	2	Dichloromethane	0.5	PCB 1016 Aroclor	0.07
2,4-Dinitrotoluene	0.1	Dichlorprop	0.5	PCB 1221 Aroclor	0.1
2-Butanone (MEK)	5	Dieldrin	0.2	PCB 1232 Aroclor	0.1
3,5-Dichlorobenzoic acid	0.5	Dieldrin	0.01	PCB 1242 Aroclor	0.1
3-Hydroxycarbofuran	2	Diethylphthalate	0.5	PCB 1248 Aroclor	0.1
4-Methyl-2-Pentanone (MIBK)	5	Di-isopropyl ether	5	PCB 1254 Aroclor	0.1
4-Nitrophenol (qualitative)	5	Dimethoate	10	PCB 1260 Aroclor	0.1
Acenaphthylene	0.1	Dimethylphthalate	0.5	p-Chlorotoluene	0.5
Acifluorfen (qualitative)	0.2	Di-n-Butylphthalate	0.5	p-Dichlorobenzene (1,4-DCB)	0.5
Alachlor	0.05	Dinoseb	0.2	Pentachlorophenol	1
Alachlor (Alanex)	0.05	Diquat	0.4	Pentachlorophenol	0.04
Aldicarb (Temik)	0.5	Endosulfan I (alpha)	0.01	Phenanthrene	0.02
Aldicarb sulfone	0.7	Endosulfan II (beta)	0.01	Picloram	0.1
Aldicarb sulfoxide	0.5	Endosulfan sulfate	0.01	p-Isopropyltoluene	0.5
Aldrin	0.05	Endothall	5	Prometryn	0.5
Aldrin	0.01	Endrin	0.1	Propachlor	0.05
Alpha-BHC	0.01	Endrin	0.01	Pyrene	0.05
Anthracene	0.02	Endrin Aldehyde	0.01	sec-Butylbenzene	0.5
Atrazine	0.05	Ethyl benzene	0.5	Simazine	0.05
Baygon	2	Ethylene Dibromide (EDB)	0.01	Styrene	0.5
Bentazon	0.5	Fluoranthene	0.1	tert-amyl Methyl Ether	3
Benz(a)Anthracene	0.05	Fluorene	0.05	tert-Butyl Ethyl Ether	3
Benzene	0.5	Fluorotrichloromethane-Freon11	0.5	tert-Butylbenzene	0.5
Benzo(a)pyrene	0.02	Glyphosate	6	Tetrachloroethylene (PCE)	0.5
Benzo(b)Fluoranthene	0.02	Heptachlor	0.04	Thiobencarb	0.2
Benzo(g,h,i)Perylene	0.05	Heptachlor	0.01	Toluene	0.5
Benzo(k)Fluoranthene	0.02	Heptachlor Epoxide	0.02	Tot DCPA Mono&Diacid Degradate	0.1
Beta-BHC	0.01	Heptachlor Epoxide	0.01	Total xylenes	0.5
Bromacil	0.2	Hexachlorobutadiene	0.5	Toxaphene	0.5
Bromobenzene	0.5	Hexachlorocyclopentadiene	0.05	trans-1,2-Dichloroethylene	0.5
Bromochloromethane	0.5	Indeno(1,2,3,c,d)Pyrene	0.05	trans-1,3-Dichloropropene	0.5
Bromodichloromethane	0.5	Isophorone	0.5	trans-Nonachlor	0.05
Bromoform	0.5	Isopropylbenzene	0.5	Trichloroethylene (TCE)	0.5
Bromomethane (Methyl Bromide)	0.5	Lindane	0.02	Trichlorotrifluoroethane(Freon)	0.5
Butachlor	0.05	Lindane (gamma-BHC)	0.01	Trifluralin	0.1
Butylbenzylphthalate	0.5	m,p-Xylenes	0.5	Vinyl chloride (VC)	0.3
Caffeine	0.02	m-Dichlorobenzene (1,3-DCB)	0.5		
Carbaryl	2	Methiocarb	2		
Carbofuran (Furadan)	0.9				

Summary

The five exploratory wells were located and constructed in the Sinapalu region of Rota, a coralline limestone plateau in the northeastern section of the island that includes the Sinapalu Village and the Rota Airport. This limestone plateau is referred to as the northern plateau and ranges in large part between 500 and 625 ft above sea level. The wells were constructed during the period from July 12 to November 23, 1999 to explore for the availability of fresh ground-water resources in an area where no other well information was available.

The wells were bored by rotary drilling with air and foam to -15 ft relative to mean sea level, the target depth for initial testing. Samples of cuttings were collected at 5-ft depth intervals during the drilling process. All five exploratory wells penetrated mainly light colored fragmental limestones containing abundant coral remains. The limestones varied from soft to medium hard and some sections penetrated by the wells, particularly towards the bottom of the borings, contain calcareous silt and clay. Volcanic basement rock was not encountered at depth by any of the five exploratory borings.

Sustained-rate, recovery, and step-drawdown aquifer tests were attempted at each of the five exploratory wells to (1) estimate aquifer properties in the vicinity of the wells and (2) to provide information to the CUC for assessment of potential for new municipal water sources to mitigate the impact of future periods of drought. The CUC installed submersible pumps for water production in wells EX-2, -3, and -4 (CUC wells SP-1, -2, and-3) based on favorable aquifer-test results. At wells EX-1 (CUC well SP-MW1) and EX-5 (CUC well SP-MW2), attempts to conduct sustained-rate aquifer tests resulted in excessive water-level drawdown to the pump intakes; these wells have been designated as monitor wells by the CUC.

An appraisal of water quality was made at wells EX-2, -3, and -4 (CUC wells SP-1, -2, and-3). Samples were analyzed for constituents included in the primary drinking-water standards established by the USEPA. Water-quality data collected by the CUC indicate that water from the three wells meet the requirements set by the USEPA for a potable water source. Based on information collected during this project, the CUC designated the three wells as new municipal water-supply wells.

References Cited

Bridge, J., 1946, Economic Survey of Micronesia, Volume 3, Geology: Microfilm call number S00796 v.3 at University of Hawaii, Manoa main library, reel 1 of 5.

Nance, T., 1993, Results of Drilling and Pump Testing of Exploratory Borings on the SNM Rota Resort Site: Tom Nance Water Resources Engineering, 18 p.

Piper, A.M., 1947, Water Resources of Guam and the Ex-Japanese Mandated Islands of the Western Pacific: unpublished U.S. Geological Survey report for the U.S. Navy on file at the U.S. Geological Survey Water Resources Division office in Honolulu,
181 p.

U.S. Environmental Protection Agency, 1989, Proposed rule, National primary and secondary drinking water regulations: U.S. Federal Register, v. 54, no. 97, May 22, 1989, p. 22,062–22,160.