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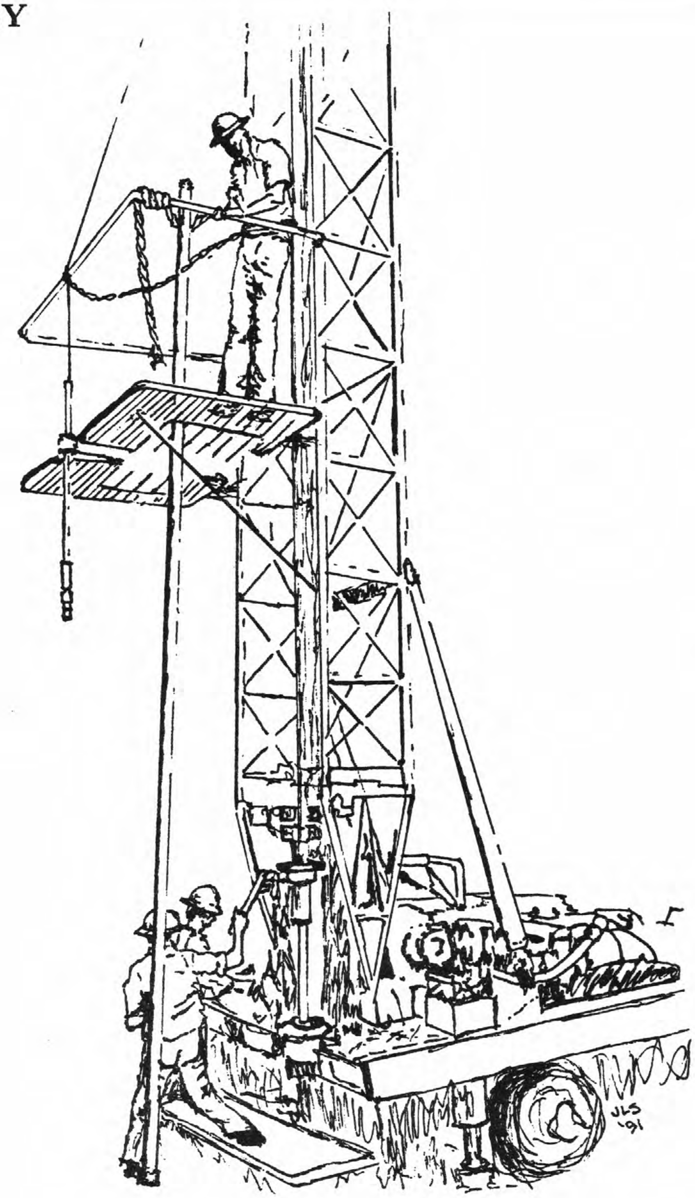
CHEMICAL ANALYSES OF WATER SAMPLES AND GEOPHYSICAL LOGS FROM CORED TEST HOLES DRILLED IN THE CENTRAL OKLAHOMA AQUIFER, OKLAHOMA

U.S. GEOLOGICAL SURVEY
Open-File Report 91-464



Test-hole drilling in the Central Oklahoma aquifer

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Prepared in cooperation with the
ASSOCIATION OF CENTRAL OKLAHOMA GOVERNMENTS

Schlottmann and Funkhouser—WATER SAMPLES AND GEOPHYSICAL LOGS, TEST HOLES IN CENTRAL OKLAHOMA AQUIFER USGS/OFR 91-464

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By Jamie L. Schlottmann and Ron A. Funkhouser

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Oklahoma City, Oklahoma
1991

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METRIC CONVERSION FACTORS

For readers who prefer metric (International System) units rather than inch-pound units (used in this report), the following conversion factors may be applied:

Multiply inch-pound unit	By	To obtain metric unit
foot	0.3048	meter
gallon	0.003785	cubic meter
gallons per minute	0.0000631	cubic meters per second

Temperature in degrees Celcius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \text{ X } °C) + 32$$

ALTITUDE DATUM

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum (NGVD) of 1929–a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

CHEMICAL ANALYSES OF WATER SAMPLES AND GEOPHYSICAL LOGS FROM CORED TEST HOLES DRILLED IN THE CENTRAL OKLAHOMA AQUIFER, OKLAHOMA

By Jamie L. Schlottmann and Ron A. Funkhouser

ABSTRACT

Chemical analyses of water from eight test holes and geophysical logs for nine test holes drilled in the Central Oklahoma aquifer are presented. The test holes were drilled to investigate local occurrences of potentially toxic, naturally occurring trace substances in ground water. These trace substances include arsenic, chromium, selenium, residual alpha-particle activities, and uranium. Eight of the nine test holes were drilled near wells known to contain large concentrations of one or more of the naturally occurring trace substances. One test hole was drilled in an area known to have only small concentrations of any of the naturally occurring trace substances.

Water samples were collected from one to eight individual sandstone layers within each test hole. A total of 28 water samples, including four duplicate samples, were collected. The temperature, pH, specific conductance, alkalinity, and dissolved-oxygen concentrations were measured at the sample site. Laboratory determinations included major ions, nutrients, dissolved organic carbon, and trace elements (aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, vanadium and zinc). Radionuclide activities and stable isotope δ values also were determined, including: gross-alpha-particle activity, gross-beta-particle activity, radium-226, radium-228, radon-222, uranium-234, uranium-235, uranium-238, total uranium, carbon-13/carbon-12, deuterium/hydrogen-1, oxygen-18/oxygen-16, and sulfur-34/sulfur-32. Additional analyses of arsenic and selenium species are presented for selected samples as well as analyses of density and iodine for two samples, tritium for three samples, and carbon-14 for one sample.

Geophysical logs for most test holes include caliper, neutron, gamma-gamma, natural-gamma logs, spontaneous potential, long- and short-normal resistivity, and single-point resistance. Logs for test-hole NOTS 7 do not include long- and short-normal resistivity, spontaneous-potential, or single-point resistivity. Logs for test-hole NOTS 7A include only caliper and natural-gamma logs.

INTRODUCTION

Studies of water and rock characteristics associated with arsenic, chromium, residual alpha-particle activity, selenium, and uranium in ground water of the Central Oklahoma aquifer, Oklahoma are part of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey. The long-term goals of the NAWQA program are to:

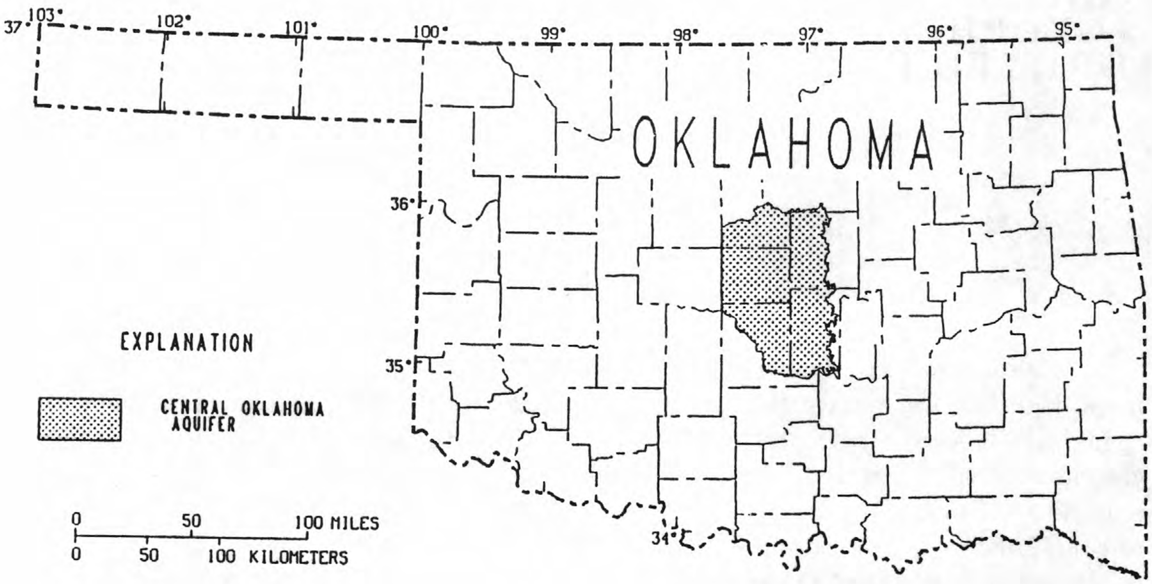


Figure 1.—Location of the Central Oklahoma aquifer and the study unit.

(1) Provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources,

(2) Define long-term trends (or lack of trends) in water quality, and

(3) Identify, describe, and explain, as possible, the major factors that affect the observed water-quality conditions and trends.

The results of the NAWQA Program will be made available to water managers, policy makers, and the public, and will provide an improved scientific basis for evaluating the effectiveness of water-quality management programs (Hirsch and others, 1988).

The Central Oklahoma aquifer (fig. 1) was selected for study because it is a major source of water in central Oklahoma and because it has several known or suspected water-quality problems (Parkhurst and others, 1989). Studies of the water-quality problems, including local occurrences of potentially toxic trace elements, address goal three of the NAWQA program.

Arsenic, chromium, residual alpha-particle activities, selenium, and uranium occur naturally in the aquifer, and in some areas are present in large concentrations. These potentially toxic naturally occurring trace substances (NOTS) appear to be more common in some parts of the aquifer than in others. Existing ground-water-quality data (through 1987) for the Central Oklahoma aquifer were reviewed at the inception of the NAWQA project by Parkhurst and others (1989). Arsenic and chromium commonly exceeded the U.S. Environmental Protection Agency's primary drinking-water standard (1986) of 50 micrograms per liter (μg/L) in water from wells deeper than 300 feet, and in some parts of the aquifer selenium commonly exceeded the standard of 10 μg/L in wells over 100 feet in depth. Residual alpha-particle activity commonly exceeded the standard of 15 picocuries per liter (pCi/L), and uranium concentrations were commonly large in water from wells in the eastern part of the study area.

A cooperative effort between the U.S. Geological Survey's Water Resources and Geologic Divisions was organized to drill cored test holes (fig. 2) in order to evaluate the sources of and processes controlling the mobilization of the NOTS. The chemical composition of the rocks has been reported by Mosier and others (1990) and an additional report describing the mineralogy and petrology of the rock cores has been presented by Breit and others (1990). The study of the NOTS in the western part of the aquifer was made in cooperation with the Association of Central Oklahoma Governments.

Purpose and Scope

The purpose of this report is to present results of chemical and isotopic analyses of water samples collected from test holes that were drilled in the Central Oklahoma aquifer, and to publish the geophysical logs of the test holes. No interpretations of the data are presented.

Description and Hydrogeology of the Study Unit

The study-unit boundary is the perimeter of the Central Oklahoma aquifer (fig. 2) as defined by Parkhurst and others (1989). The Central Oklahoma aquifer extends from the Canadian River on the south to the Cimarron River on the north and from the Oklahoma-Canadian and Logan-Kingfisher County lines on the west to the eastern limit of the outcrop of the Chase, Council Grove, and Admire Groups on the east. The study unit contains all of Cleveland and Oklahoma Counties and parts of Lincoln, Logan, and Pottawatomie Counties. The base of the aquifer and thus the study unit is defined as the lower limit of ground water containing less than 5,000 milligrams per liter dissolved solids. The boundary, defined by the increase in dissolved-solids concentration, ranges in depth from 100 to about 1,000 feet and is referred to as the base of fresh water.

The Central Oklahoma aquifer includes Quaternary alluvial and terrace deposits and underlying Permian-age units including the Garber Sandstone, the Wellington Formation, and the Chase, Council Grove, and Admire Groups (fig. 3). This study is restricted to the Permian-age rocks in the aquifer and the overlying Hennessey Group. The Permian-age part of the aquifer is overlain in the western part of the study unit by the Permian-age Hennessey Group, which acts as a confining layer. In the east the aquifer overlies the Pennsylvanian-age Vanoss Group. Transmissivities of Permian-age rocks within the Central Oklahoma aquifer are larger than transmissivities for equivalent-age rocks outside of the aquifer boundary (Parkhurst and others, 1989). The stratigraphic relation between the geologic units in the study unit are shown in table 2 with the corresponding geohydrologic categories. All

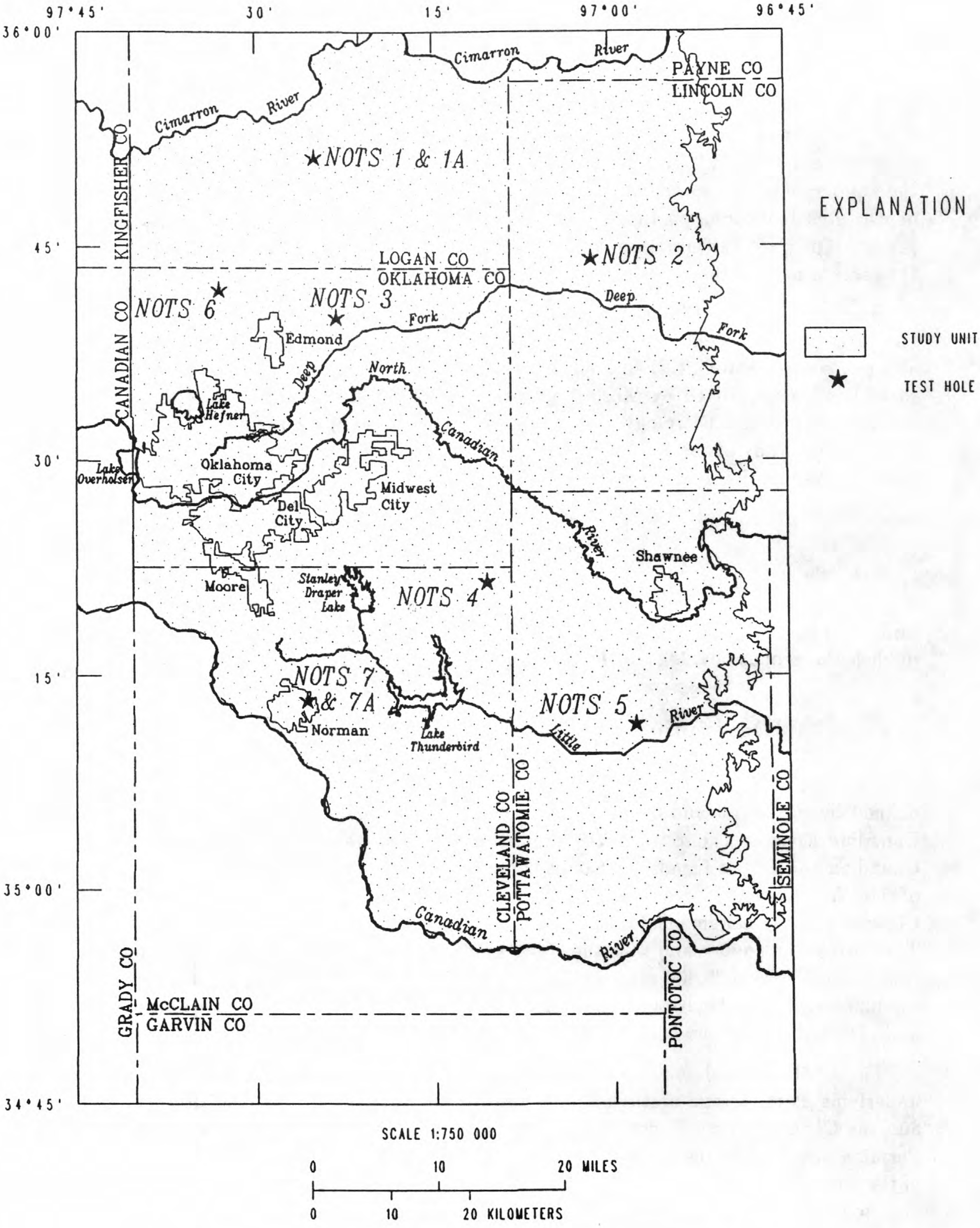


Figure 2.—Geographic features of study unit and location of test-holes drilled in the Central Oklahoma aquifer.

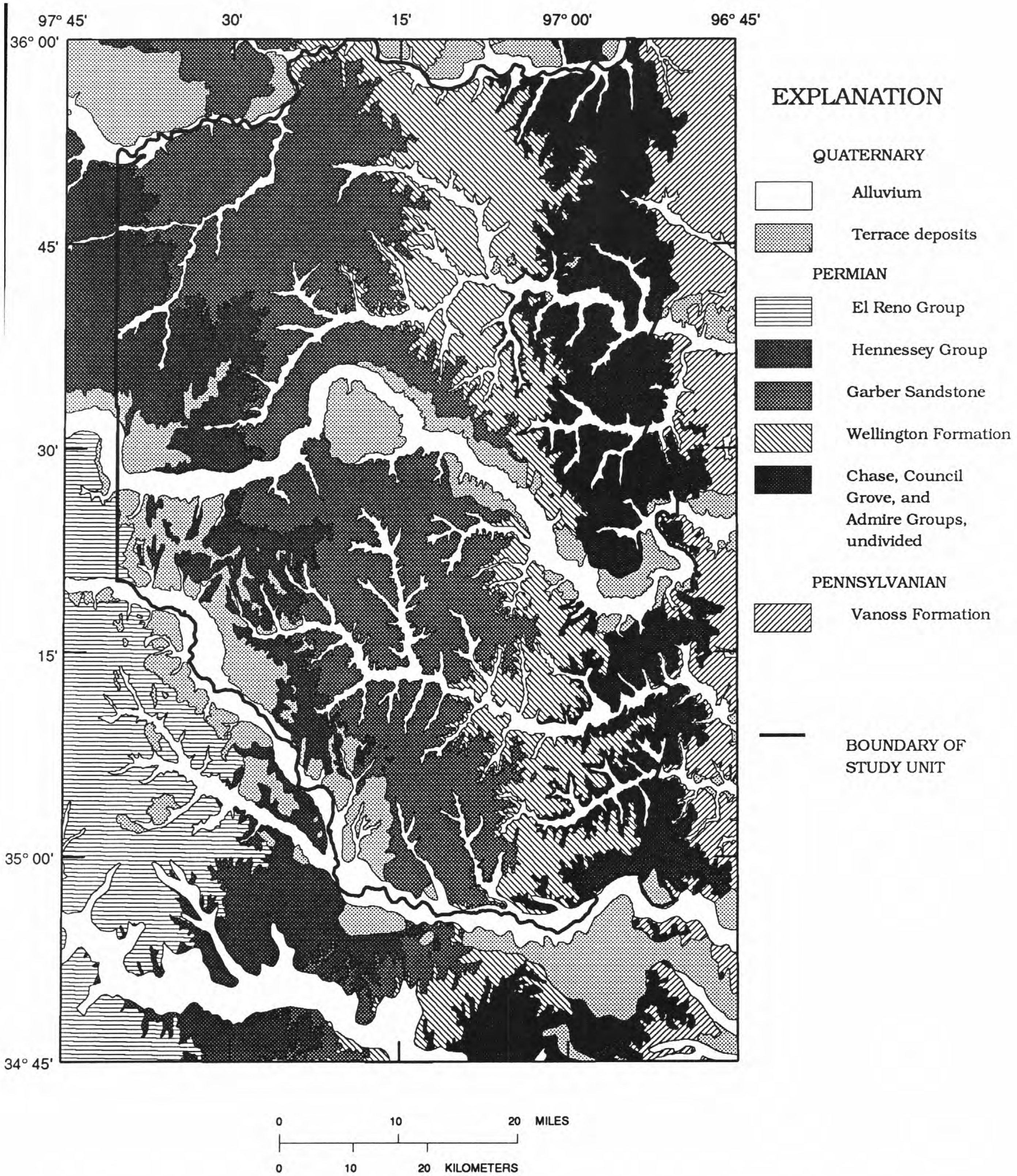


Figure 3.—Geologic map of central Oklahoma (modified from Bingham and Moore, 1975, and Hart, 1974).

Permian rocks in the study unit dip to the west-southwest at a gradient of approximately 50 feet per mile (Parkhurst and others, 1989).

Table 1.—*Correlation of major chronostratigraphic units, geologic units, and geohydrologic categories in central Oklahoma* (from Parkhurst and others, 1989, p. 8, table 1)

Erathem	System	Geologic unit	Geohydrologic category
Cenozoic	Quaternary	Alluvium	Alluvium-Terrace
		Terrace deposits	
Paleozoic	Permian	El Reno Group	El Reno
		Hennessey Group	Hennessey
		Garber Sandstone	Garber-Wellington Shallow Medium-depth Deep
		Wellington Formation	
		Chase Group	Chase-Admire
		Council Grove Group	
		Admire Group	
	Pennsylvanian	Vanoss Formation	Vanoss

Description of the NOTS Drilling Project

Nine test holes were cored at various locations in the aquifer to study the water-rock interactions that lead to increased concentrations of arsenic, chromium, selenium, residual alpha-particle activity, and uranium in the ground water (fig. 2). One of the test holes, NOTS 4, was located in an area of generally good water quality; the remaining eight were located in areas known to have high concentrations of one or more of the potentially toxic substances. The lithology of rock core collected from each test hole was briefly described at the site before the core was labeled and placed in core boxes. Each test hole was logged geophysically. Water was collected from one to eight water-producing sandstone layers penetrated by eight of the test holes and chemically analyzed. The rock core collected from eight of the test holes was split and one half was sampled for chemical and petrographic analyses; the other half was reserved for detailed description of lithology and sedimentology. One of the test holes, NOTS 1, was not sampled because of hole instability. Another test hole, NOTS 1A, was drilled adjacent to NOTS 1 and was sampled. The test holes are described in table 1.

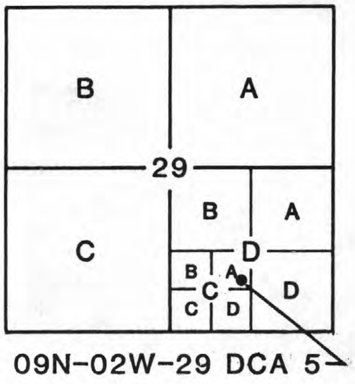
Table 2.— *Description of NOTS test holes and number of water-chemistry samples taken from intervals in each hole*

[Open-hole water level in feet below land surface; Geologic units intercepted: Hennessey, Hennessey Group; Garber, Garber Sandstone; Wellington, Wellington Formation; Chase, Chase-Council Grove-Admire Groups. Number of duplicate water samples collected at each test hole in addition to the actual samples are shown in parentheses next to number of water samples collected]

Well name	Local identifier	Latitude	Longitude	County	Altitude (feet above sea level)	Depth of hole (feet)	Open-hole water level (feet)	Geologic units intercepted	Number of water-chemistry samples
NOTS 1	16N-02W-21 BAA 2	355120	0972500	Logan	1,050	272	50.5	Garber	0
NOTS 1A	16N-02W-21 BAA 3	355118	0972500	Logan	1,045	268	10.0	Garber	2
NOTS 2	15N-03E-31 BAA 2	354418	0970135	Lincoln	900	277	42.0	Chase	1
NOTS 3	14N-02W-23 CCA 1	354012	0972310	Oklahoma	1,035	195	36.0	Garber	2(1)
NOTS 4	10N-01E-11 BBB 1	352142	0971035	Cleveland	1,145	291	31.0	Garber, Wellington	4
NOTS 5	08N-03E-03 DAA 1	351142	0965801	Pottawatomie	945	238	18.5	Chase	3(1)
NOTS 6	14N-03W-07 DAA 2	354208	0973302	Oklahoma	1,085	587	46.0	Garber	8(1)
NOTS 7	09N-02W-29 DCA 5	351315	0972543	Cleveland	1,172	456	74.0	Hennessey, Garber	1
NOTS 7A	09N-02W-29 DCA 6	351315	0972542	Cleveland	1,172	631	97.0	Hennessey, Garber	3(1)

Explanation of the Local Identifier

The locations of the test holes are specified by latitude and longitude to the nearest second and by a local identifier, which is based on the public land survey. The local identifier includes the township and range followed by the section and a series of letters that designate the quarter-section subdivisions from largest to smallest. The order of the quarter-section subdivisions is opposite of that used in the public land survey. A sequence number is added to make the local identifier unique in the U.S. Geological Survey data base. As illustrated in the following diagram, the public land survey description of the site indicated by the dot is NE 1/4 SW 1/4 SE 1/4 sec. 29, T. 09 N., R. 02 W., which is denoted by the local identifier 09N–02W–29 DCA. If the sequence number is 5, the complete identifier is 09N–02W–29 DCA 5.



WATER CHEMISTRY

Field Methods

When possible, ground water from sandstone layers penetrated by the test holes was sampled for chemical analysis. In order to sample water from an individual sandstone layer, the layer was isolated using two inflatable packers separated by 5 or 10 feet of stainless steel well screen and enough galvanized pipe to make the isolated interval span the entire thickness of the sandstone (fig. 4). The centers of the packers generally were set 2 to 3 feet below the top and above the bottom of each sandstone layer. They were set there because the interbedded mudstone layers sloughed rapidly in the open hole, making it impossible to inflate the packers against the mudstone above and below the sand. For some samples, one of the packers was set near the edge of the next adjacent sandstone layer because the shortest packer-assembly length was too long to fit within the sandstone to be sampled. Table 3 describes the water samples collected from the test holes. The sampling depth is the depth of the center of the sampling interval below land surface. The sample depth interval is designated as the distance in feet below land surface of the vertical centers of the upper and lower packer.

Before inserting the sampling pump, each interval was developed until the produced water was clear. The intervals were developed by airlifting or another pumping method if airlifting was not possible. Some intervals did not produce clear water. If the water was not clear, the interval was pumped as long as possible (1.5 to 32 hours, depending on hole stability and available work hours) before inserting the sampling pump. Samples were collected using either a submersible electric pump, a pump jack, or a teflon bladder pump, depending on the rate at which the sand would produce water and the water level

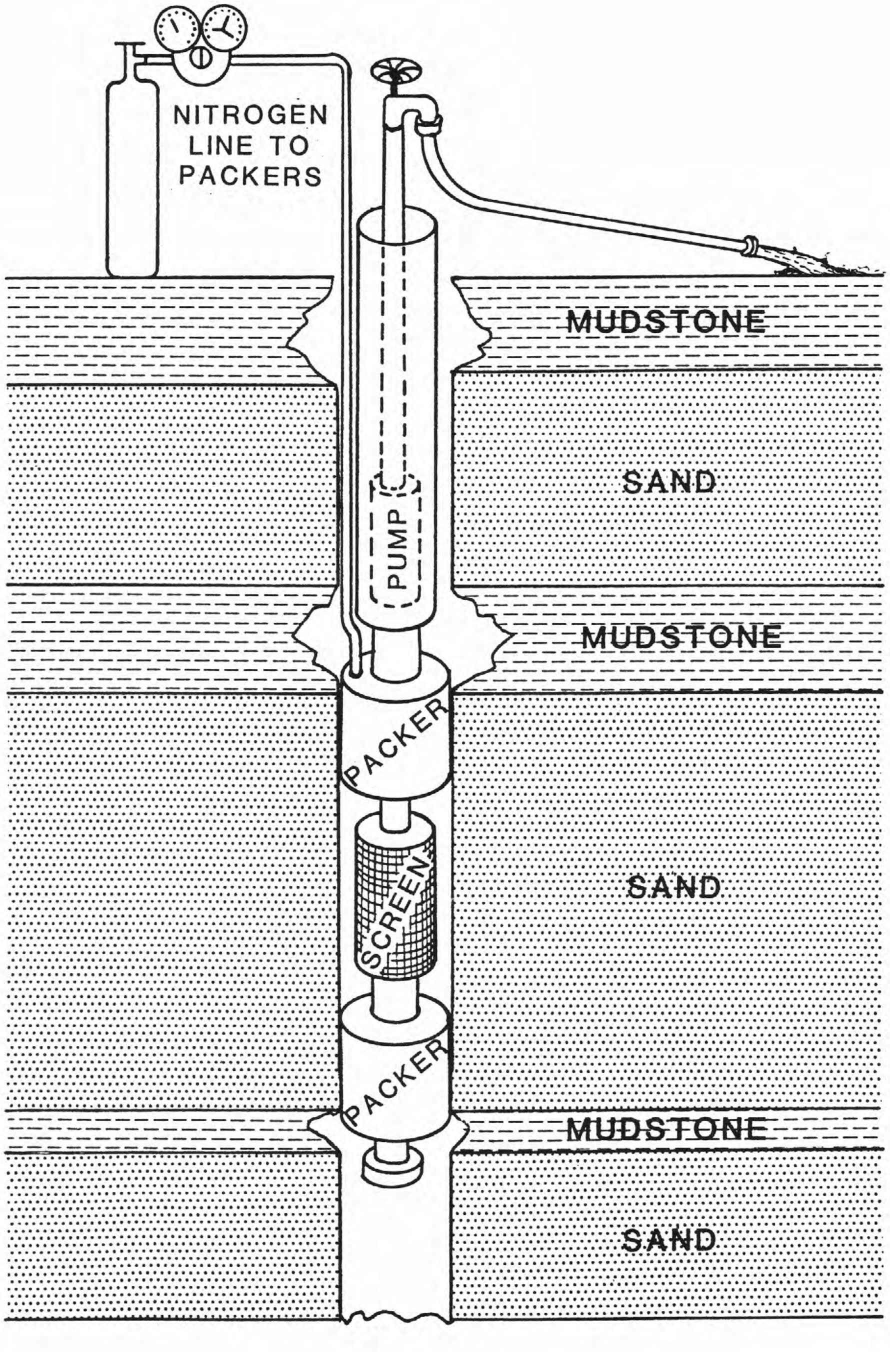


Figure 4.—Simplified diagram of packer and pump assembly to isolate and sample water from sandstone layers intercepted by the NOTS test holes.

Table 3.—*Description of water-chemistry samples collected from NOTS test holes*

[CST, central standard time; Geologic units sampled: Garber, Garber Sandstone; Wellington, Wellington Formation; Chase, Chase-Council Grove-Admire Groups; Interval water level in feet below land surface]

Test-hole name	Local identifier	Sampling depth (feet)	Sampling date	Sampling time (CST)	Sample depth interval (feet)	Geologic unit sampled	Interval water level (feet)
NOTS 1A	16N-02W-21 BAA 3	176.0	04/21/88	1600	166.0–186.0	Garber	62.75
		229.0	04/20/88	1300	210.0–248.0	Garber	55.95
NOTS 2	15N-03E-31 BAA 2	106.4	05/11/88	1300	96.4–116.0	Chase	40.00
NOTS 3	14N-02W-23 CCA 1	119.5	05/24/88	1100	110.0–129.0	Garber	60.75
		119.5	05/24/88	1600	110.0–129.0	Garber	60.75
		164.9	05/20/88	1100	155.4–174.4	Garber	62.28
NOTS 4	10N-01E-11 BBB 1	101.0	06/21/88	1200	87.0–115.0	Garber	51.60
		156.2	06/20/88	1200	142.2–170.2	Garber	49.19
		189.0	06/23/88	1200	178.0–200.0	Garber	25.90
		257.5	06/17/88	1000	243.5–271.5	Wellington	89.40
NOTS 5	08N-03E-03 DAA 1	62.0	07/06/88	1000	48.0–76.0	Chase	18.52
		62.0	07/06/88	1400	48.0–76.0	Chase	18.52
		131.0	07/05/88	1000	127.0–155.0	Chase	30.83
		183.5	07/01/88	1000	169.5–197.5	Chase	29.55
NOTS 6	14N-03W-07 DAA 2	106.2	11/02/88	900	96.4–116.8	Garber	61.22
		141.0	11/08/88	1100	121.4–160.5	Garber	64.06
		180.8	11/07/88	1500	161.2–200.3	Garber	72.64
		180.8	11/07/88	1300	161.2–200.3	Garber	72.64
		222.8	11/04/88	900	203.2–242.3	Garber	74.04
		276.2	11/01/88	900	266.0–286.0	Garber	114.50
		296.2	10/28/88	1500	286.0–306.4	Garber	120.30
		327.1	11/03/88	1300	307.5–346.6	Garber	110.13
		475.1	12/07/88	900	456.0–494.2	Garber	168.88
NOTS 7	09N-02W-29 DCA 5	262.7	02/17/89	1100	229.2–276.2	Garber	209.34
NOTS 7A	09N-02W-29 DCA 6	330.1	07/20/89	1300	316.6–343.6	Garber	250.00
		407.5	08/08/89	1500	397.0–418.0	Garber	251.40
		480.0	09/20/89	1200	460.0–500.0	Garber	267.60
		480.0	09/20/89	1500	460.0–500.0	Garber	267.60

for the sampled interval. With the exception of the samples from test-holes NOTS 2, 7, and 7A, each sampled interval was purged of at least two bore volumes of water before sampling began. A bore volume was estimated to be the volume of the column of water between the packers plus the volume of water within the pipe above the packers. NOTS 2 produced too little water to purge an adequate volume before sampling. Problems with the pumps prevented adequate purging of the sampled intervals in NOTS 7 and 7A, with the the sample from NOTS 7 having the smallest volume purged. Data pertaining to the pumps and pumping times used to develop and sample each interval are summarized in table 4.

After the sampling pump was inserted and the interval had been purged of at least one bore volume, specific conductance, water temperature, pH, and dissolved-oxygen concentration were measured at 10- to 15-minute intervals. Measurements were made at the land surface in a flow-through cell by probes attached to portable meters. Water temperature was measured with the temperature sensor of the specific conductance meter.

Water sampling began after at least two consistent readings were obtained for water temperature, pH, dissolved oxygen, and specific conductance for readings taken 10 to 15 minutes apart. Alkalinity was measured by an incremental titration (Knapton, 1985) using 0.1639-Normal sulfuric acid on a filtered 25-milliliter aliquot which was collected immediately after consistent readings were obtained.

Water samples were collected using methods described in Brown and others (1970) or by other methods recommended by the analyzing laboratories. Table 5 summarizes the sample collection and preservation procedures used, with the exception of a sample collected for carbon-14 determination.

The sample collected for carbon-14 determination for use in water-age estimation was prepared by filtering approximately 30 gallons of water under nitrogen into a stainless steel separatory funnel. The filters used included a 0.45-micrometer pre-filter and a 0.2-micrometer membrane filter. Carbon-free sodium hydroxide and strontium chloride solutions were added to the filtered water to precipitate strontium carbonate. The precipitate was collected under nitrogen gas in a baked glass bottle. No preservatives were added.

Analytical Methods

All determinations, with the exception of those for arsenic species, selenium species, and carbon dating, were done by the U.S. Geological Survey National Water Quality Laboratory (NWQL). Specific conductance, pH, major elements, nutrients, trace elements, and dissolved organic carbon concentrations were determined using standard methods described in Fishman and Friedman (1989). Radiochemical analyses were completed using standard methods as described in Thatcher and others (1977). Methods used by the NWQL for this study are listed in table 6 (at back of report).

Arsenic species concentration was determined at two laboratories. One sample from the deepest sampled interval in NOTS 6 was analyzed by the Branch of Regional Research, Western Region of the U.S. Geological Survey, Water Resources Division, Menlo Park,

Table 4.—*Summary of pumps and pumping times used to develop sampling intervals and collect water samples from NOTS test holes*

[Sampling depth, center of sampling interval as depth below land surface; —, indicates data not available; pump types: Sub. elec., submersible electric; Bladder, stainless steel case with teflon bladder; gal/min, gallons per minute; Water clear: N, no, water still muddy, mostly opaque with sediment; Y, yes, water pumped until clear; M, mostly, water translucent with some suspended sediment]

Test-hole name	Local identifier	Sampling depth (feet)	Developing pump	Developing pumping rate (gal/min)	Developing pumping time (hours)	Sampling pump	Sampling pumping rate (gal/min)	Pre-sampling pumping time (hours)	Water clear
NOTS 1A	16N-02W-21 BAA 3	176.0	Air lift	—	1.5	Sub. elec.	6	4	N
		229.0	Air lift	—	2	Sub. elec.	6	2	N
NOTS 2	15N-03E-31 BAA 2	106.4	Air lift	0.25	7	Bladder	0.3	4	N
NOTS 3	14N-02W-23 CCA 1	119.5	Air lift	2.5	4.5	Sub. elec.	7.5	3	Y
		119.5	Air lift	2.5	4.5	Sub. elec.	7.5	3	Y
		164.9	Air lift	0.5	5	Sub. elec.	3	1	M
NOTS 4	10N-01E-11 BBB 1	101.0	Air lift	4	3	Sub. elec.	7.5	3	Y
		156.2	Air lift	15	3	Sub. elec.	10	2	Y
		189.0	Air lift	3	3	Sub. elec.	3	2	Y
		257.5	Air lift	—	4	Sub. elec.	10	3	Y
NOTS 5	08N-03E-03 DAA 1	62.0	Air lift	3.5	1.5	Sub. elec.	10	1	Y
		62.0	Air lift	3.5	1.5	Sub. elec.	10	1	Y
		131.0	Air lift	0.5	3	Sub. elec.	1	1	M
		183.5	Air lift	—	3	Sub. elec.	6	2	Y
NOTS 6	14N-03W-07 DAA 2	106.2	Air lift	2	1	Sub. elec.	3	1	Y
		141.0	Air lift	7	2.5	Sub. elec.	7	3	Y
		180.8	Air lift	17	3	Sub. elec.	10	2	Y
		180.8	Air lift	17	3	Sub. elec.	10	2	Y
		222.8	Air lift	30	2	Sub. elec.	9	1	Y
		276.2	Air lift	2.5	3.5	Sub. elec.	6	2	Y
		296.2	Air lift	3	4	Sub. elec.	—	2	Y
		327.1	Air lift	7	3	Sub. elec.	7	3	M
		475.1	Air lift	15	3	Sub. elec.	5.5	6	N
NOTS 7	09N-02W-29 DCA 5	262.7	Sub. elec.	0.5	5	Sub. elec.	—	—	N
NOTS 7A	09N-02W-29 DCA 6	330.1	Bladder,	0.2	24	Pump jack	2.5	1.5	N
			then pump jack	1.7	5				
		407.5	Pump jack	2.5	10	Bladder	—	—	N
		480.0	Pump jack	2.5	32	Bladder	.25	8	N
		480.0	Pump jack	2.5	32	Bladder	.25	8	N

Table 5.—*Field procedures for collection and preservation of water samples for laboratory analysis*

[Dissolved, concentration in filtered sample; total, total recoverable concentration including suspended and colloidal solids; °C, degrees Celsius; DCP, direct coupled plasma]

Constituents to be analysed	Filter type(s) used	Collection bottle type	Preservation method
Major cations and trace elements, dissolved except those listed below	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Acid-rinsed polyethylene	Nitric acid to pH 2 or less
Major anions, dissolved, pH, and specific conductance	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Non-acid-rinsed polyethylene	None
Nutrients	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Amber polyethylene	Mercuric chloride-sodium chloride ampoule, chill to 4 °C
Trace elements, total, including uranium	Unfiltered, sieved through 325 mesh plastic screen to remove sand	Acid-rinsed polyethylene	Nitric acid to pH 2 or less
Arsenic and selenium species, dissolved	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Acid-rinsed polyethylene	Ultrapure hydrochloric acid to pH 1, keep dark, chill to 4 °C
Chromium, dissolved for analysis by DCP	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Acid-rinsed teflon	Ultrapure nitric acid to pH 2 or less, keep dark
Chromium, hexavalent, dissolved	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Acid-rinsed polyethylene	Nitric acid to pH 3, keep dark, chill to 4 °C
Mercury, dissolved	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Baked glass	Nitric acid/potassium dichromate ampoule
Organic carbon, dissolved	0.45-micrometer silver filter	Baked glass	Mercuric chloride-sodium chloride ampoule, chill to 4 °C
Carbon-13/carbon-12 isotope ratio	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Glass	Ammoniacal strontium chloride, mercuric chloride tablet
Gross-alpha and -beta activity, suspended and dissolved	Unfiltered, sieved through 325 mesh plastic screen to remove sand	Acid-rinsed polyethylene	None
Radium and uranium isotopes	0.45-micrometer cartridge prefilter with 0.2-micrometer membrane filter	Acid-rinsed polyethylene	Hydrochloric acid to pH 2 or less
Radon, total	Unfiltered, sampled under pressure with plastic syringe	Scintillation vial	Express under scintillation cocktail, shake
Stable hydrogen and oxygen isotope ratios	Unfiltered, sieved through 325 mesh plastic screen to remove sand	Glass	Mercuric chloride tablet
Stable sulfur isotope ratio	Unfiltered, sieved through 325 mesh plastic screen to remove sand	Acid-rinsed polyethylene	Mercuric chloride tablet
Tritium	Unfiltered, sieved through 325 mesh plastic screen to remove sand	Glass	None

California. All other samples for arsenic species were analyzed by Battelle Pacific Northwest Division[1], Marine Sciences Laboratory, Sequim, Washington.

Determinations of arsenic species concentrations made by the Branch of Regional Research were made using flow-through hydride-generation atomic-absorption spectrophotometry. Arsenite was analyzed from an aliquot of the sample buffered to pH 5 using a buffer composed of 1.78-molar sodium acetate and 1-molar acetic acid. The aliquot was then reacted with a solution of 1-percent sodium borohydride to generate an arsenic hydride. The hydride was carried by nitrogen carrier gas to the absorption cell placed in the flame of the spectrophotometer. Total arsenic concentration was measured from a sample aliquot that was reduced with a solution of potassium iodide in 40-percent hydrochloric acid. A solution of 10-Normal hydrochloric acid was added in place of the buffer used for arsenite. Total arsenic in the aliquot was analyzed by generating arsenic hydride in the same manner as that used for arsenite. Arsenate was calculated to be the difference between total arsenic and arsenite (Tallman and Shaikh, 1980).

Battelle used a similar method for the analysis of arsenic species using hydride-generation atomic-adsorption spectrophotometry as described by Andreae (1977). In that method, as in the Branch of Regional Research method, arsenite and total arsenic concentrations are analyzed and arsenate concentration is determined by the difference between the two.

Selenium species were determined by the California District Office of the U.S. Geological Survey, Water Resources Division, Sacramento, California. The methods used are described in Fio and Fujii (1988).

Carbon-14 was determined by the Radiocarbon Laboratory at the Institute for the Study of Earth and Man, Southern Methodist University, Dallas, Texas. The sample was hydrolyzed with 80 percent hydrochloric acid and the carbon in the resulting gas was frozen in a cold trap using liquid nitrogen. The frozen carbon was transferred to a benzene synthesis system and was converted to benzene. The carbon-14 content of the benzene was measured to determine the percent modern carbon (personal communication, Herbert Haas).

Stable isotopes were analysed using mass spectrometry after the element was converted to a gas or included in a gaseous compound. Carbon-13 and carbon-12 were determined from CO_2 gas generated by reacting the strontium carbonate precipitate with 100 percent orthophosphoric acid. The amount of CO_2 gas produced was measured monometrically. The carbon-13–carbon-12 ratio was then normalized to a δ-value in permil relative to the PDB (Peedee Belemnite) standard (Crey, 1950). Deuterium and hydrogen were measured after conversion to H_2 gas by reduction with zinc metal. The deuterium-hydrogen isotope ratio was then normalized to a δ-value in permil relative to the VSMOW-SLAP (Vienna Standard Mean Ocean Water-Standard Light Antartic Precipitation) scale such that SLAP has a value of -428 permil (Kendall and Coplen, 1985). Oxygen-18 and oxygen-16 were determined from CO_2 gas which was equilibrated with the water sample. The oxygen isotope ratio was normalized to a δ-value relative to the VSMOW-SLAP scale such that SLAP has a value of -55.5 permil (Epstein and Mayeda, 1953). The normalized values for oxygen and hydrogen isotopes are related back to the original Standard Mean Ocean Water

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[1] Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Water (SMOW) through SLAP by the VSMOW-SLAP scale and are reported as permil relative to SMOW. Sulfur-34 and sulfur-32 were measured in SO_2 gas that was generated by precipitating $BaSO_4$ from the sample by adding $BaCl_2$ and then roasting that precipitate mixed with Cu_2O and SiO_2 at 1,125° Celsius. The SO_2 gas was purified using a vacuum distillation line. The sulfur isotope ratio was normalized to a δ-value relative to CDT (Canyon Diablo Troilite) using the McMaster University reference standards (Rees, 1978, Woodruff and Shanks, 1988).

Analytical Results

Analytical results, for all parameters except carbon-14, are summarized in tables 7 through 13. Results listed as having no data available were either lost in transit to the analyzing laboratory, were not collected due to difficulty filtering the samples, or a decision was made not to have that determination done on all samples.

Determinations listed as "dissolved" in the column header were measured from a filtered sample. Determinations listed as "total" or "whole" were measured from an unfiltered sample that had passed through a 325-mesh plastic screen. Thus, concentrations listed for total or whole determinations include contributions to the concentration of the element from suspended clays or colloidal material in the sample. Determinations listed as "suspended" were measured from the material retained on a 0.45-micrometer membrane filter after filtering a sample that had previously been passed through a 325-mesh plastic screen.

Carbon-14 determination for a sample collected from test-hole NOTS 7A at a sampling depth of 329.1 ft gave a calculated percent modern carbon of 20.556 ± 0.485.

GEOPHYSICAL LOGS

Methods

For the NOTS project the Geological Survey ran a suite of logs which included: Mechanical caliper log; neutron, gamma-gamma, and natural-gamma nuclear logs; spontaneous-potential, long- and short-normal-resistivity, and single-point-resistance electric logs. A brief description of each log classified by log type follows. These descriptions are adapted from Keys and McCrary (1971).

Mechanical log

Caliper.— The caliper log is a record of the average diameter of a drill hole. This log provides information about the borehole size and stability.

Nuclear logs

Neutron.— A neutron log is a record of the signal from a neutron source to a detector arranged in a probe such that the signal is primarily a function of the hydrogen content of the borehole environment. Neutron logs are useful for the measurement of the moisture content of formations above the water table, and of total porosity of the formation below the water table.

Gamma-gamma.— Gamma-gamma logs are records of the intensity of gamma radiation that is back-scattered by the rocks in the surrounding borehole environment. Gamma radiation is emitted from a source in the probe and the amount of radiation returning to the probe is measured. The intensity of the back-scattered radiation, with the appropriate corrections, is inversely proportional to the bulk density of the formation adjacent to the borehole. The gamma-gamma log is sensitive to borehole variations and is useful in finding washouts as well as determining bulk densities.

Natural gamma.— Natural-gamma logs are records of the amount of natural-gamma radiation that is emitted by rocks. All rocks emit gamma radiation. Certain types of rocks such as shale tend to emit more gamma rays than other types of rocks. Natural-gamma logs are generally good shale indicators and are useful in determining the lithologies intercepted by the borehole.

Electric logs

Spontaneous potential.— Spontaneous-potential logs are records of the potentials or voltages that develop naturally at the contacts between a bed of shale or clay and a bed of sand where penetrated by a borehole. Spontaneous potential is strongly affected by the salinities of the borehole fluid and the formation water. The direction of the spontaneous potential response to changes in lithology depends on which fluid, borehole or formation, is more saline. This factor is important to interpretation and application of spontaneous potential logs to ground-water studies. Spontaneous potential logs are useful for determining lithology and bed thickness.

Normal resistivity.— Normal-resistivity logs measure the apparent resistivity of a volume of rock surrounding the electrodes. The short-normal (16-inch spacing between electrodes) records the apparent resistivity of the zone invaded by the drilling fluids very near the well bore and gives good vertical detail of changes in lithology. The long-normal (64-inch spacing between electrodes) records the apparent resistivity beyond the zone invaded by the drilling fluid and is more indicative of the true formation resistivity.

Single-point resistance.— Single-point resistance logs measure the resistance of the earth materials lying between an in-hole electrode and a surface electrode, or between two in-hole electrodes. The NOTS project utilized in-hole and surface electrodes to measure single-point resistance. Single-point-resistance logs cannot be used quantitatively, but are excellent for providing lithologic information.

On test-holes NOTS 1 through NOTS 5 all logs were obtained using a single conductor EG&G Mount Sopris Instruments [2] model II portable borehole logger. The individual tools were run one at a time and their responses were recorded from the bottom to the top of the borehole.

Test-hole NOTS 6 was logged in two stages because of hole degradation. The entire array of logs could not be run before the hole collapsed. The bottom parts of the neutron, gamma-gamma, spontaneous-potential, and single-point-resistivity logs were obtained after the upper part of the hole was reamed to a larger diameter, cased with 6-inch steel casing, and the bottom of the hole restored.

Test-holes NOTS 7 and 7A were cored, logged, reamed, and cased in sections to help preserve the integrity of the holes. The suite of logs run in test-hole NOTS 7 did not include long- and short-normal logs because the normal resistivity tool did not function. Geophysical logs of NOTS 7A were gathered using a modified multi-conductor Well-Reconnaissance logger. Due to technical difficulties with the Well-Reconnaissance logger only the natural-gamma logs were usable.

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[2] Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Description of Log Presentation

Figures 5–13 show the recorded logs for test-holes NOTS 1 through NOTS 7A. The log presentations are graphical plots of the digitized geophysical logs. The quality of the logs depends on the condition of the borehole, and the condition and availability of the logging equipment.

Long- and short-normal resistivity logs are presented as one plot. The 64-inch long-normal resistivity is represented by a dashed line and the 16-inch short-normal resistivity by a solid line. Open-hole water levels, sampled intervals, and geologic units are represented by symbols. Open-hole water levels were determined before any development of the test holes and are not necessarily representative of the static water levels. Numeric scales were omitted from the log presentation because the logging tools were not calibrated.

On test-holes NOTS 6 and 7 the gaps in the logs are intervals that were cased to stabilize the upper portion of the test hole. The upper part of the natural-gamma log of NOTS 7A between 200 feet and 570 feet depth was run through steel casing that extended from land surface to 475 feet.

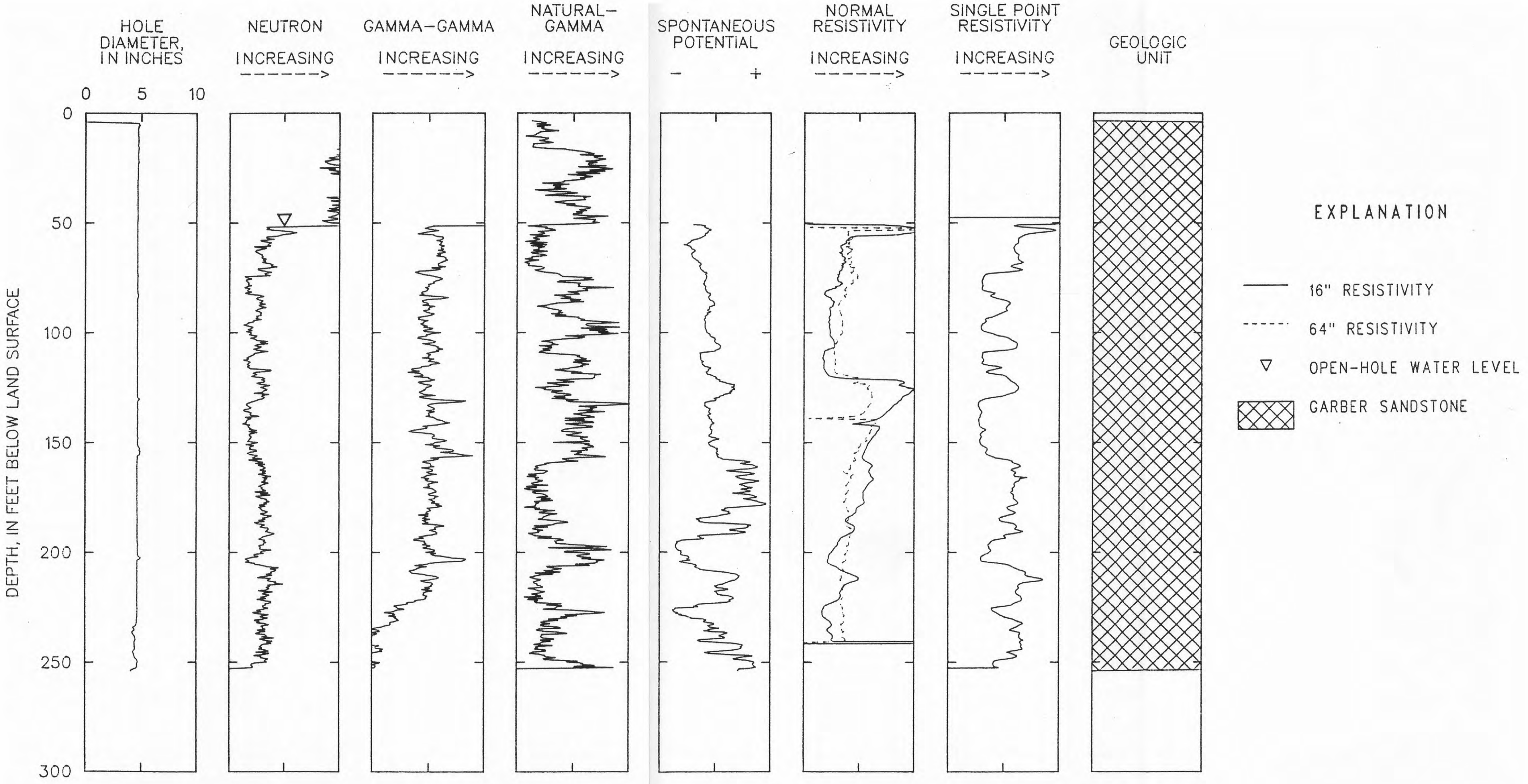

Figure 5.—Geophysical logs for test-hole NOTS 1.

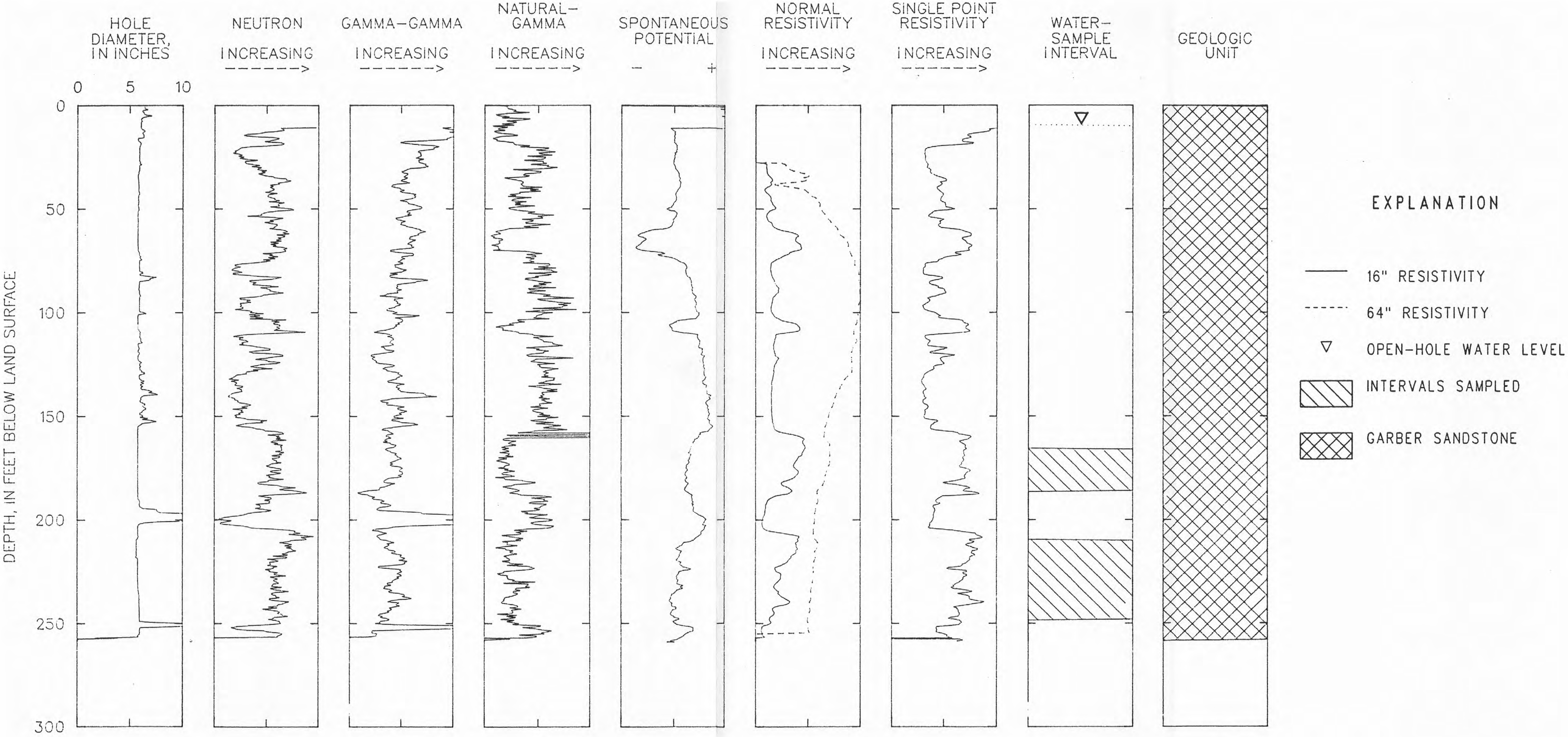

Figure 6.—Geophysical logs for test-hole NOTS 1A.

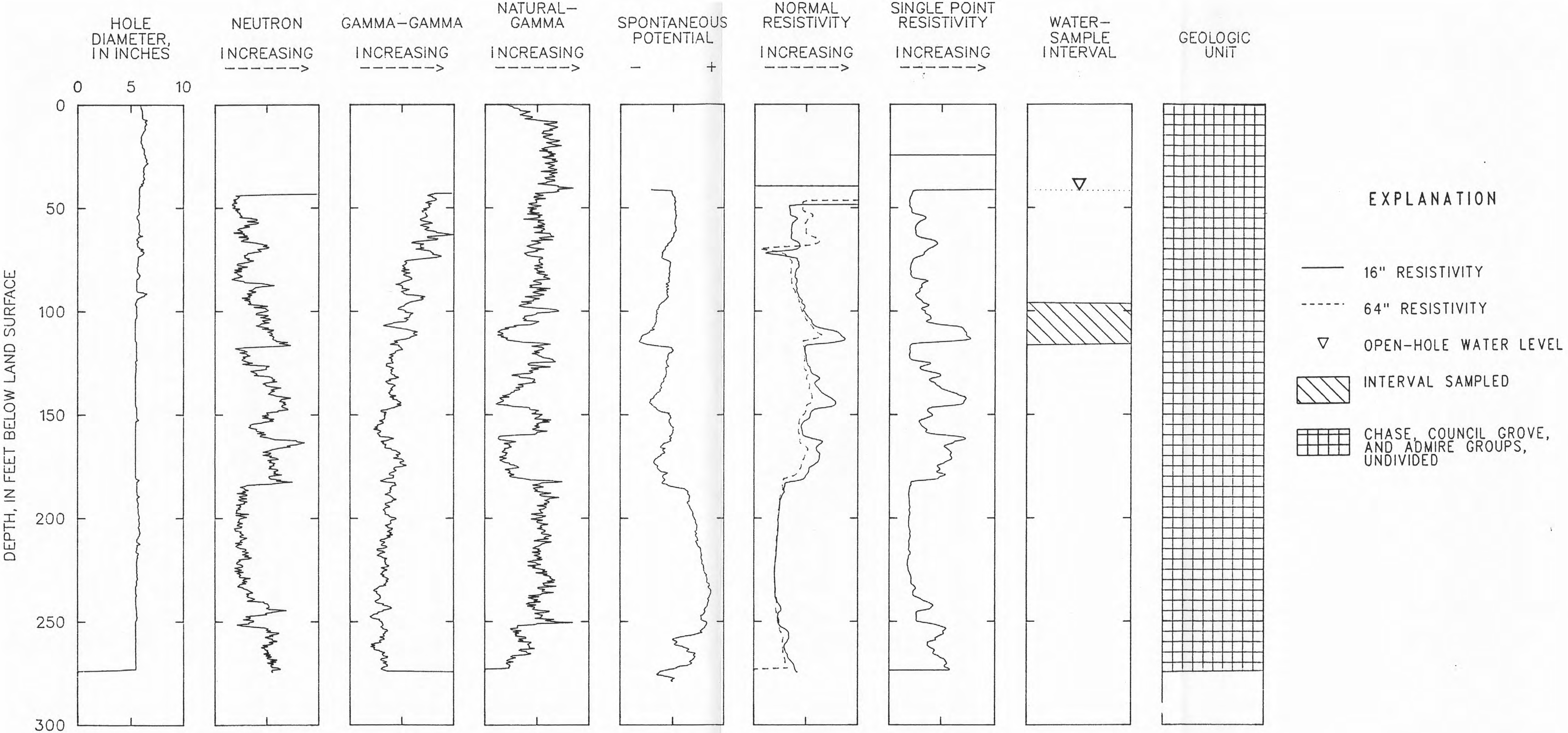

Figure 7.—Geophysical logs for test-hole NOTS 2.

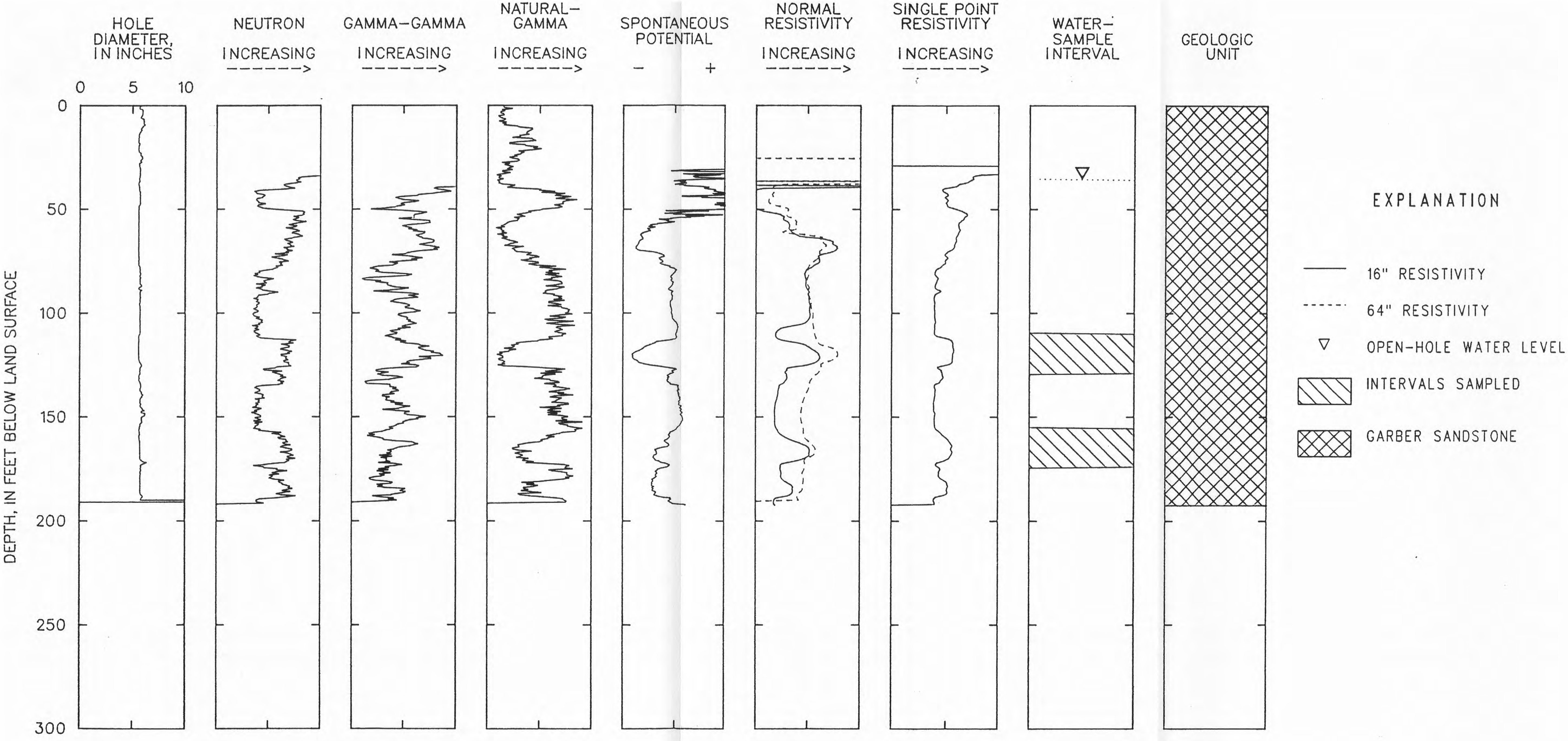

Figure 8.–Geophysical logs for test-hole NOTS 3.

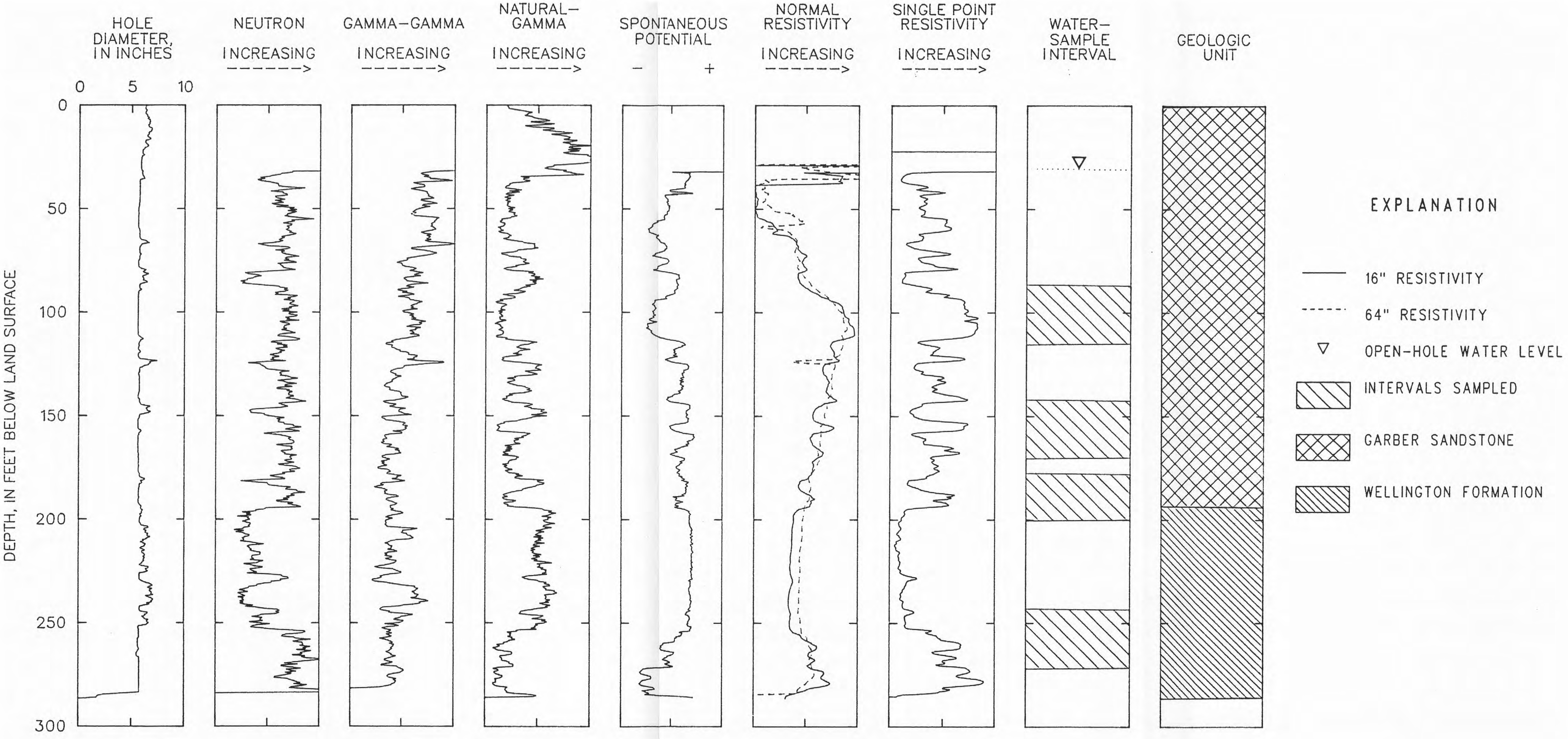

Figure 9.—Geophysical logs for test-hole NOTS 4.

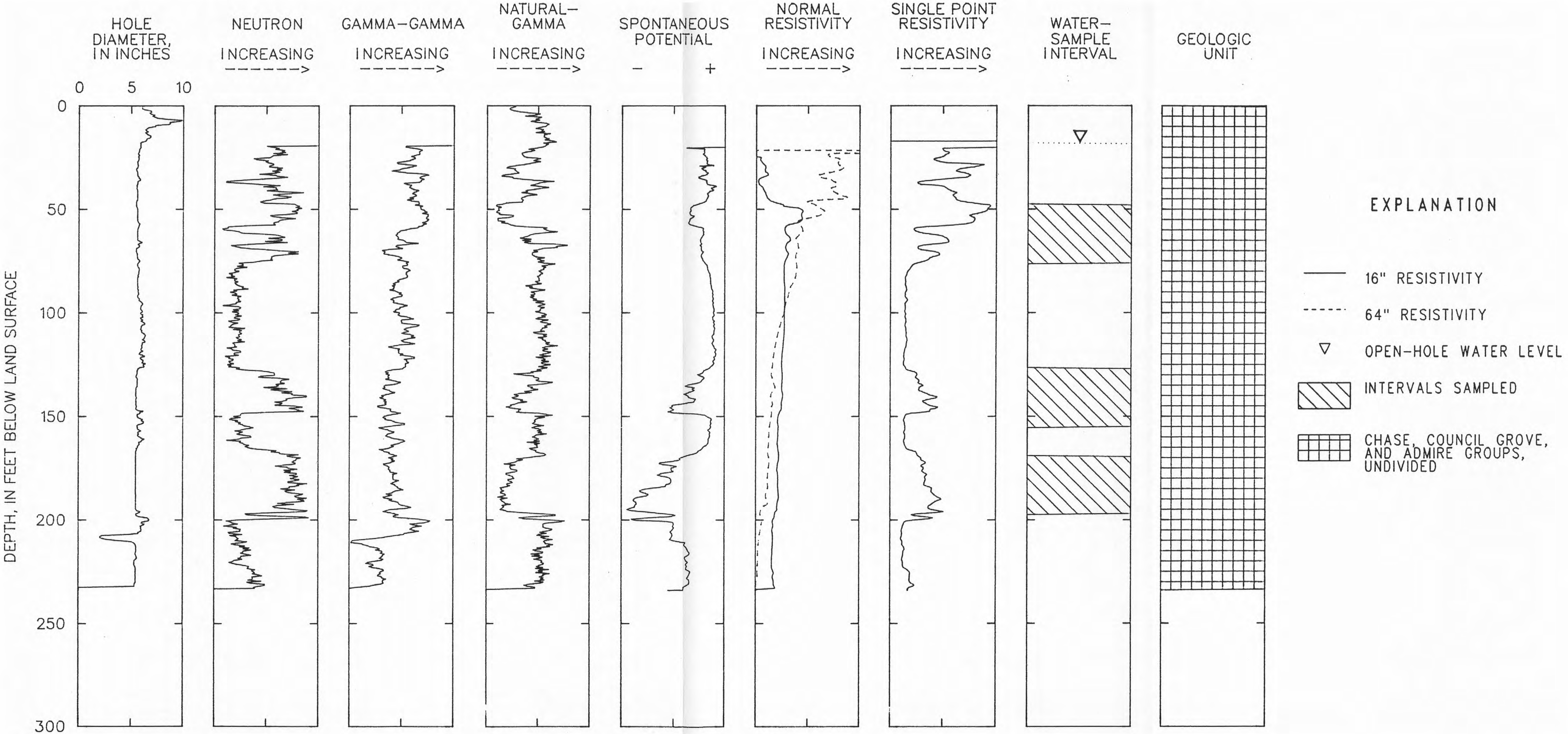

Figure 10.—Geophysical logs for test-hole NOTS 5.

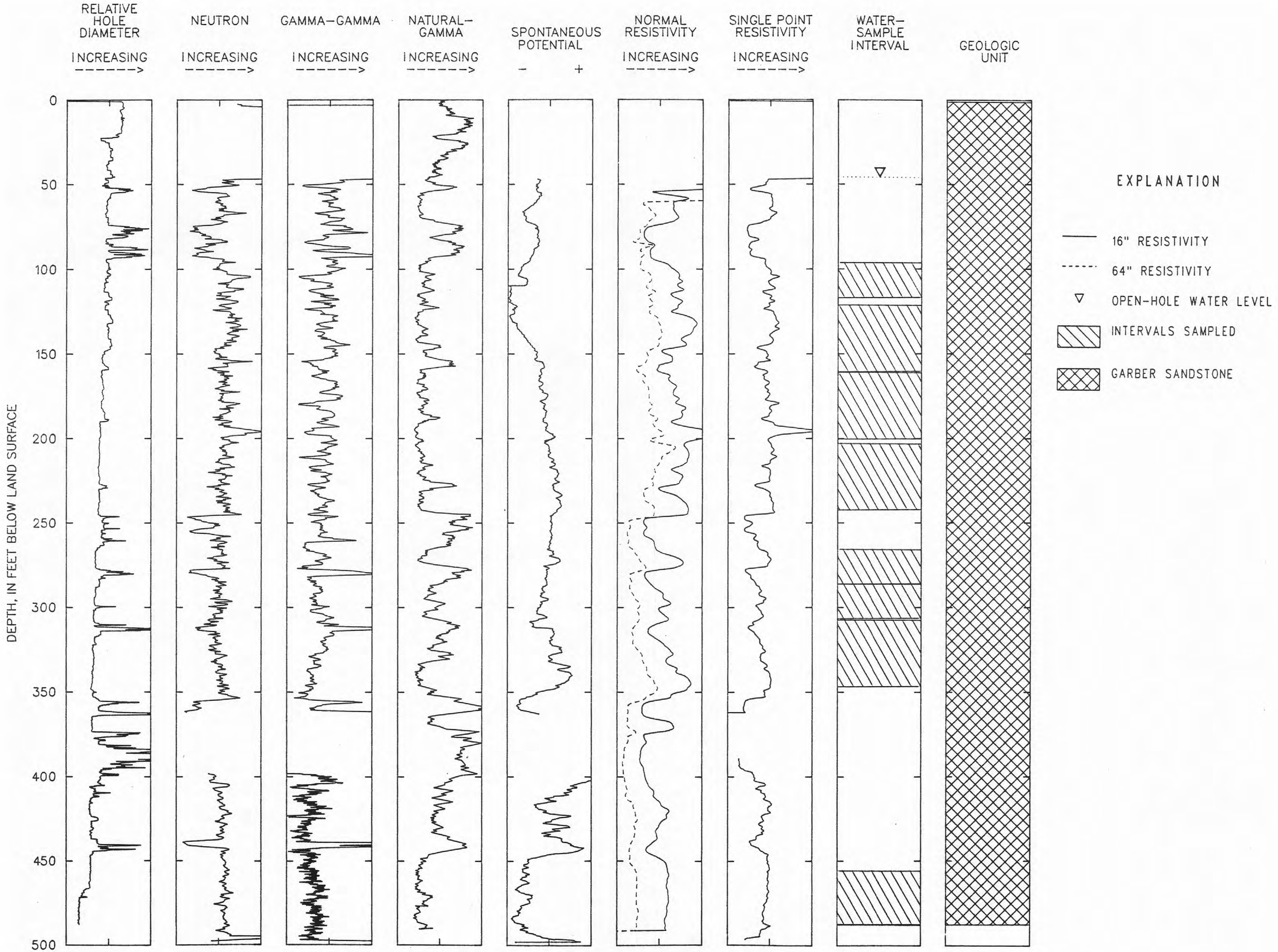

Figure 11.—Geophysical logs for test-hole NOTS 6.

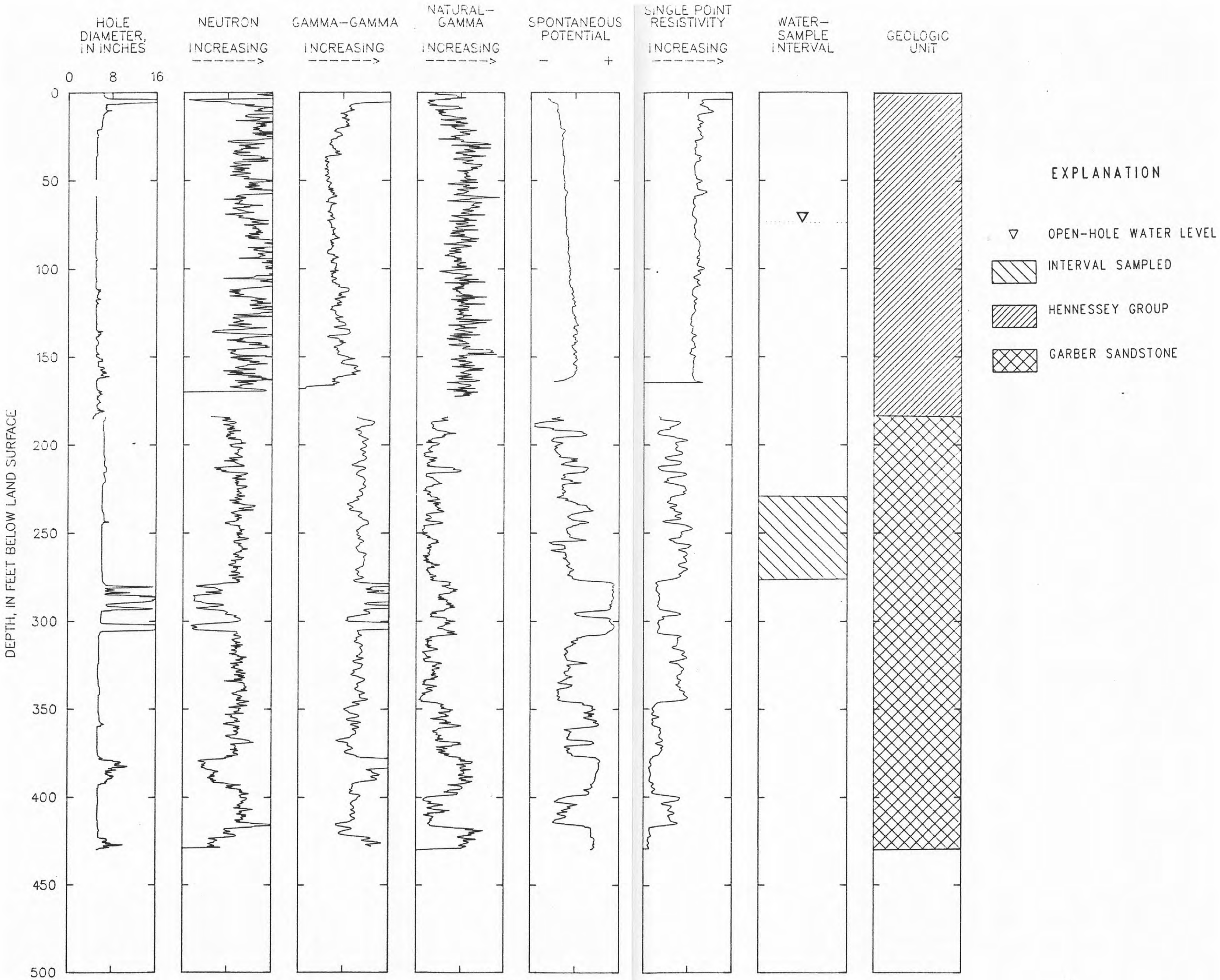

Figure 12.—Geophysical logs for test-hole NOTS 7.

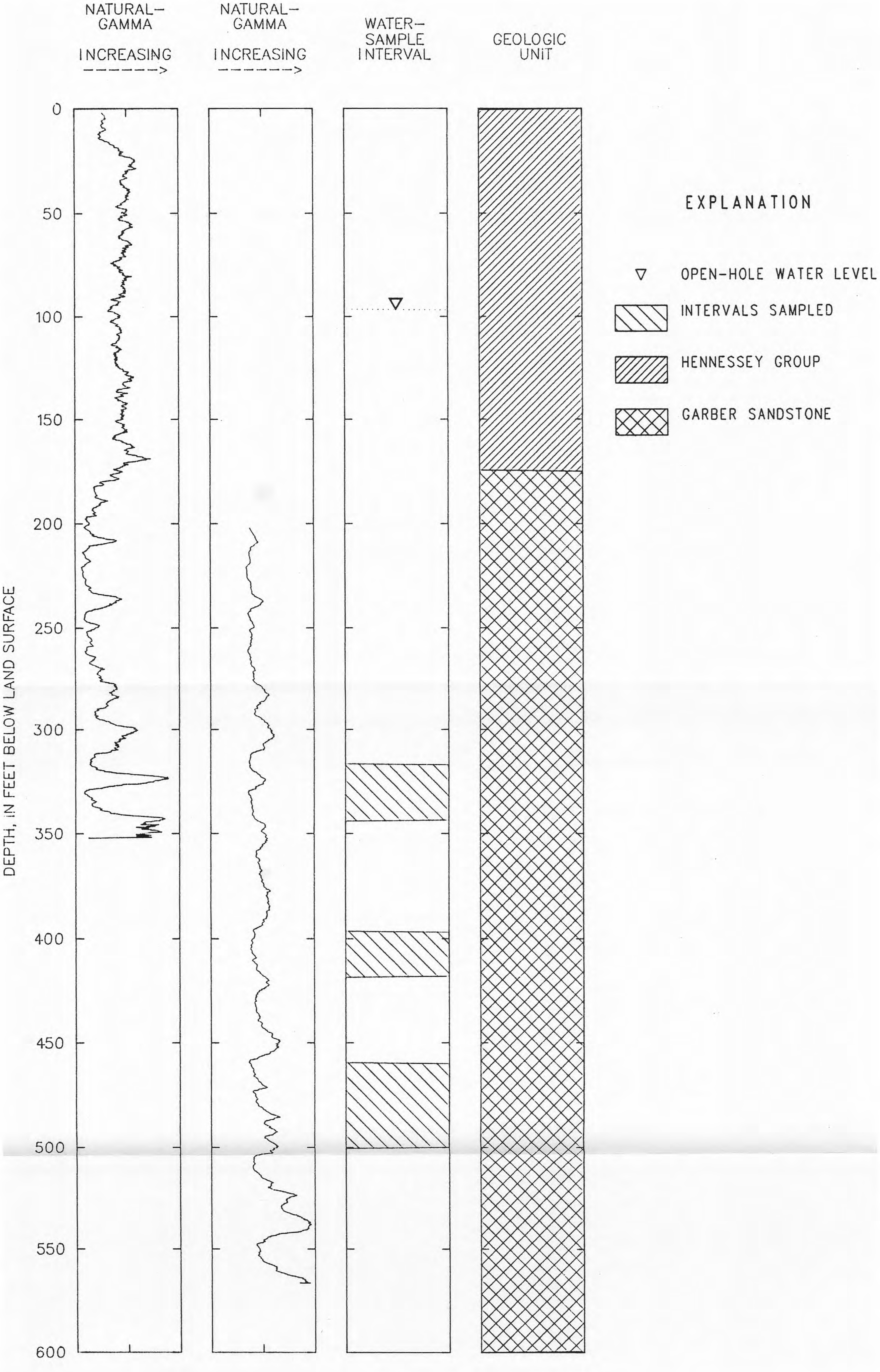

Figure 13.—Geophysical logs for test-hole NOTS 7A.

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Table 6.—*Listing of analytical methods used at the National Water Quality Laboratory*

[Parameter code; codes used to designate chemical constituents in the WATSTORE data base of the U.S. Geological Survey and in the STORET data base of the Environmental Protection Agency; g/ml, grams per milliliter; cm, centimeter; mg/L, milligrams per liter; ug/L, micrograms per liter; —, indicates no code available; Method: auto, automated; AE, atomic emission; ICP, inductively coupled plasma; AA, atomic absorption; DCP, directly coupled plasma; method number and laboratory code, codes used by the National Water Quality Laboratory of the U.S. Geological Survey to specify analytical methods; dissolved, concentration in filtered sample; total, total recoverable concentration including suspended and colloidal solids; pCi/L, picocuries per liter; PDB, Peedee Belemnite; SMOW, Standard Mean Ocean Water; CDT, Canyon Diablo Troilite]

Parameter code	Parameter name phase and units	Method	Method number	Laboratory code	Detection limit
		WATER PROPERTIES			
71820	Density, dissolved g/ml at 20 degrees Celcius	Gravimetry	1312-85	LC0024	0.99
00403	pH laboratory (standard units)	Electrometry, glass electrode, auto	2587-85	SH1043	4.0
90095	Specific conductance, laboratory microsiemens/cm at 25 degrees Celcius	Electrometry, auto	2781-85	SH1043	1
		MAJOR CATIONS			
00915	Calcium, dissolved (mg/L as Ca)	AE ICP, direct	1472-85	SH1043	.02
00925	Magnesium, dissolved (mg/L as Mg)	AE ICP, direct	1472-85	SH1043	.01
00935	Potassium, dissolved (mg/L as K)	AA, direct	1630-85	LC0054	.1
00930	Sodium, dissolved (mg/L as Na)	AE ICP, direct	1472-85	SH1043	1
		MAJOR ANIONS			
71870	Bromide, dissolved (mg/L as Br)	Colorimetry, fluorescein, auto	2129-85	LC1246	.01
00940	Chloride, dissolved (mg/L as Cl)	Colorimetry, thiocyanate, auto	2187-85	LC0015	.1
00950	Fluoride, dissolved (mg/L as F)	Ion selective electrode, auto	2327-85	LC0031	.1
71865	Iodide, dissolved (mg/L as I)	Colorimetry, ceric-arsenious oxide, auto	2371-85	LC1202	.001
00955	Silica, dissolved (mg/L as SiO_2)	AE ICP, direct	1472-85	SH1043	.01
00945	Sulfate, dissolved (mg/L as SO_4)	Turbidimetry, auto, background corrected	—	LC1551	1
		NUTRIENTS			
00608	Nitrogen, ammonia, dissolved (mg/L as N)	Colorimetry, auto	2522-85	LC0301	.01
00613	Nitrogen, nitrite, dissolved, (mg/L as N)	Colorimetry, diazotization, auto	2540-85	LC0160	.01

Table 6.—*Listing of analytical methods used at the National Water Quality Laboratory*—Continued

Parameter code	Parameter name phase and units	Method	Method number	Laboratory code	Detection limit
		NUTRIENTS			
00631	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Colorimetry, Cd-reduction, auto	2545-85	LC0228	.1
00671	Phosphorous, orthophosphate, dissolved (mg/L as P)	Colorimetry, phosphomolybdate, auto	2601-86	LC0162	.01
		CARBON			
00681	Carbon, organic, dissolved (mg/L as C)		0002-78	LC0113	.1
		TRACE ELEMENTS			
01106	Aluminum, dissolved (ug/L as Al)	AE, DCP	1054-86	LC1284	10
01105	Aluminum, total (ug/L as Al)	AE, DCP	3054-86	LC1283	10
01000	Arsenic, dissolved (ug/L as As)	AA, hydride, auto	2062-85	LC0112	1
01002	Arsenic, total (ug/L as As)	AA, hydride, auto	4062-85	LC0118	1
01005	Barium, dissolved (ug/L as Ba)	AE, ICP, direct	1472-85	SH1043	2
01010	Beryllium, dissolved (ug/L as Be)	AE, ICP, direct	1472-85	SH1043	.5
01020	Boron, dissolved (ug/L as B)	AE, DCP, direct	1114-86	LC1183	10
01025	Cadmium, dissolved (ug/L as Cd)	AE, ICP, direct	1472-85	SH1043	1
01030	Chromium, dissolved (ug/L as Cr)	AE, ICP, direct	1472-85	SH1043	5
01030	Chromium, dissolved (ug/L as Cr)	AE, DCP, direct	1229-87	LC0727	1
01032	Chromium, hexavalent, dissolved (ug/L as Cr)	AA, Chelate-extraction	1232-85	LC0016	1
01034	Chromium, total (ug/L as Cr)	Digest, DCP, direct	3229-87	LC0726	1
01035	Cobalt, dissolved (ug/L as Co)	AE, ICP, direct	1472-85	SH1043	3
01040	Copper, dissolved (ug/L as Cu)	AE, ICP, direct	1472-85	SH1043	10
01046	Iron, dissolved (ug/L as Fe)	AE, ICP, direct	1472-85	SH1043	3
01045	Iron, total (ug/L as Fe)	Digest, AA, direct	3381-85	LC0189	10
01049	Lead,	AE, ICP, direct			

Table 6.—*Listing of analytical methods used at the National Water Quality Laboratory*—Continued

Parameter code	Parameter name phase and units	Method	Method number	Laboratory code	Detection limit
		TRACE ELEMENTS			
01130	Lithium, dissolved (ug/L as Li)	AE, ICP, direct	1472-85	SH1043	4
01056	Manganese, dissolved (ug/L as Mn)	AE, ICP, direct	1472-85	SH1043	1
71890	Mercury, dissolved (ug/L as Hg)	AA, flameless, auto	2462-85	LC0226	.1
01060	Molybdenum, dissolved (ug/L as Mo)	AE, ICP, direct	1472-85	SH1043	10
01065	Nickel, dissolved (ug/L as Ni)	AE, ICP, direct	1472-88	SH1043	10
01145	Selenium, dissolved (ug/L as Se)	AA, hydride, auto	2667-85	LC0087	1
01147	Selenium, total (ug/L as Se)	AA, hydride, auto	4667-85	LC0286	1
01075	Silver, dissolved (ug/L as Ag)	AE, ICP, direct	1472-85	SH1043	1
01080	Strontium, dissolved (ug/L as Sr)	AE, ICP, direct	1472-85	SH1043	.5
01085	Vanadium, dissolved (ug/L as V)	AE, ICP, direct	1472-85	SH1043	6
01090	Zinc, dissolved (ug/L as Zn)	AE, ICP, direct	1472-85	SH1043	3
		RADIATION AND RADIONUCLIDES			
80030	Gross-alpha radioactivity, dissolved, (ug/L as U natural)	Residue procedure	1120-76	LC0444	.4
	Gross-alpha radioactivity, dissolved, (pCi/L as Th)	Residue procedure	1120-76	LC0444	.4
80040	Gross-alpha radioactivity, suspended, total (ug/L as U natural)	Residue procedure	7120-79	LC0456	.4
03515	Gross-beta radioactivity, dissolved (pCi/L as Cs-137)	Residue procedure	1120-76	LC0455	.4
80050	Gross-beta radioactivity, dissolved (pCi/L as Sr/Yt-90)	Residue procedure	1120-76	LC0445	.4
03516	Gross-beta radioactivity, suspended, total (pCi/L as Cs-137)	Residue procedure	7120-79	LC0446	.4
80060	Gross-beta radioactivity, suspended, total (pCi/L as Sr/Yt-90)	Residue procedure	1120-76	LC0447	.4

Table 6.—*Listing of analytical methods used at the National Water Quality Laboratory*—Continued

Parameter code	Parameter name phase and units	Method	Method number	Laboratory code	Detection limit
		RADIATION AND RADIONUCLIDES			
09511	Radium 226, dissolved (pCi/L as Ra-226)	Radon emanation	1141-76	LC0794	.01
81366	Radium 228, dissolved (pCi/L as Ra-228)	Separation, beta count	—	LC1363	1.0
82303	Radon 222, total (pCi/L as Rn 222)	Liquid scintillation	—	LC1369	80
07000	Tritium, total (pCi/L)	Electro enrichment, gas	1174-76	LC1043	.2
22610	Uranium-234, water, dissolved (pCi/L)	Alpha spectrometry	—	LC1366	.1
22703	Uranium-235, dissolved (pCi/L)	Alpha spectrometry	—	LC1367	.1
22603	Uranium-238, dissolved (pCi/L)	Alpha spectrometry	—	LC1368	.1
22703	Uranium, natural, dissolved (ug/L as U)	Calculated	—	—	.3
28011	Uranium, natural, total (ug/L as U)	Fluorimetry, direct	—	LC1365	1.0
		STABLE ISOTOPES			
82081	Carbon-13/carbon-12 δ in permil relative to PDB	Conversion to CO_2 with orthophosphoric acid, mass spectrometry	—	LC0440	.15
82082	Hydrogen-2/hydrogen-1 δ in permil relative to SMOW	Conversion to H_2 by reaction with zinc metal, mass spectrometry	—	LC0300	1.5
82085	Oxygen-18/oxygen-16 δ in permil relative to SMOW	Equilibration with CO_2, mass spectrometry	—	LC0489	.15
82086	Sulfur-34/sulfur-32 δ in permil relative to CDT	Precipitation of $BaSO_4$ by addition of $BaCl_2$, conversion to SO_2 by roasting with Cu_2O and SiO_2, mass spectrometry	—	LC0298	1.0

Table 7.—*Properties and major constituents of water from NOTS test holes*

[Sampling depth, center of sampling interval below land surface; uS/cm, microsiemens per centimeter; °C, degrees Celcius; field, analysis conducted at the sampling site; g/ml, grams per milliliter; dissolved, concentration measured in filtered sample except dissolved oxygen, which is measured in unfiltered flowing water; —, indicates no data are available; mg/L, milligrams per liter; incremental, incremental titration conducted at sampling site; <, indicates concentration is less than the specified value. All samples analyzed by the National Water Quality Laboratory of the U.S. Geological Survey with the exception of analyses conducted at the sampling site]

Test-hole name	Local identifier	Sampling depth (feet)	Water properties						
			Specific conductance, field (uS/cm)	Specific conductance, laboratory (uS/cm at 25 °C)	pH, field (standard units)	pH, laboratory (standard units)	Water temperature, field (°C)	Density, (g/ml at 25 °C)	Oxygen, dissolved, field (mg/L)
NOTS 1A	16N-02W-21 BAA 3	176.0	607	630	8.8	8.7	17.5	—	1.7
		229.0	907	855	8.9	8.9	18.0	—	0.2
NOTS 2	15N-03E-31 BAA 2	106.4	732	791	9.0	9.1	20.0	—	1.0
NOTS 3	14N-02W-23 CCA 1	119.5	569	566	7.3	7.6	16.5	—	8.0
		119.5	569	566	7.3	7.6	16.5	—	8.0
		164.9	667	666	8.9	8.0	17.5	—	6.0
NOTS 4	10N-01E-11 BBB 1	101.0	413	402	7.7	7.7	17.5	—	3.7
		156.2	402	410	7.7	7.6	17.5	—	5.5
		189.0	383	388	7.8	7.7	17.5	—	5.2
		257.5	397	433	7.7	7.8	17.5	—	3.6
NOTS 5	08N-03E-03 DAA 1	62.0	913	984	7.5	7.6	18.0	—	0.8
		62.0	913	989	7.5	7.7	18.0	—	0.8
		131.0	11,600	12,400	7.9	7.8	19.5	1.008	0.1
		183.5	8,210	8,910	8.2	7.9	18.0	1.003	0.1
NOTS 6	14N-03W-07 DAA 2	106.2	579	587	7.5	7.7	17.5	—	8.0
		141.0	603	612	7.4	7.4	17.0	—	7.9
		180.8	523	528	7.6	7.8	17.5	—	7.0
		180.8	523	526	7.6	7.6	17.5	—	7.0
		222.8	490	500	7.6	7.7	17.5	—	6.6
		276.2	428	438	8.0	7.8	18.0	—	6.0
		296.2	490	499	7.7	7.9	17.0	—	3.7
		327.1	490	499	8.0	8.0	18.0	—	5.7
		475.1	1,160	1,170	8.6	8.4	18.0	—	0.2
NOTS 7	09N-02W-29 DCA 5	262.7	560	608	9.6	9.1	17.0	—	2.5
NOTS 7A	09N-02W-29 DCA 6	330.1	856	858	9.1	8.9	17.5	—	0.4
		407.5	736	752	9.3	9.2	18.5	—	0.5
		480.0	599	633	9.3	9.2	18.5	—	0.1
		480.0	599	627	9.3	9.2	18.5	—	0.1

Table 7.—*Properties and major constituents of water from NOTS test holes* —Continued

			Water properties, continued			Cations			
Test-hole name	Local identifier	Sampling depth (feet)	Hardness, total calculated (mg/L as $CaCO_3$)	Hardness non-carbonate, dissolved (mg/L as $CaCO_3$)	Alkalinity, dissolved, incremental (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
NOTS 1A	16N-02W-21 BAA 3	176.0	14	0	264	3.1	1.5	140	0.60
		229.0	9	0	312	2.1	0.83	190	0.50
NOTS 2	15N-03E-31 BAA 2	106.4	4	0	386	1.0	0.42	190	0.60
NOTS 3	14N-02W-23 CCA 1	119.5	280	24	260	59	33	13	0.90
		119.5	280	24	260	59	33	13	0.90
		164.9	16	0	308	3.5	1.8	160	0.60
NOTS 4	10N-01E-11 BBB 1	101.0	200	0	210	44	23	10	1.4
		156.2	210	0	212	45	24	8.9	0.90
		189.0	200	0	198	42	22	9.7	1.8
		257.5	220	7	214	47	25	9.9	2.2
NOTS 5	08N-03E-03 DAA 1	62.0	150	0	464	28	19	180	2.7
		62.0	150	0	464	28	19	180	2.8
		131.0	240	85	156	29	40	3,100	7.3
		183.5	140	0	186	19	22	2,300	5.4
NOTS 6	14N-03W-07 DAA 2	106.2	230	0	284	55	23	48	1.3
		141.0	250	0	296	57	25	41	1.3
		180.8	220	0	248	41	29	37	1.5
		180.8	220	0	248	40	28	36	1.4
		222.8	210	0	240	37	27	37	1.5
		276.2	100	0	202	22	11	62	1.1
		296.2	120	0	234	26	14	65	1.2
		327.1	78	0	240	17	8.5	90	1.0
		475.1	15	0	346	3.6	1.4	260	0.70
NOTS 7	09N-02W-29 DCA 5	262.7	10	0	234	2.5	1.0	140	1.2
NOTS 7A	09N-02W-29 DCA 6	330.1	12	0	362	2.9	1.2	210	1.0
		407.5	8	0	356	2.2	0.60	180	0.60
		480.0	6	0	284	1.5	0.55	150	0.20
		480.0	5	0	284	1.2	0.38	150	0.10

Table 7.—*Properties and major constituents of water from NOTS test holes* —Continued

			Anions						
Test-hole name	Local identifier	Sampling depth (feet)	Bicarbonate, dissolved, incremental (mg/L as HCO_3)	Carbonate, dissolved, incremental (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Iodide, dissolved (mg/L as I)
NOTS 1A	16N-02W-21 BAA 3	176.0	303	10	27	29	0.80	—	—
		229.0	354	12	39	54	0.30	0.16	—
NOTS 2	15N-03E-31 BAA 2	106.4	422	24	12	13	0.50	0.086	—
NOTS 3	14N-02W-23 CCA 1	119.5	317	0	25	12	0.30	0.15	—
		119.5	317	0	25	12	0.30	0.14	—
		164.9	371	2	20	13	0.30	0.17	—
NOTS 4	10N-01E-11 BBB 1	101.0	256	0	4.2	5.8	0.20	0.064	—
		156.2	259	0	4.8	7.2	0.30	0.080	—
		189.0	242	0	17	5.1	0.30	0.041	—
		257.5	261	0	6.9	9.3	0.30	0.064	—
NOTS 5	08N-03E-03 DAA 1	62.0	566	0	34	31	0.40	0.22	—
		62.0	566	0	35	31	0.50	0.20	—
		131.0	190	0	5,100	1,300	2.3	4.1	0.099
		183.5	227	0	4,700	150	2.3	0.57	0.020
NOTS 6	14N-03W-07 DAA 2	106.2	346	0	18	9.9	0.30	0.051	—
		141.0	361	0	18	11	0.20	0.063	—
		180.8	302	0	18	12	0.30	0.039	—
		180.8	302	0	13	12	0.30	0.038	—
		222.8	293	0	11	11	0.20	0.037	—
		276.2	246	0	14	11	0.20	0.049	—
		296.2	285	0	10	13	0.20	0.046	—
		327.1	293	0	9.9	11	0.20	0.073	—
		475.1	398	12	72	110	1.6	0.21	—
NOTS 7	09N-02W-29 DCA 5	262.7	256	15	44	16	1.0	0.31	—
NOTS 7A	09N-02W-29 DCA 6	330.1	373	34	76	14	1.2	0.17	—
		407.5	322	56	25	6.8	0.30	0.13	—
		480.0	283	32	17	6.2	0.40	0.060	—
		480.0	283	32	18	8.2	0.50	0.20	—

Table 7.—*Properties and major constituents of water from NOTS test holes* —Continued

			Anion	Nutrients				Carbon
Test-hole name	Local identifier	Sampling depth (feet)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrite (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorous, ortho-phosphate, dissolved (mg/L as P)	Organic carbon, dissolved (mg/L as C)
NOTS 1A	16N-02W-21 BAA 3	176.0	11	<0.010	0.350	<0.010	0.020	1.4
		229.0	10	<0.010	0.510	0.010	0.020	0.8
NOTS 2	15N-03E-31 BAA 2	106.4	9.5	<0.010	<0.100	0.100	0.020	0.8
NOTS 3	14N-02W-23 CCA 1	119.5	19	<0.010	2.80	0.010	0.040	0.9
		119.5	19	<0.010	2.80	0.010	0.040	0.8
		164.9	9.3	<0.010	2.10	<0.010	<0.010	1.2
NOTS 4	10N-01E-11 BBB 1	101.0	13	—	—	—	—	0.9
		156.2	15	<0.010	0.110	<0.010	0.040	0.8
		189.0	9.6	<0.010	0.150	<0.010	0.020	0.8
		257.5	11	<0.010	0.280	0.030	0.010	0.7
NOTS 5	08N-03E-03 DAA 1	62.0	15	<0.010	0.450	<0.010	<0.010	1.3
		62.0	15	—	—	—	—	1.0
		131.0	17	<0.010	<0.100	1.50	<0.010	0.8
		183.5	19	<0.010	<0.100	0.720	<0.010	0.7
NOTS 6	14N-03W-07 DAA 2	106.2	22	0.260	1.20	0.020	<0.010	1.0
		141.0	23	<0.010	1.40	<0.010	<0.010	0.6
		180.8	21	<0.010	0.940	<0.010	<0.010	0.5
		180.8	21	0.010	0.970	<0.010	<0.010	0.7
		222.8	20	<0.010	0.790	<0.010	<0.010	4.8
		276.2	17	<0.010	0.950	<0.010	<0.010	0.3
		296.2	18	<0.010	0.710	0.010	<0.010	0.4
		327.1	15	<0.010	0.850	0.170	<0.010	0.6
		475.1	11	0.020	0.470	<0.010	0.030	0.4
NOTS 7	09N-02W-29 DCA 5	262.7	7.1	—	—	—	—	—
NOTS 7A	09N-02W-29 DCA 6	330.1	9.0	<0.010	0.130	0.110	0.050	1.6
		407.5	6.3	0.090	0.220	0.010	0.010	1.7
		480.0	6.7	0.060	<0.100	0.010	0.010	3.5
		480.0	6.5	0.060	<0.100	<0.010	0.010	—

Table 8.—*Concentrations of trace elements in water from NOTS test holes*

[Sampling depth, center of sampling interval below land surface; <, indicates concentration is less than the specified value; ug/L, micrograms per liter; —, indicates no data are available; *, indicates possible contamination during sampling. All samples analyzed by the National Water Quality Laboratory of the U.S. Geological Survey]

Test-hole name	Local identifier	Sampling depth (feet)	Aluminum, dissolved (ug/L as Al)	Aluminum, total (ug/L as Al)	Barium, dissolved (ug/L as Ba)	Beryllium, dissolved (ug/L as Be)	Boron, dissolved (ug/L as B)	Cadmium, dissolved (ug/L as Cd)	Cobalt, dissolved (ug/L as Co)
NOTS 1A	16N-02W-21 BAA 3	176.0	30	5,300	54	1	2,100	<1.0	<3
		229.0	60	14,000	40	3	2,600	<1.0	<3
NOTS 2	15N-03E-31 BAA 2	106.4	70	3,700	15	0.9	1,400	<1.0	<3
NOTS 3	14N-02W-23 CCA 1	119.5	<10	10	270	<0.5	50	<1.0	<3
		119.5	<10	20	270	<0.5	50	<1.0	<3
		164.9	<10	5,500	38	<0.5	1,300	<1.0	<3
NOTS 4	10N-01E-11 BBB 1	101.0	<10	230	320	<0.5	80	<1.0	<3
		156.2	<10	90	180	<0.5	80	<1.0	<3
		189.0	<10	50	250	<0.5	80	<1.0	<3
		257.5	<10	400	350	<0.5	100	<1.0	<3
NOTS 5	08N-03E-03 DAA 1	62.0	<10	<10	170	<0.5	1,300	<1.0	<3
		62.0	<10	30	180	<0.5	1,300	<1.0	<3
		131.0	<10	2,400	<100	<10	7,400	<1.0	<1
		183.5	<10	1,200	<100	<10	6,700	<1.0	1
NOTS 6	14N-03W-07 DAA 2	106.2	<10	50	280	<0.5	320	<1.0	<3
		141.0	<10	60	280	<0.5	290	1.0	<3
		180.8	<10	40	220	<0.5	330	4.0	<3
		180.8	<10	40	220	<0.5	330	2.0	<3
		222.8	<10	30	210	<0.5	340	<1.0	<3
		276.2	<10	30	160	<0.5	1,000	<1.0	<3
		296.2	<10	60	230	<0.5	540	<1.0	<3
		327.1	<10	900	220	<0.5	680	<1.0	<3
		475.1	20	12,000	28	3	3,400	<1.0	<3
NOTS 7	09N-02W-29 DCA 5	262.7	140	83,000	16	<0.5	2,400	<1.0	<3
NOTS 7A	09N-02W-29 DCA 6	330.1	<10	2,200	13	<0.5	3,700	<1.0	<3
		407.5	10	7,500	39	<0.5	1,500	<1.0	<3
		480.0	30	15,000	33	<0.5	760	<1.0	<3
		480.0	<10	11,000	31	<0.5	710	<1.0	<3

Table 8.—*Concentrations of trace elements in water from NOTS test holes*—Continued

Test-hole name	Local identifier	Sampling depth (feet)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Iron, total (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Lithium, dissolved (ug/L as Li)	Manganese, dissolved (ug/L as Mn)	Mercury, dissolved (ug/L as Hg)
NOTS 1A	16N-02W-21 BAA 3	176.0	<10	15	2,200	<10	<4	7	—
		229.0	<10	8	6,200	<10	5	4	31*
NOTS 2	15N-03E-31 BAA 2	106.4	<10	7	3,200	<10	<4	3	—
NOTS 3	14N-02W-23 CCA 1	119.5	<10	35	30	<10	12	3	<0.1
		119.5	<10	35	20	<10	11	3	—
		164.9	<10	5	1,300	<10	11	3	—
NOTS 4	10N-01E-11 BBB 1	101.0	<10	<3	230	<10	23	<1	<0.1
		156.2	<10	5	90	<10	20	8	<0.1
		189.0	<10	8	60	<10	34	8	<0.1
		257.5	<10	14	420	<10	22	2	<0.1
NOTS 5	08N-03E-03 DAA 1	62.0	<10	42	70	<10	31	7	<0.1
		62.0	<10	33	60	<10	31	5	<0.1
		131.0	48	30	1,100	<5	100	50	0.1
		183.5	<1	80	440	<5	80	30	<0.1
NOTS 6	14N-03W-07 DAA 2	106.2	<10	30	120	<10	14	10	0.4
		141.0	<10	13	70	<10	7	6	<0.1
		180.8	<10	10	40	<10	12	5	<0.1
		180.8	<10	9	40	<10	12	5	<0.1
		222.8	<10	6	120	<10	9	6	<0.1
		276.2	<10	10	70	<10	10	4	0.1
		296.2	<10	32	250	30	10	5	0.5
		327.1	<10	24	870	<10	8	7	<0.1
		475.1	<10	6	3,400	<10	10	8	<0.1
NOTS 7	09N-02W-29 DCA 5	262.7	10	87	37,000	<10	11	4	—
NOTS 7A	09N-02W-29 DCA 6	330.1	<10	44	1,700	<10	10	9	—
		407.5	<10	6	5,600	<10	8	11	<0.1
		480.0	<10	17	19,000	<10	9	6	<0.1
		480.0	<10	5	16,000	<10	8	5	<0.1

Table 8.—*Concentrations of trace elements in water from NOTS test holes*—Continued

Test-hole name	Local identifier	Sampling depth (feet)	Molybdenum, dissolved (ug/L as Mo)	Nickel, dissolved (ug/L as Ni)	Silver, dissolved (ug/L as Ag)	Strontium, dissolved (ug/L as Sr)	Vanadium, dissolved (ug/L as V)	Zinc, dissolved (ug/L as Zn)
NOTS 1A	16N-02W-21 BAA 3	176.0	<10	<10	<1.0	96	450	<3
		229.0	<10	<10	<1.0	330	910	<3
NOTS 2	15N-03E-31 BAA 2	106.4	<10	<10	<1.0	36	180	<3
NOTS 3	14N-02W-23 CCA 1	119.5	<10	<10	<1.0	300	7	65
		119.5	<10	<10	<1.0	300	7	64
		164.9	<10	<10	<1.0	72	160	7
NOTS 4	10N-01E-11 BBB 1	101.0	<10	<10	<1.0	120	<6	75
		156.2	<10	<10	<1.0	100	<6	46
		189.0	<10	<10	1.0	790	<6	210
		257.5	<10	<10	1.0	180	8	110
NOTS 5	08N-03E-03 DAA 1	62.0	<10	<10	3.0	430	48	160
		62.0	<10	<10	<1.0	420	47	160
		131.0	13	<1	<1.0	3,600	<30	5,500
		183.5	17	2	<1.0	2,100	<30	310
NOTS 6	14N-03W-07 DAA 2	106.2	<10	<10	<1.0	520	11	100
		141.0	<10	<10	2.0	730	16	93
		180.8	<10	<10	<1.0	1,400	24	110
		180.8	<10	<10	<1.0	1,400	25	110
		222.8	<10	<10	<1.0	1,500	26	110
		276.2	<10	<10	3.0	940	35	95
		296.2	<10	<10	<1.0	1,100	22	89
		327.1	<10	<10	<1.0	690	27	190
		475.1	20	<10	<1.0	93	880	4
NOTS 7	09N-02W-29 DCA 5	262.7	10	<10	<1.0	42	44	75
NOTS 7A	09N-02W-29 DCA 6	330.1	30	<10	<1.0	52	60	38
		407.5	<10	<10	<1.0	42	120	<3
		480.0	<10	<10	<1.0	26	36	<3
		480.0	<10	<10	<1.0	22	37	<3

Table 9.—*Concentrations of arsenic in water from NOTS test holes*

[Sampling depth, center of sampling interval below land surface; *, analyzed by Battelle Pacific Northwest Division, Marine Sciences Laboratory, Sequim, Washington; **, analyzed by the Branch of Regional Research, Western Region of the U.S. Geological Survey, Water Resources Division, Menlo Park, California; ug/L, micrograms per liter; <, indicates concentration is less than the specified value; —, indicates no data are available. All samples analyzed by the National Water Quality Laboratory of the U.S. Geological Survey unless otherwise noted]

Test-hole name	Local identifier	Sampling depth (feet)	Arsenic, dissolved, (ug/L as As)	Arsenic, total, (ug/L as As)	Arsenic, dissolved, (ug/L as As)	Arsenate, $HAsO_4^{=}$ dissolved, (ug/L as As)	Arsenite, AsO_2^{-} dissolved, (ug/L as As)
NOTS 1A	16N-02W-21 BAA 3	176.0	53	56	—	—	—
		229.0	69	65	—	—	—
NOTS 2	15N-03E-31 BAA 2	106.4	20	15	—	—	—
NOTS 3	14N-02W-23 CCA 1	119.5	1	1	—	—	—
		119.5	1	1	—	—	—
		164.9	23	24	—	—	—
NOTS 4	10N-01E-11 BBB 1	101.0	1	1	—	—	—
		156.2	2	1	—	—	—
		189.0	1	1	—	—	—
		257.5	1	—	—	—	—
NOTS 5	08N-03E-03 DAA 1	62.0	1	1	—	—	—
		62.0	1	1	—	—	—
		131.0	<1	1	—	—	—
		183.5	1	1	—	—	—
NOTS 6	14N-03W-07 DAA 2	106.2	1	1	—	—	—
		141.0	1	1	—	—	—
		180.8	2	2	—	—	—
		180.8	2	2	—	—	—
		222.8	2	2	—	—	—
		276.2	3	3	3*	2.5 *	0.32*
		296.2	1	2	2*	1.7 *	0.03*
		327.1	3	4	3*	2.9 *	0.11*
		475.1	65	65	72**	70 **	1.7 **
NOTS 7	09N-02W-29 DCA 5	262.7	33	21	—	—	—
NOTS 7A	09N-02W-29 DCA 6	330.1	51	57	57*	57 *	0.06*
		407.5	20	20	17*	17 *	0.16*
		480.0	9	7	10*	10 *	0.31*
		480.0	8	6	—	—	—

Table 10.—*Concentrations of chromium in water from NOTS test holes*

[Sampling depth, center of sampling interval below land surface; ICP, analyzed using inductively coupled plasma spectrophotometry; DCP, analyzed using direct coupled plasma spectrophometry; ug/L, micrograms per liter; —, indicates no data are available; <, indicates concentration is less than the specified value. All samples analyzed by the National Water Quality Laboratory of the U.S. Geological Survey]

Test-hole name	Local identifier	Sampling depth (feet)	Chromium, dissolved, ICP (ug/L as Cr)	Chromium, dissolved, DCP (ug/L as Cr)	Chromium hexavalent, dissolved (ug/L as Cr)	Chromium, total (ug/L as Cr)
NOTS 1A	16N-02W-21 BAA 3	176.0	80	90	110	82
		229.0	60	60	58	74
NOTS 2	15N-03E-31 BAA 2	106.4	<5	<1	<1	9
NOTS 3	14N-02W-23 CCA 1	119.5	<5	1	1	<1
		119.5	<5	1	2	<1
		164.9	5	4	5	14
NOTS 4	10N-01E-11 BBB 1	101.0	<5	2	1	3
		156.2	<5	3	2	1
		189.0	<5	4	3	7
		257.5	8	7	4	5
NOTS 5	08N-03E-03 DAA 1	62.0	<5	<1	<1	<1
		62.0	<5	<1	<1	1
		131.0	<1	<1	1	8
		183.5	<1	<1	<1	4
NOTS 6	14N-03W-07 DAA 2	106.2	<5	—	1	4
		141.0	<5	—	1	4
		180.8	20	—	12	15
		180.8	20	—	11	14
		222.8	20	—	17	19
		276.2	30	—	26	29
		296.2	20	—	12	21
		327.1	20	—	14	24
		475.1	40	—	<1	89
NOTS 7	09N-02W-29 DCA 5	262.7	<5	—	—	98
NOTS 7A	09N-02W-29 DCA 6	330.1	<5	—	3	1
		407.5	<5	—	<1	16
		480.0	<5	—	1	28
		480.0	<5	—	—	23

Table 11.—*Concentrations of selenium in water from NOTS test holes*

[Sampling depth, center of sampling interval below land surface; *, analyzed by California District Office of the U.S. Geological Survey, Water Resources Division, Sacramento California; ug/L, micrograms per liter; <, indicates concentration is less than the specified value; —, indicates no data are available; tr, trace amount detected. All sanples analyzed by the National Water Quality Laboratory of the U.S.Geological Survey unless otherwise noted]

Test-hole name	Local identifier	Sampling depth (feet)	Selenium, dissolved (ug/L as Se)	Selenium, total (ug/L as Se)	Selenium, dissolved (ug/L as Se)	Selenate, $SeO_4^=$ dissolved (ug/L as Se)	Selenite, $SeO_3^=$ dissolved (ug/L as Se)	Selenium, organic, dissolved (ug/L as Se)
NOTS 1A	16N-02W-21 BAA 3	176.0	75	75	70*	70*	0.0*	<0.5*
		229.0	250	240	227*	228*	5.0*	<0.5*
NOTS 2	15N-03E-31 BAA 2	106.4	13	12	11*	11*	1.0*	<0.5*
NOTS 3	14N-02W-23 CCA 1	119.5	<1	<1	—	—	—	—
		119.5	<1	<1	—	—	—	—
		164.9	1	1	—	—	—	—
NOTS 4	10N-01E-11 BBB 1	101.0	<1	<1	—	—	—	—
		156.2	<1	<1	—	—	—	—
		189.0	<1	<1	—	—	—	—
		257.5	<1	—	—	—	—	—
NOTS 5	08N-03E-03 DAA 1	62.0	16	18	17*	17*	0.0*	0.0*
		62.0	18	18	17*	16 *	0.0*	1.0*
		131.0	<1	<1	—	—	—	—
		183.5	<1	<1	—	—	—	—
NOTS 6	14N-03W-07 DAA 2	106.2	6	6	—	—	—	—
		141.0	4	3	—	—	—	—
		180.8	3	3	—	—	—	—
		180.8	3	3	—	—	—	—
		222.8	2	1	—	—	—	—
		276.2	10	9	10*	10*	0.0*	0.0*
		296.2	3	3	—	—	—	—
		327.1	11	12	11*	11*	0.0*	0.0*
		475.1	380	390	394*	369*	25*	tr*
NOTS 7	09N-02W-29 DCA 5	262.7	11	12	—	—	—	—
NOTS 7A	09N-02W-29 DCA 6	330.1	93	92	92*	90*	2.0*	0.0*
		407.5	19	18	18*	18*	0.0*	<0.5*
		480.0	3	3	—	—	—	—
		480.0	3	3	2.5*	2.5*	<0.5*	<0.5*

Table 12.—*Concentrations of selected radionuclides in water from NOTS test holes*

[Sampling depth, center of sampling interval below land surface; pCi/L, picocuries per liter; Th-230, thorium-230; ug/L, micrograms per liter; U-nat, uranium natural; —, indicates no data are available; <, indicates concentration is less than the specified value; Cs-137, cesium-137; Sr/Y-90, strontium-90/yttrium-90; U, uranium. All samples analyzed by the National Water Quality Laboratory of the U.S. Geological Survey]

Test-hole name	Local identifier	Sampling depth (feet)	Gross alpha, dissolved (pCi/L as Th-230)	Gross alpha, suspended (pCi/L as Th-230)	Gross alpha, dissolved (ug/L as U-nat)	Gross alpha, suspended (ug/L as U-nat)
NOTS 1A	16N-02W-21 BAA 3	176.0	72 ± 9.2	<0.4 ± 0.20	65 ± 9.0	<0.4 ± 0.35
		229.0	160 ± 17	9.4 ± 3.7	150 ± 20	13 ± 5.2
NOTS 2	15N-03E-31 BAA 2	106.4	43 ± 6.1	5.1 ± 2.5	39 ± 5.9	5.7 ± 2.8
NOTS 3	14N-02W-23 CCA 1	119.5	1.9 ± 0.82	<0.4 ± 0.41	3.8 ± 1.6	<0.4 ± 0.39
		119.5	2.0 ± 0.81	<0.4 ± 0.30	4.0 ± 1.6	<0.4 ± 0.35
		164.9	52 ± 7.5	5.9 ± 3.0	52 ± 7.8	7.1 ± 3.6
NOTS 4	10N-01E-11 BBB 1	101.0	1.5 ± 0.85	<0.4 ± 0.33	1.5 ± 0.83	<0.4 ± 0.54
		156.2	4.5 ± 1.5	0.5 ± 0.53	4.3 ± 1.4	0.6 ± 0.55
		189.0	7.8 ± 3.1	1.4 ± 0.86	7.4 ± 3.0	1.3 ± 0.78
		257.5	12 ± 2.3	1.0 ± 0.82	12 ± 2.5	0.8 ± 0.64
NOTS 5	08N-03E-03 DAA 1	62.0	46 ± 7.7	<0.4 ± 0.29	45 ± 6.6	0.4 ± 0.47
		62.0	62 ± 8.4	<0.4 ± 0.27	56 ± 8.2	<0.4 ± 0.44
		131.0	12 ± 2.8	19 ± 4.8	11 ± 2.7	17 ± 4.2
		183.5	6.1 ± 1.8	3.2 ± 1.3	5.9 ± 1.8	2.5 ± 1.0
NOTS 6	14N-03W-07 DAA 2	106.2	6.7 ± 1.5	<0.4 ± 0.21	9.9 ± 2.1	<0.4 ± 0.36
		141.0	7.1 ± 1.5	<0.4 ± 0.23	11 ± 2.2	<0.4 ± 0.37
		180.8	5.8 ± 1.4	<0.4 ± 0.30	8.2 ± 1.9	<0.4 ± 0.55
		180.8	11 ± 2.3	<0.4 ± 0.27	17 ± 3.2	<0.4 ± 0.47
		222.8	11 ± 1.9	<0.4 ± 0.21	16 ± 2.9	<0.4 ± 0.40
		276.2	19 ± 2.8	<0.4 ± 0.41	27 ± 4.0	0.5 ± 0.63
		296.2	16 ± 2.5	<0.4 ± 0.35	23 ± 3.5	0.6 ± 0.55
		327.1	16 ± 2.6	0.5 ± 0.51	23 ± 3.7	0.6 ± 0.59
		475.1	240 ± 26	3.7 ± 2.5	350 ± 33	2.8 ± 1.9
NOTS 7	09N-02W-29 DCA 5	262.7	18 ± 4.8	150 ± 62	26 ± 7.0	180 ± 76
NOTS 7A	09N-02W-29 DCA 6	330.1	40 ± 4.5	3.5 ± 0.72	37 ± 4.1	3.8 ± 0.79
		407.5	5.1 ± 0.92	6.4 ± 1.5	4.7 ± 0.84	7.2 ± 1.7
		480.0	4.0 ± 0.83	8.8 ± 2.0	3.7 ± 0.75	7.9 ± 1.7
		480.0	13 ± 3.4	6.9 ± 1.5	12 ± 3.1	6.3 ± 1.3

Table 12.—*Concentrations of selected radionuclides in water from NOTS test holes*—Continued

Test-hole name	Local identifier	Sampling depth (feet)	Gross beta, dissolved (pCi/L as Cs-137)	Gross beta, suspended (pCi/L as Cs-137)	Gross beta, dissolved (pCi/L Sr/Y-90)	Gross beta, suspended (pCi/L Sr/Y-90)
NOTS 1A	16N-02W-21 BAA 3	176.0	21 ± 3.2	<0.4 ± 0.45	16 ± 2.4	<0.4 ± 0.47
		229.0	62 ± 7.7	36 ± 4.5	44 ± 5.5	31 ± 3.9
NOTS 2	15N-03E-31 BAA 2	106.4	19 ± 3.0	3.4 ± 0.97	13 ± 2.2	3.0 ± 0.85
NOTS 3	14N-02W-23 CCA 1	119.5	2.7 ± 1.1	<0.4 ± 0.48	2.0 ± 0.82	<0.4 ± 0.48
		119.5	2.2 ± 1.0	<0.4 ± 0.46	1.6 ± 0.77	<0.4 ± 0.45
		164.9	16 ± 2.7	9.1 ± 1.6	12 ± 2.0	8.0 ± 1.4
NOTS 4	10N-01E-11 BBB 1	101.0	1.6 ± 0.85	<0.4 ± 0.45	1.2 ± 0.64	<0.4 ± 0.44
		156.2	3.2 ± 1.1	1.1 ± 0.59	2.4 ± 0.82	1.1 ± 0.58
		189.0	3.8 ± 1.3	1.4 ± 0.64	2.7 ± 0.82	1.4 ± 0.65
		257.5	6.7 ± 1.5	2.0 ± 0.73	5.1 ± 1.2	1.9 ± 0.70
NOTS 5	08N-03E-03 DAA 1	62.0	25 ± 4.0	1.8 ± 0.68	17 ± 2.7	1.9 ± 0.70
		62.0	21 ± 3.5	1.2 ± 0.60	15 ± 2.4	1.2 ± 0.59
		131.0	15 ± 13	7.0 ± 1.3	9.3 ± 8.3	6.3 ± 1.2
		183.5	15 ± 9.7	3.0 ± 0.84	9.9 ± 6.4	3.0 ± 0.81
NOTS 6	14N-03W-07 DAA 2	106.2	3.6 ± 1.2	<0.4 ± 0.43	2.6 ± 0.86	<0.4 ± 0.44
		141.0	3.3 ± 1.1	<0.4 ± 0.38	2.5 ± 0.82	<0.4 ± 0.39
		180.8	4.4 ± 1.3	<0.4 ± 0.53	3.3 ± 0.96	<0.4 ± 0.52
		180.8	5.6 ± 1.4	<0.4 ± 0.46	4.1 ± 1.1	<0.4 ± 0.48
		222.8	6.7 ± 1.6	<0.4 ± 0.43	5.0 ± 1.2	<0.4 ± 0.43
		276.2	5.5 ± 1.4	4.3 ± 0.96	4.2 ± 1.0	4.2 ± 0.94
		296.2	4.5 ± 1.3	2.5 ± 0.75	3.4 ± 0.97	2.5 ± 0.74
		327.1	5.2 ± 1.4	3.5 ± 0.88	3.9 ± 1.0	3.4 ± 0.86
		475.1	51 ± 6.7	90 ± 11	35 ± 4.6	83 ± 9.6
NOTS 7	09N-02W-29 DCA 5	262.7	7.5 ± 1.7	120 ± 26	5.7 ± 1.3	100 ± 22
NOTS 7A	09N-02W-29 DCA 6	330.1	10 ± 1.4	17 ± 2.0	9.0 ± 1.3	17 ± 2.0
		407.5	3.7 ± 0.94	9.3 ± 1.4	3.3 ± 0.83	7.4 ± 1.1
		480.0	9.3 ± 1.5	13 ± 1.9	8.0 ± 1.2	10 ± 1.5
		480.0	12 ± 3.0	8.5 ± 1.4	9.6 ± 2.4	6.8 ± 2.4

Table 12.—*Concentrations of selected radionuclides in water from NOTS test holes*—Continued

Test-hole name	Local identifier	Sampling depth (feet)	Radium-226, dissolved (pCi/L)	Radium-228, dissolved (pCi/L)	Radon-222, total (pCi/L)	Tritium, total (pCi/L)
NOTS 1A	16N-02W-21 BAA 3	176.0	0.06 ± 0.013	<1.0 ± 0.73	<80 ± 51	— —
		229.0	0.04 ± 0.012	<1.0 ± 0.36	118 ± 36	— —
NOTS 2	15N-03E-31 BAA 2	106.4	0.03 ± 0.013	<1.0 ± 0.97	200 ± 40	— —
NOTS 3	14N-02W-23 CCA 1	119.5	0.32 ± 0.057	<1.0 ± 0.68	<80 ± 38	— —
		119.5	0.34 ± 0.064	<1.0 ± 0.67	<80 ± 36	— —
		164.9	0.05 ± 0.014	<1.0 ± 0.62	290 ± 47	— —
NOTS 4	10N-01E-11 BBB 1	101.0	0.11 ± 0.023	<1.0 ± 0.46	<80 ± 36	— —
		156.2	0.29 ± 0.052	1.3 ± 0.71	<80 ± 35	— —
		189.0	0.52 ± 0.088	<1.0 ± 0.73	430 ± 33	— —
		257.5	0.31 ± 0.056	1.5 ± 0.62	93 ± 42	— —
NOTS 5	08N-03E-03 DAA 1	62.0	0.56 ± 0.093	1.3 ± 0.73	580 ± 39	— —
		62.0	0.50 ± 0.097	1.1 ± 0.73	490 ± 39	— —
		131.0	1.1 ± 0.189	1.2 ± 0.76	1,300 ± 42	— —
		183.5	0.90 ± 0.147	2.5 ± 0.90	<80 ± 51	— —
NOTS 6	14N-03W-07 DAA 2	106.2	0.28 ± 0.055	<1.0 ± 0.46	200 ± 33	— —
		141.0	0.26 ± 0.045	<1.0 ± 0.40	300 ± 31	— —
		180.8	0.24 ± 0.043	<1.0 ± 0.57	350 ± 39	— —
		180.8	0.23 ± 0.043	<1.0 ± 0.53	360 ± 35	— —
		222.8	0.31 ± 0.060	<1.0 ± 0.46	320 ± 47	— —
		276.2	0.22 ± 0.039	<1.0 ± 0.40	260 ± 39	— —
		296.2	0.20 ± 0.036	<1.0 ± 0.37	520 ± 40	— —
		327.1	0.18 ± 0.033	<1.0 ± 0.45	330 ± 53	— —
		475.1	0.08 ± 0.017	<1.0 ± 0.73	180 ± 43	— —
NOTS 7	09N-02W-29 DCA 5	262.7	— —	— —	<80 ± 43	— —
NOTS 7A	09N-02W-29 DCA 6	330.1	0.08 ± 0.017	<1.0 ± 0.64	<80 ± 40	6.1 ± 0.57
		407.5	0.08 ± 0.017	<1.0 ± 0.92	<80 ± 26	1.2 ± 0.64
		480.0	0.06 ± 0.018	<1.0 ± 0.31	<80 ± 26	4.0 ± 0.58
		480.0	— —	— —	<80 ± 26	3.8 ± 0.58

Table 12.—*Concentrations of selected radionuclides in water from NOTS test holes*—Continued

Test-hole name	Local identifier	Sampling depth (feet)	Uranium-234, dissolved (pCi/L)	Uranium-235, dissolved (pCi/L)	Uranium-238, dissolved (pCi/L)	Uranium natural, dissolved (ug/L as U)
NOTS 1A	16N-02W-21 BAA 3	176.0	32 ± 2.4	0.8 ± 0.26	22 ± 3.4	66 ± 10
		229.0	44 ± 4.6	1.5 ± 0.38	36 ± 3.8	110 ± 12
NOTS 2	15N-03E-31 BAA 2	106.4	23 ± 2.4	0.6 ± 0.18	14 ± 1.5	40 ± 4.6
NOTS 3	14N-02W-23 CCA 1	119.5	0.6 ± 0.08	<0.1 ± 0.01	0.2 ± 0.04	0.6 ± 0.13
		119.5	0.8 ± 0.10	<0.1 ± 0.01	0.3 ± 0.05	0.8 ± 0.16
		164.9	24 ± 2.4	0.5 ± 0.12	9.7 ± 1.0	29 ± 3.2
NOTS 4	10N-01E-11 BBB 1	101.0	0.6 ± 0.09	<0.1 ± 0.01	0.2 ± 0.04	0.6 ± 0.14
		156.2	1.2 ± 0.16	<0.1 ± 0.01	0.3 ± 0.06	0.9 ± 0.18
		189.0	2.3 ± 0.27	<0.1 ± 0.01	0.3 ± 0.07	1.0 ± 0.20
		257.5	6.1 ± 0.63	<0.1 ± 0.02	0.8 ± 0.11	2.3 ± 0.34
NOTS 5	08N-03E-03 DAA 1	62.0	18 ± 1.9	0.5 ± 0.15	15 ± 1.6	44 ± 4.8
		62.0	18 ± 1.9	0.6 ± 0.17	14 ± 1.5	42 ± 4.6
		131.0	9.3 ± 1.2	0.3 ± 0.14	1.6 ± 0.36	5.0 ± 1.1
		183.5	7.6 ± 0.86	<0.1 ± 0.05	0.9 ± 0.17	2.6 ± 0.54
NOTS 6	14N-03W-07 DAA 2	106.2	3.9 ± 0.47	0.2 ± 0.07	1.8 ± 0.26	5.5 ± 0.81
		141.0	4.4 ± 0.54	<0.1 ± 0.04	1.8 ± 0.27	5.3 ± 0.82
		180.8	8.1 ± 1.0	<0.1 ± 0.06	2.3 ± 0.41	7.0 ± 1.3
		180.8	6.8 ± 0.98	<0.1 ± 0.08	2.2 ± 0.49	6.6 ± 1.5
		222.8	7.7 ± 0.93	0.1 ± 0.07	2.3 ± 0.39	7.0 ± 1.2
		276.2	14 ± 1.6	0.2 ± 0.11	6.0 ± 0.83	18 ± 2.5
		296.2	9.7 ± 1.3	0.7 ± 0.29	4.7 ± 0.81	14 ± 2.5
		327.1	3.5 ± 0.38	<0.1 ± 0.03	1.4 ± 0.18	4.1 ± 0.56
		475.1	110 ± 12	5.1 ± 0.70	110 ± 12	320 ± 35
NOTS 7	09N-02W-29 DCA 5	262.7	— —	— —	— —	— —
NOTS 7A	09N-02W-29 DCA 6	330.1	24 ± 3.0	1.0 ± 0.28	12 ± 1.5	35 ± 4.6
		407.5	3.6 ± 0.56	0.1 ± 0.10	1.8 ± 0.35	5.4 ± 1.1
		480.0	3.4 ± 0.59	0.3 ± 0.17	1.9 ± 0.40	5.8 ± 1.3
		480.0	— —	— —	— —	— —

Table 12.—*Concentrations of selected radionuclides in water from NOTS test holes*—Continued

Test-hole name	Local identifier	Sampling depth (feet)	Uranium natural, total (ug/L as U)
NOTS 1A	16N-02W-21 BAA 3	176.0	49 ± 15
		229.0	130 ± 36
NOTS 2	15N-03E-31 BAA 2	106.4	32 ± 10
NOTS 3	14N-02W-23 CCA 1	119.5	1.0 ± 0.42
		119.5	<1.0 ± 0.34
		164.9	27 ± 9.1
NOTS 4	10N-01E-11 BBB 1	101.0	<1.0 ± 1.5
		156.2	<1.0 ± 1.5
		189.0	1.4 ± 1.7
		257.5	2.6 ± 0.88
NOTS 5	08N-03E-03 DAA 1	62.0	36 ± 11
		62.0	43 ± 14
		131.0	16 ± 6.0
		183.5	19 ± 7.2
NOTS 6	14N-03W-07 DAA 2	106.2	4.8 ± 1.5
		141.0	5.1 ± 1.5
		180.8	6.4 ± 1.9
		180.8	7.4 ± 2.2
		222.8	14 ± 4.0
		276.2	18 ± 5.1
		296.2	11 ± 3.2
		327.1	14 ± 3.9
		475.1	270 ± 74
NOTS 7	09N-02W-29 DCA 5	262.7	14 ± 4.1
NOTS 7A	09N-02W-29 DCA 6	330.1	32 ± 7.3
		407.5	5.6 ± 1.3
		480.0	4.9 ± 1.1
		480.0	4.7 ± 1.1

Table 13.—δ-values in permil for stable isotopes in water from NOTS test holes

[Sampling depth, center of sampling interval below land surface; PDB, Peedee Belemnite; SMOW; Standard Mean Ocean Water; CDT, Canyon Diablo Troilite; δ-value in permil, ((isotope ratio in sample minus ratio in standard) divided by ratio in standard) multiplied by 1,000; —, indicates no data are available. All samples analyzed by the National Water Quality Laboratory of the U.S. Geological Survey]

Test-hole name	Local identifier	Sampling depth (feet)	Carbon 13/12, δ-value relative to PDB (permil)	Hydrogen 2/1, δ-value relative to SMOW (permil)	Oxygen 18/16, δ-value relative to SMOW (permil)	Sulfur 34/32, δ-value relative to CDT (permil)
NOTS 1A	16N-02W-21 BAA 3	176.0	-11.30	-42.9	-7.00	7.80
		229.0	-10.90	-43.5	-6.95	9.10
NOTS 2	15N-03E-31 BAA 2	106.4	-9.90	-37.0	-6.20	14.30
NOTS 3	14N-02W-23 CCA 1	119.5	-14.20	-36.4	-6.05	5.60
		119.5	-14.50	-36.5	-6.05	7.50
		164.9	-13.60	-36.5	-6.00	11.30
NOTS 4	10N-01E-11 BBB 1	101.0	-14.60	-33.5	-5.75	9.60
		156.2	-13.10	-32.5	-5.70	7.20
		189.0	-13.20	-33.0	-5.65	—
		257.5	-12.90	-32.5	-5.70	8.30
NOTS 5	08N-03E-03 DAA 1	62.0	-11.70	-32.5	-5.45	9.90
		62.0	-11.30	-31.0	-5.50	9.50
		131.0	-12.50	-36.4	-6.15	10.90
		183.5	-13.10	-36.5	-6.10	10.80
NOTS 6	14N-03W-07 DAA 2	106.2	-7.30	-35.5	-5.55	8.20
		141.0	-7.30	-35.0	-5.55	9.80
		180.8	-10.10	-35.0	-5.80	5.30
		180.8	-10.10	-35.0	-5.80	6.30
		222.8	-10.80	-35.5	-5.85	3.50
		276.2	-13.00	-38.0	-6.20	3.00
		296.2	-10.90	-35.5	-5.95	3.20
		327.1	-12.10	-37.5	-6.25	3.60
		475.1	-9.40	-42.5	-6.75	-11.90
NOTS 7	09N-02W-29 DCA 5	262.7	—	-24.0	-4.10	7.70
NOTS 7A	09N-02W-29 DCA 6	330.1	-9.50	-34.5	-5.30	8.20
		407.5	-8.30	-44.5	-6.80	9.20
		480.0	-9.60	-40.5	-6.30	7.50
		480.0	—	-39.5	-6.30	8.10