HYDROGEOLOGIC, WATER-LEVEL, AND WATER-QUALITY DATA FROM MONITORING WELLS AT THE U.S. MARINE CORPS AIR STATION, CHERRY POINT, NORTH CAROLINA

By Louis C. Murray, Jr., and Kathleen M. Keoughan

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HYDROGEOLOGIC, WATER-LEVEL, AND WATER-QUALITY DATA FROM MONITORING WELLS AT THE U.S. MARINE CORPS AIR STATION, CHERRY POINT, NORTH CAROLINA

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ABSTRACT

Unlined hazardous-waste disposal sites at the U.S. Marine Corps Air Station, Cherry Point, North Carolina, are located near drinking-water supply wells that tap the Castle Hayne aquifer. Hydrogeologic and water-quality data were collected near 2 of these sites from 12 monitoring wells installed in May through June 1987.

Near the northernmost landfill site, differences in hydraulic head between the surficial, intermediate Yorktown, and Castle Hayne aquifers indicate a potential for migration of contaminants downward into the intermediate Yorktown and Castle Hayne aquifers. Movement would be impeded, however, by two confining units of silty sand to sandy clay that separate these aquifers. Geophysical and lithologic data show the upper confining unit to be approximately 26 feet thick near this landfill.

Near the southernmost landfill, these confining units are thin and discontinuous in an area that coincides with the location of a buried paleochannel. Static water-level data collected in this area indicate that both the Castle Hayne and Yorktown aquifers discharge into the surficial aquifer, minimizing the potential for downward contaminant movement. Ground water in the surficial aquifer at both landfills moves laterally away from nearby drinking-water supply wells and toward Slocum Creek, a tributary of the Neuse River.

Concentrations of organic compounds and trace inorganic constituents included on the U.S. Environmental Protection Agency's list of priority pollutants were determined for water samples from the surficial and Yorktown

aquifers. High concentrations of two purgeable organic compounds, trichloroethylene and 1,2-dichloroethene (4,600 and 4,800 micrograms per liter, respectively), were detected in water samples collected from the surficial aquifer near the southernmost landfill; much smaller concentrations of trichloroethylene and 1,2-dichloroethene were detected in samples from wells in the Yorktown aquifer (up to 16 and 12 micrograms per liter, respectively). These compounds may have migrated into the Yorktown aquifer from the surficial aquifer during periods of pumping from nearby drinking-water supply wells if the pumping were sufficient to reverse the hydraulic head between these aquifers. Only trace amounts of organic compounds were detected in the surficial and Yorktown aquifers near the northernmost landfill. Trace metals were detected in most of the wells sampled near both landfills, but none exceeded U.S. Environmental Protection Agency drinking-water standards except for iron and manganese. Highest concentrations of priority pollutant metals detected were for zinc (60 micrograms per liter) and chromium (36 micrograms per liter).

INTRODUCTION

Location and Background

The U.S. Marine Corps Air Station, Cherry Point, North Carolina, is located in the Coastal Plain physiographic province of the State, in southeastern Craven County (fig. 1). The Air Station includes an area of about 19 mi^2 (square miles) just north of the town of Havelock and is bounded by the Neuse River estuary on the north, by Hancock Creek on the east, by North Carolina Highway 101 on the south, and by an irregular north-south boundary located about 0.75 mile west of Slocum Creek on the west (fig. 2).

In April 1986, the U.S. Geological Survey (USGS), in cooperation with the U.S. Marine Corps (USMC), initiated a four-year (1987-90) study of ground-water resources at the Cherry Point Marine Corps Air Station. The study is divided into four phases (I, IIa, IIb, and III) and is being conducted in response to the increasing water-supply needs reported by the Air Station and the potential for contamination of the water-supply aquifer

(Castle Hayne) by waste materials deposited in numerous unlined landfill sites (fig. 2). Large amounts and various kinds of hazardous wastes from aircraft refitting and manufacturing operations at the Air Station spilled or disposed of at these sites have contaminated ground water in surrounding areas of the surficial aquifer (NUS Corp., 1985, 1986, and 1987). Most of these sites are near wells that tap the Castle Hayne aquifer and supply potable water to the Air Station (fig. 2).

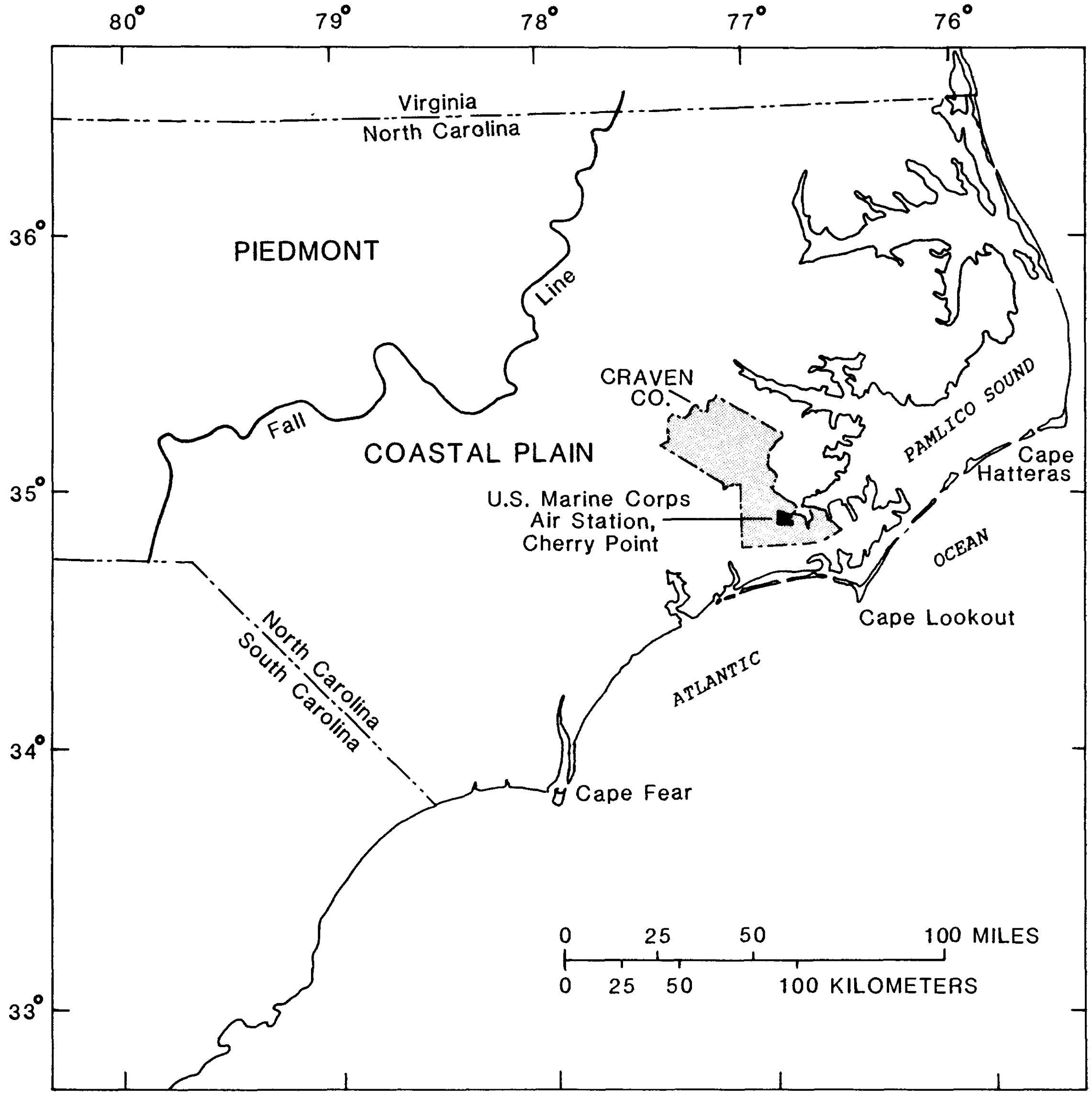


Figure 1.--Location of U.S. Marine Corps Air Station, Cherry Point, North Carolina.

Data collected during Phase I of the USGS study and reported by Lloyd and Daniel (1988) were used to (1) appraise the hydrogeologic setting underlying the Air Station, and (2) evaluate the water quality of the drinking-water supply wells tapping the Castle Hayne aquifer. The most significant result of the Phase I study was the detection of priority pollutant organic compounds in several of the supply wells located near waste-disposal sites 10 and 16 (fig. 2). Benzene was detected in concentrations up to 1.9 and 1.7 micrograms per liter (µg/L) in wells 99 and 103, respectively (fig. 2), where geophysical logs indicate that the confining units separating the surficial aquifer, the intermediate Yorktown aquifer, and the Castle Hayne aquifer are relatively thin and (or) discontinuous. Toluene and di-n-octyl phthalate were detected in supply wells near site 10, the largest waste-disposal site at the Air Station.

In Phase IIa work (1988), the results of which are discussed in this report, the objectives were to (1) define the water-quality characteristics of the surficial and Yorktown aquifers that overlie the Castle Hayne aquifer and (2) assess the potential for further contaminant movement from these aquifers into the Castle Hayne. Hydrogeologic and water-quality data required to meet these objectives were collected from test wells drilled near selected waste-disposal sites.

Purpose and Scope

The purpose of this report is to present and discuss data collected from four monitoring well clusters installed in May through June 1987 at the Air Station for Phase IIa (the second year) of the ongoing ground-water resource study. Specifically, the report describes (1) hydrogeologic data collected at the four well-cluster sites; (2) the distribution of hydraulic head (water levels) within the intermediate Yorktown aquifer, and temporal and spatial differences in hydraulic head between the surficial, Yorktown, and Castle Hayne aquifers; and (3) the quality of water collected from the surficial and Yorktown aquifers at each of the four well-cluster sites. Also presented are a revision of the preliminary hydrogeologic framework described by Lloyd and Daniel (1988) and a description of monitoring wells constructed for this study.

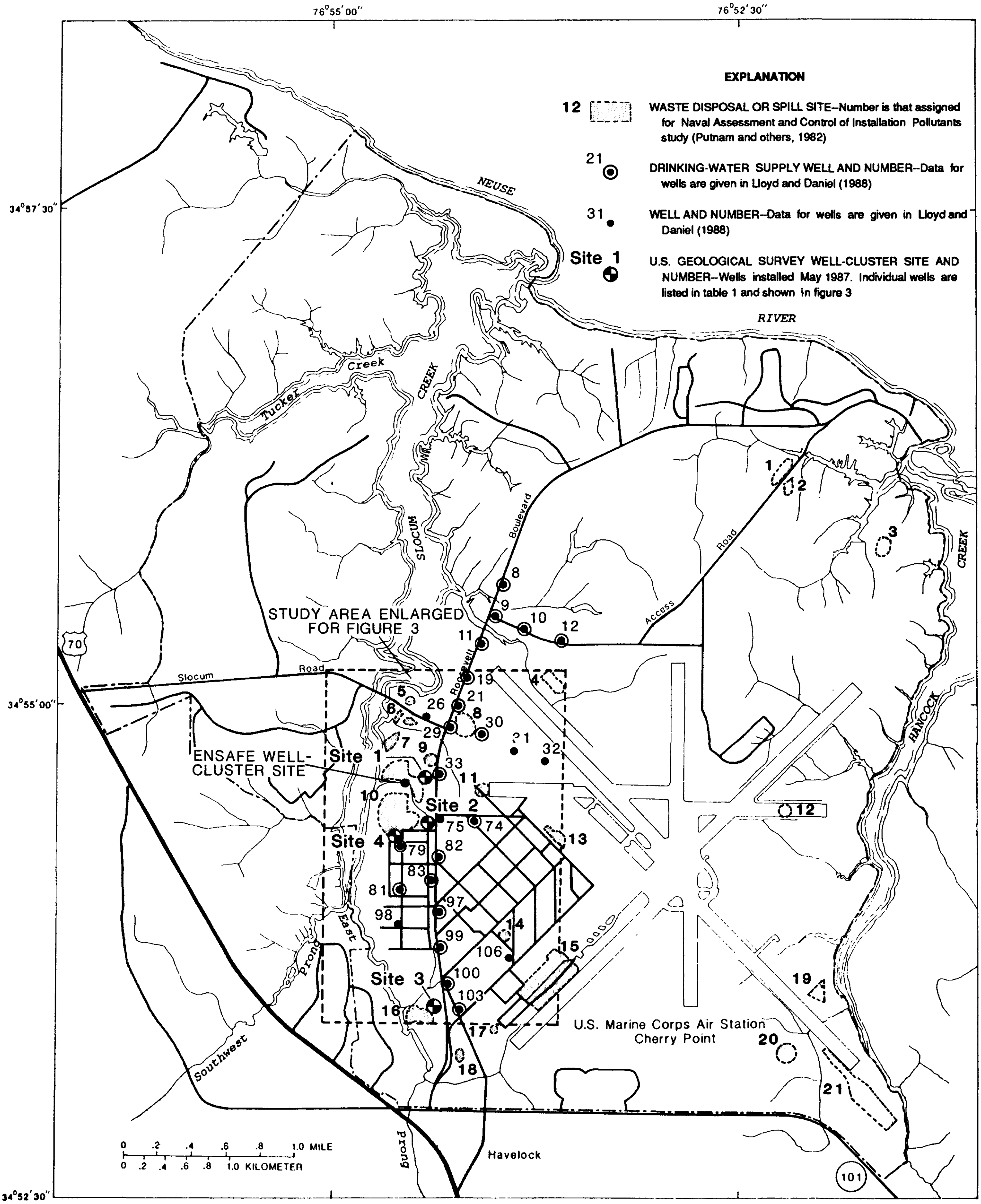


Figure 2.--Location of U.S. Geological Survey well-cluster sites, drinking-water supply wells, and hazardous-waste disposal and spill sites.

The descriptions and interpretations that follow are based primarily on data obtained from lithologic and geophysical logs and mineralogical analyses of fine-grained sediments, water-level measurements, and chemical analyses of water samples. New wells were installed on the western half of the Air Station where the greatest number of water-supply wells and waste sites are located. Results presented in this report are used to assess, to the degree that the data will allow, the potential for and extent of contamination in the surficial and Yorktown aquifers at these sites.

Acknowledgments

The authors wish to thank the U.S. Marine Corps Air Station (MCAS) for their cooperation and assistance in this phase of the ground-water study. Appreciation is also extended to the North Carolina Department of Environment, Health, and Natural Resources (EHNR), formerly called the North Carolina Department of Natural Resources and Community Development (NRCD), for their support and to the Geology Department at the University of North Carolina, Chapel Hill, for the X-ray diffraction analyses of sediment samples.

The authors are particularly indebted to R.D. Nelson, Tim Curtin, Gary Edwards, of the MCAS Natural Resources and Environmental Affairs (NREA) Department, and to David Criswell (formerly with NREA), for help in planning and implementing the logistical support that was vital to the construction of the wells and collection of water samples; to the supervisory staff and equipment operators of the Facilities Maintenance Department for the use of cranes and backhoes during well-construction activities; and to Oscar Howard of EHNR for the geophysical logging of the wells.

MONITORING WELLS

Location and Number

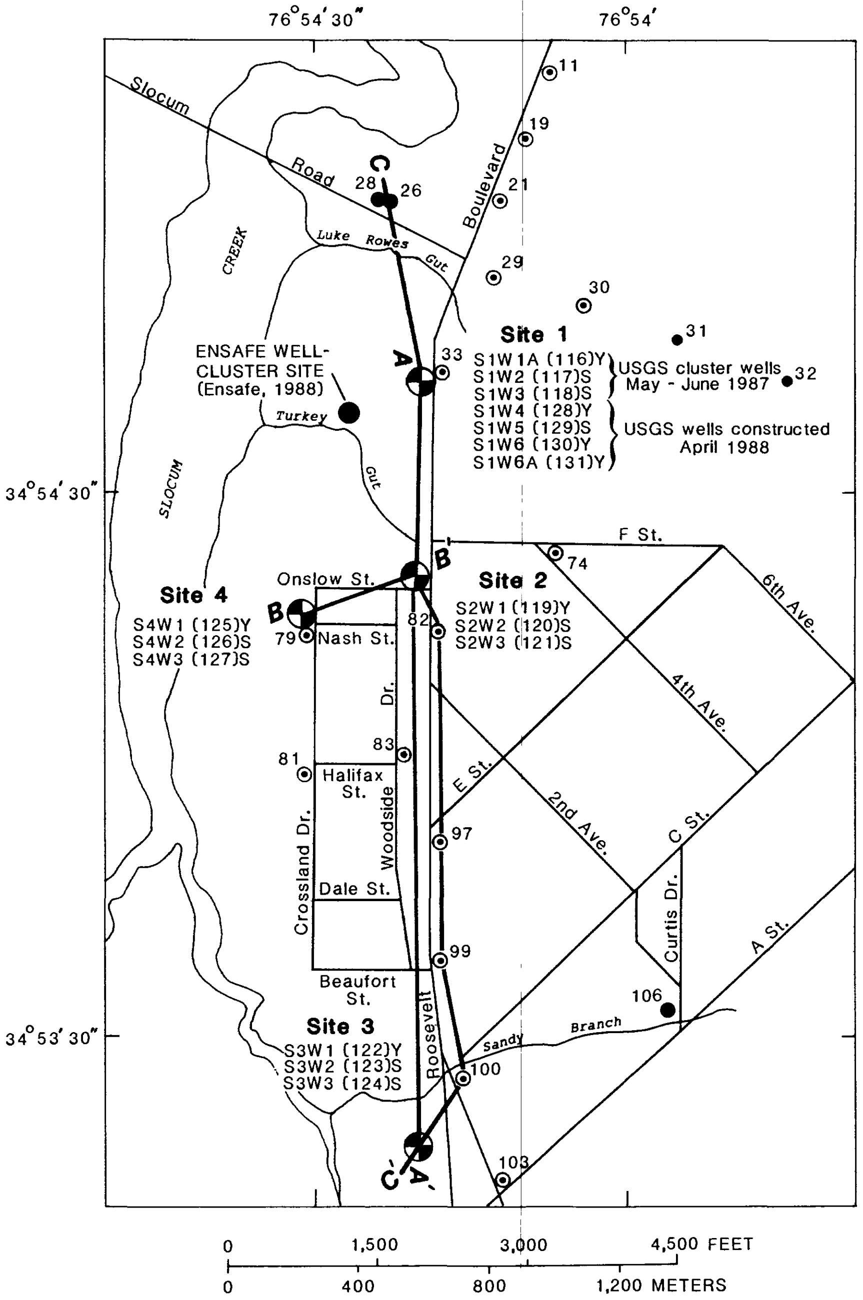
Twelve monitoring wells were installed at four well-cluster sites (three wells per site) in May through June 1987, by the U.S. Geological Survey in a north-south orientation along Roosevelt Boulevard (fig. 2). At each site, one deep well was screened in the confined Yorktown aquifer, and two shallow wells were screened in the unconfined surficial aquifer. The three wells at each site were constructed within 10 to 30 ft of each other to permit water-quality and water-level data to be collected from both aquifers at the same locations. It should be noted that the aquifer names given above are different from those used by Lloyd and Daniel (1988). This revised nomenclature, discussed later in this report, is based on more recent detailed lithologic analyses of cored material collected from the four well-cluster sites.

Water-level data were also collected from a well cluster constructed by Environmental and Safety Designs, Inc., (Ensafe) in September 1988 to the southwest of well-cluster site 1 (fig. 2). This cluster consists of one Yorktown aquifer well and two surficial aquifer wells installed as part of a post-closure plan for the former surface impoundments at waste-disposal site 10.

Well numbers shown alongside the wells in figure 2 were assigned to these wells during the Phase I study. This numbering system is retained in this report to be consistent with Lloyd and Daniel (1988). Well identification numbers previously assigned to the drinking-water supply wells by the MCAS that correspond to the numbers shown on figure 2 are provided in the report by Lloyd and Daniel (1988, table 2). These MCAS well numbers are provided in this report only for those drinking-water supply wells referenced in the text.

A map of that part of the study area that encompasses the four well-cluster sites is shown in figure 3, which also lists the individual USGS well numbers at each site, and identifies the aquifer tapped by each well. Map well numbers assigned to the USGS wells shown on figure 3 continue in sequence from those listed in the previous report by Lloyd and Daniel (1988, table 2).

The USGS well clusters were constructed between waste-disposal sites and water-supply wells to test for movement of contaminants toward the water-supply wells. Well-cluster site 1 was placed between water-supply



EXPLANATION

⊕ **Site 2**
S2W1 (119)Y
S2W2 (120)S
S2W3 (121)S
U.S. GEOLOGICAL SURVEY WELL-CLUSTER SITE AND NUMBER, AND COMPONENT WELLS AND NUMBERS--S2, cluster-site number; W1, cluster-well number; (119), Map well number listed in table 1; Y, well screened in Yorktown aquifer; S, well screened in surficial aquifer

● 26 WELL AND NUMBER--Data for wells are given in Lloyd and Daniel (1988)

⊙ 99 DRINKING-WATER SUPPLY WELL AND NUMBER--Data for wells are given in Lloyd and Daniel (1988)

A———*A'* LINE OF HYDROGEOLOGIC SECTION--Sections shown in figures 8, 9, and 11

Figure 3.--Location of wells and lines of hydrogeologic section.

well 33 (MCAS Well 8) and the eastern perimeter of the northern half of the old sanitary landfill (waste-disposal site 10 on fig. 2), the largest of the waste-disposal sites at the Air Station. The Yorktown aquifer well at this site, designated as S1W1A, was constructed after the first borehole had to be abandoned and plugged with cement when 40 ft of hollow-stem auger became locked-up in the borehole during the drilling operation. Four other wells located at well-cluster site 1 and listed on figure 3 (S1W4, S1W5, S1W6, and S1W6A) were installed by the USGS between April and August 1988, during a separate hydrogeologic and water-quality investigation conducted near the waste-water treatment plant and polishing lagoons. Preliminary reports on the results of this study are in review.

Well-cluster site 2 was constructed between the eastern perimeter of the southern half of the old sanitary landfill and water-supply wells 74 and 82 (MCAS Wells 9 and 11, respectively). Well-cluster site 4 was installed west of well-cluster site 2 near the southern perimeter of the landfill. Water-level data from this site can be used to estimate the hydraulic gradient of the Yorktown aquifer in the direction of Slocum Creek. Also, the close proximity of this cluster to water-supply well 79 (MCAS Well 13) allows for water levels in the surficial, Yorktown, and Castle Hayne aquifers to be measured at roughly the same location. Such hydraulic-head data are needed to assess the potential for downward movement of contaminants from one aquifer to the next.

The southernmost well cluster, well-cluster site 3, was constructed near Sandy Branch between waste-disposal site 16 and water-supply wells 100 and 103 (MCAS Wells 16 and 17, respectively). Collection of hydrogeologic and water-quality data in this area is particularly critical because the upper and lower confining units that overlie the Castle Hayne aquifer are thin and (or) discontinuous near Sandy Branch and waste-disposal site 16 (Lloyd and Daniel, 1988).

Construction and Development

Construction and development procedures for the USGS cluster wells are discussed below. Data on well construction, water levels, available logs, and water-quality analyses are summarized for each well in table 1. To minimize the potential for contamination between individual wells and drilling sites, all drill bits, rods, auger stems, well casing, and screens were steam cleaned prior to drilling and well construction. Also, protective steel casing with locking caps were installed at each location to protect the integrity of the wells.

Boreholes for all of the surficial aquifer wells were drilled with a 7-inch diameter hollow-stem auger. At each site, one stainless steel well and one polyvinylchloride (PVC) well were installed in the surficial aquifer. Split-spoon core samples extracted during the drilling operations for the stainless steel wells (S1W2, S2W2, S3W2, and S4W2) were examined, and lithologic logs were prepared. No samples were retrieved during construction of the PVC wells. Once the borehole for each surficial aquifer well was drilled, 2-inch diameter casing and screen were set through the hollow stem of the auger, and the formation was allowed to collapse around the screen when the auger was withdrawn. A bentonite-pellet seal, at least 2 ft thick, was placed above the screen to prevent downward migration of fluids in the annular space between the casing and the borehole. The annular space remaining above the bentonite layer was filled with cement. Construction specifications for the surficial aquifer wells are shown in figure 4.

The Yorktown aquifer wells were constructed with the hydraulic mud-rotary drilling method. At each site, 8-inch PVC casing was grouted into a 12-inch borehole with cement grout. After the cement was allowed to set overnight, a 7 5/8-inch borehole was drilled through the cement plug at the bottom of the 8-inch casing, into and through the Yorktown aquifer, and terminated several feet into the underlying confining unit. Split-spoon core samples collected during this time were sealed for later inspection. A 10-ft length of 2-inch diameter stainless steel screen attached to stainless steel casing was then placed into the borehole. The annular space around the screen and casing was then backfilled with clean sand or natural sand formation collapse to a depth of several feet above the top of the screen. A granular bentonite seal, approximately 2 ft thick, was then placed above the sand filter pack. The remaining annular space was grouted

Table 1.--*Records of U.S. Geological Survey wells*

[<u>USGS well number</u>: Numbers that have been assigned by the U.S. Geological Survey to identify wells constructed at the Air Station. <u>USGS identification number</u>: Numbers are comprised of degrees, minutes, and seconds of latitude (first six numbers) north of the equator, and longitude (next seven numbers) west of the zero meridian. M, monitoring and (or) observation well. Y, Yorktown aquifer; S, surficial aquifer. SS, stainless steel casing and screen; PVC, polyvinylchloride casing. SR, screen (screen length is total depth minus casing length). Yes, water-quality data are available; No, water-quality data are not available. G, geophysical log; L, lithologic log; --, no data available. USGS, U.S. Geological Survey files.]

Map well number (fig. 3)	USGS well number	USGS identification number	Use	Land surface altitude above sea level (feet)	Aquifer	Total well depth below land surface (feet)	Casing length (feet)	Diameter (inches) and casing material	Finish	Water level above sea level (feet)	Date of water-level measurement	Height of measuring point above land surface (feet)	Water-quality analysis	Geophysical or lithologic log	Data source	Remarks
116	S1W1A	345442076542501	M	23.53	Y	76	66	2 SS	SR	5.19	12/9/88	1.61	Yes	G,L	USGS	
117	S1W2	345442076542502	M	23.50	S	38	28	2 SS	SR	8.56	12/9/88	1.86	Yes	--	USGS	
118	S1W3	345442076542503	M	23.52	S	38	28	2 PVC	SR	8.61	12/9/88	1.77	Yes	--	USGS	Water-level recorder
119	S2W1	345423076542501	M	21.81	Y	95	85	2 SS	SR	5.13	12/9/88	2.15	Yes	G,L	USGS	Water-level recorder
120	S2W2	345423076542502	M	22.03	S	38	28	2 SS	SR	11.78	12/9/88	1.95	Yes	--	USGS	Water-level recorder
121	S2W3	345423076542503	M	22.25	S	38	28	2 PVC	SR	11.85	12/9/88	2.36	Yes	--	USGS	
122	S3W1	345318076542001	M	19.84	Y	90	80	2 SS	SR	3.84	12/9/88	2.55	Yes	G,L	USGS	Water-level recorder
123	S3W2	345318076542002	M	19.88	S	48	38	2 SS	SR	3.18	12/9/88	2.60	Yes	--	USGS	Water-level recorder
124	S3W3	345318076542003	M	19.9	S	48	38	2 PVC	SR	3.22	12/9/88	2.55	Yes	--	USGS	
125	S4W1	345419076543601	M	23.4	Y	90	80	2 SS	SR	4.85	12/9/88	2.13	Yes	G,L	USGS	Water-level recorder
126	S4W2	345419076543602	M	23.4	S	30	20	2 SS	SR	9.11	12/9/88	2.06	Yes	--	USGS	Water-level recorder
127	S4W3	345419076543603	M	23.4	S	30	20	2 PVC	SR	9.16	12/9/88	2.40	Yes	--	USGS	
128	S1W4	345442076542504	M	23.28	Y	88	58	2 SS	SR	5.23	12/9/88	2.50	No	L	USGS	Water-level recorder
129	S1W5	345442076542505	M	23.66	S	28	18	2 SS	SR	8.65	12/9/88	2.23	Yes	--	USGS	
130	S1W6	345442076542506	M	23.09	Y	81	71	4 PVC	SR	5.21	12/9/88	2.64	No	--	USGS	Aquifer test
131	S1W6A	345442076542507	M	23.18	Y	74	64	4 PVC	SR	5.26	12/9/88	3.06	No	--	USGS	Aquifer test

with cement. Circulation of approximately 3,000 gallons (gal) of water and drilling mud was lost into the surficial and Yorktown aquifers during the construction of well S3W1. No such circulation loss occurred at any of the other wells. Construction specifications for the Yorktown aquifer wells are shown in figure 5.

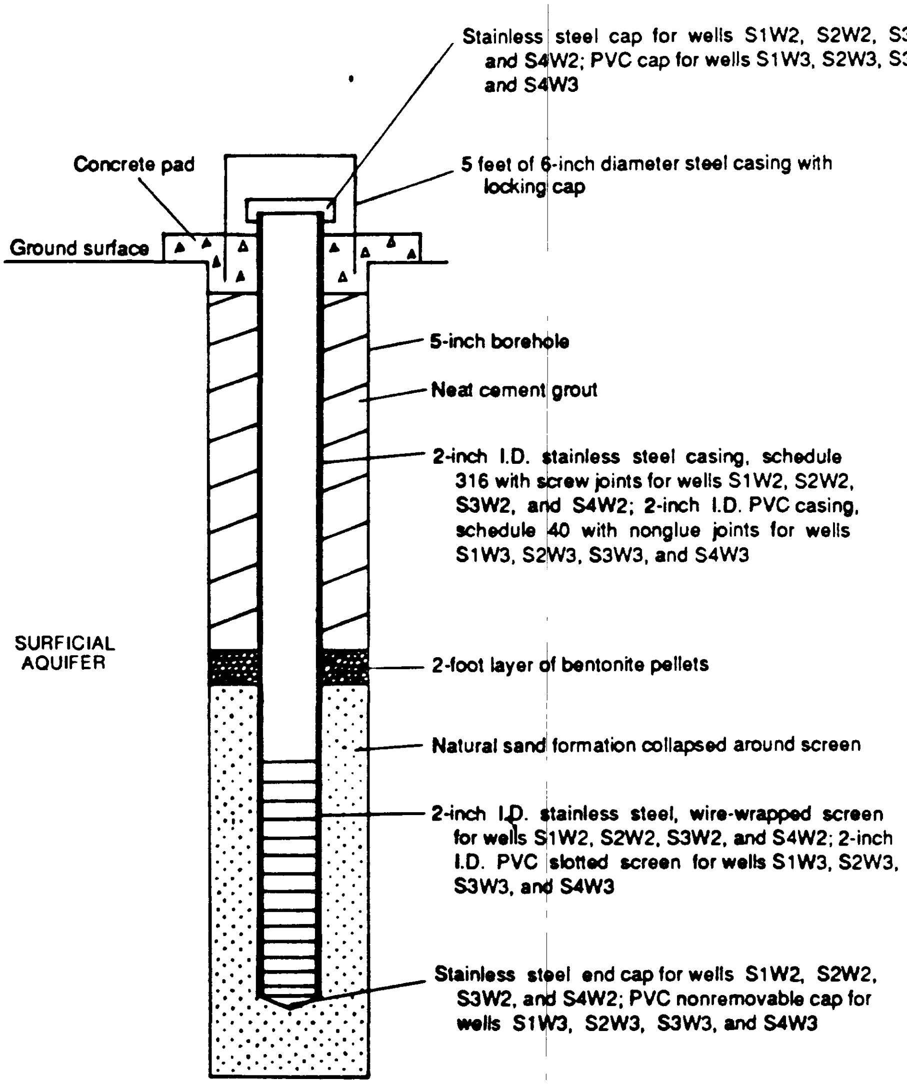


Figure 4.--Schematic showing typical well-construction specifications for wells S1W2, S1W3, S2W2, S2W3, S3W2, S3W3, S4W2, and S4W3 in the surficial aquifer.

Once construction was completed, the altitudes of the ground surface and the top of the protective 6-inch casing were determined using standard USGS techniques. The top of the protective casing was used as the measuring point for water-level data discussed later in this report. Altitudes surveyed at each well are given in table 1. In May 1988, two automatic recorders were installed at each well-cluster site to monitor water-level fluctuations in the surficial and Yorktown aquifers.

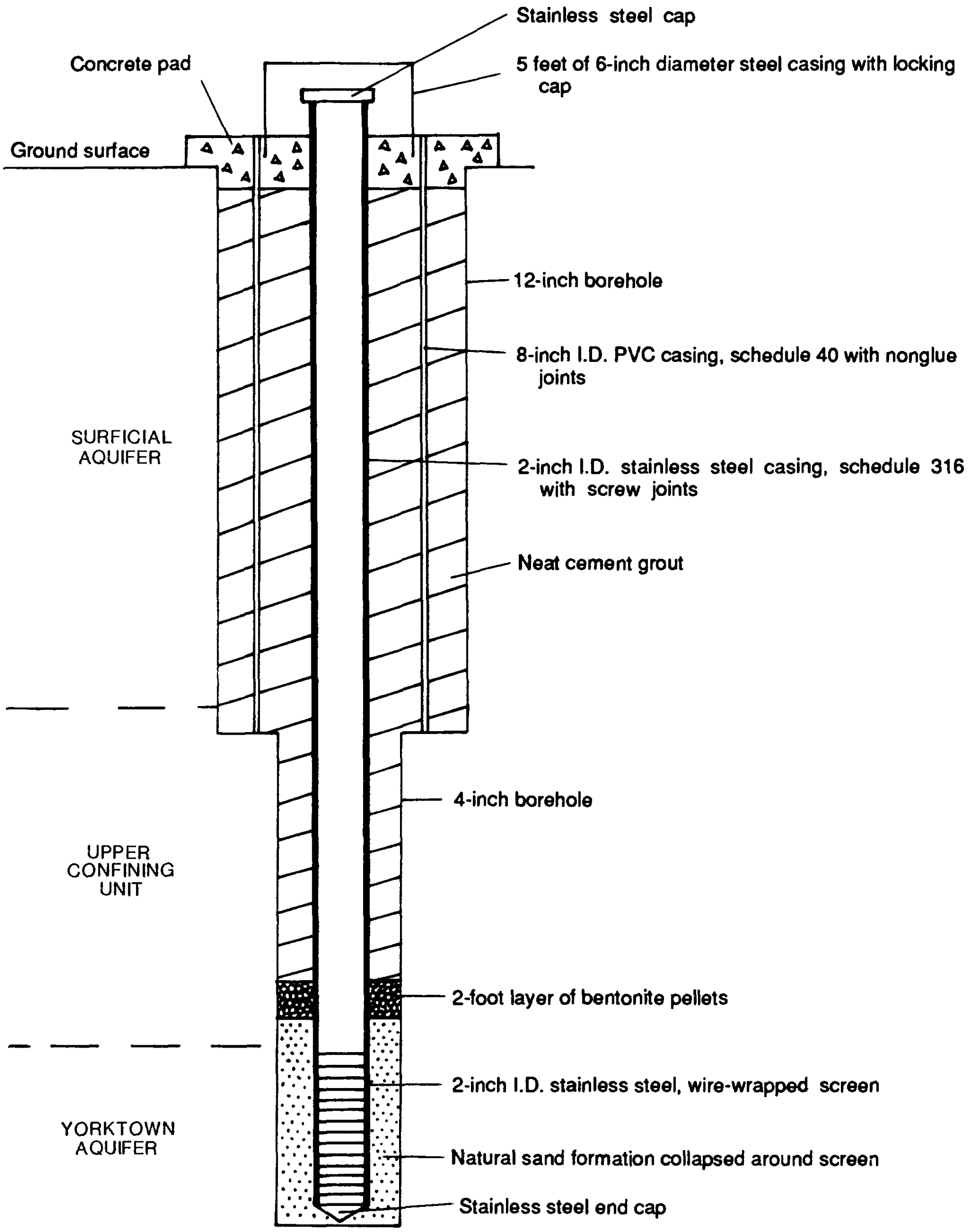


Figure 5.--Schematic showing typical well-construction specifications for wells S1W1A, S2W1, S3W1, and S4W1 in the Yorktown aquifer.

The wells were developed to increase yields and to clear the water of drilling fluid and formation sediment. At each well, a flexible PVC tubing was lowered to the screened interval and attached at ground surface to a centrifugal pump. Each well was pumped at the highest rate possible for several hours while the effluent was measured for its specific conductivity. Pumpage was terminated once the effluent was clear and the conductivity readings had stabilized.

HYDROGEOLOGIC DATA

Revised Hydrogeologic Framework

The hydrogeologic framework at the Air Station, previously defined by Lloyd and Daniel (1988), has been redefined on the basis of more detailed lithologic analyses of cored material collected at the four well-cluster sites and from other existing well data by Keoughan (1988). A brief description of the revised framework follows to familiarize the reader with the nomenclature used to identify the hydrogeologic units referenced in this report. Detailed lithologic descriptions are discussed later in this section.

The aquifers lying in the upper 300 ft at Cherry Point have been renamed as the unconfined surficial aquifer and the confined Yorktown and Castle Hayne aquifers. The relation between those hydrogeologic units defined by Lloyd and Daniel (1988) and the revised names described in this report are shown in figure 6.

The geologic units previously described as the undifferentiated deposits and underlying Yorktown Formation by Lloyd and Daniel (1988) at the Air Station, are now considered to be the Flanner Beach Formation by Keoughan (1988). The Flanner Beach Formation of middle Pleistocene age is composed of fine, well-sorted sand to silty sand as defined by Mixon and Pilkey (1976). Maximum thicknesses of the Flanner Beach Formation (40 to 50 ft or more) occur along an inferred Neuse River paleochannel (Mixon and Pilkey, 1976), which trends northwest-southeast and lies in the southwestern part of the study area (fig. 7). Keoughan (1988) used the term Flanner Beach aquifer at the Air Station, but for the purposes of this report it is hereafter referred to as the unconfined surficial aquifer.

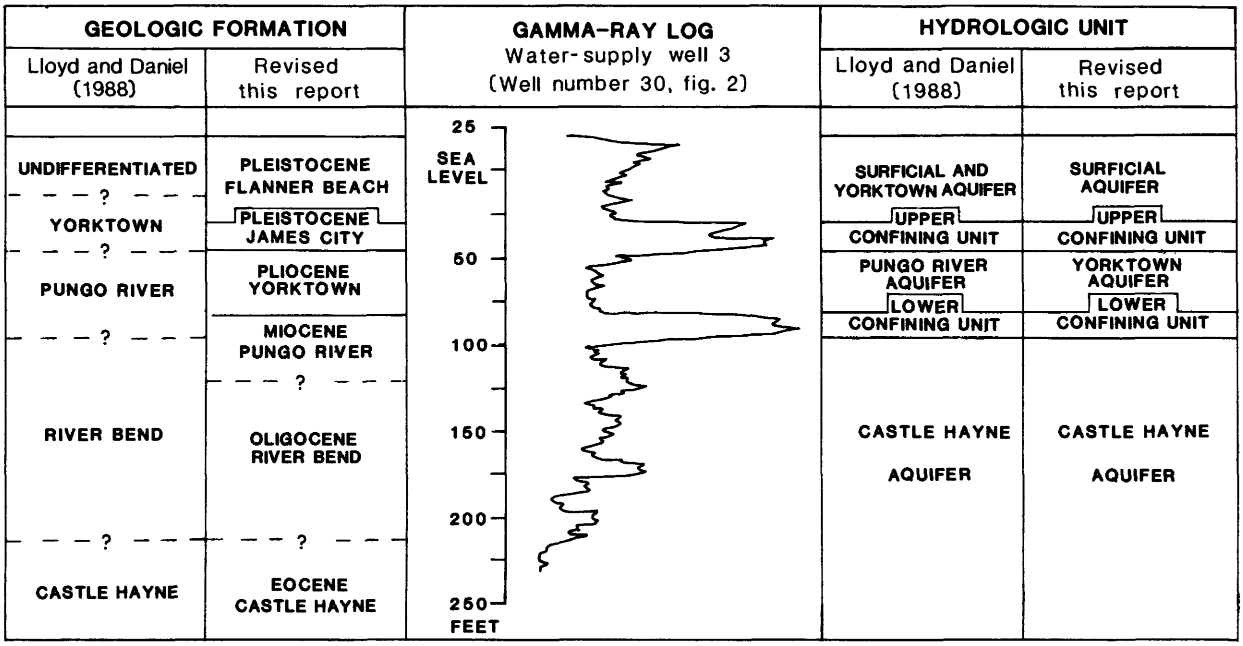


Figure 6.--Revised hydrogeologic framework for aquifers and confining units that underlie the U.S. Marine Corps Air Station.

The surficial aquifer is underlain by a confining unit (fig. 6) consisting of slightly shelly, silty sand of the James City Formation of early Pleistocene age (Keoughan, 1988; Dubar and Solliday, 1963). This unit is hereafter referred to as the upper confining unit in this report.

The unit previously called the Pungo River aquifer by Lloyd and Daniel (1988) is called the Yorktown aquifer by Keoughan (1988) in this report. The sediments constituting the Yorktown aquifer consist of fine to medium quartz sands of the Yorktown Formation of Pliocene age (Ward and Blackwelder, 1980).

The Yorktown aquifer is underlain by a confining unit (fig. 6) consisting of contiguous clays of the lowermost Yorktown Formation and the upper clay and sandy silt beds of the Pungo River Formation of middle Miocene age (Kimrey, 1965). This unit is hereafter referred to as the lower confining unit.

The hydrogeologic unit previously described as the Castle Hayne aquifer by Lloyd and Daniel (1988) included the River Bend Formation of Oligocene

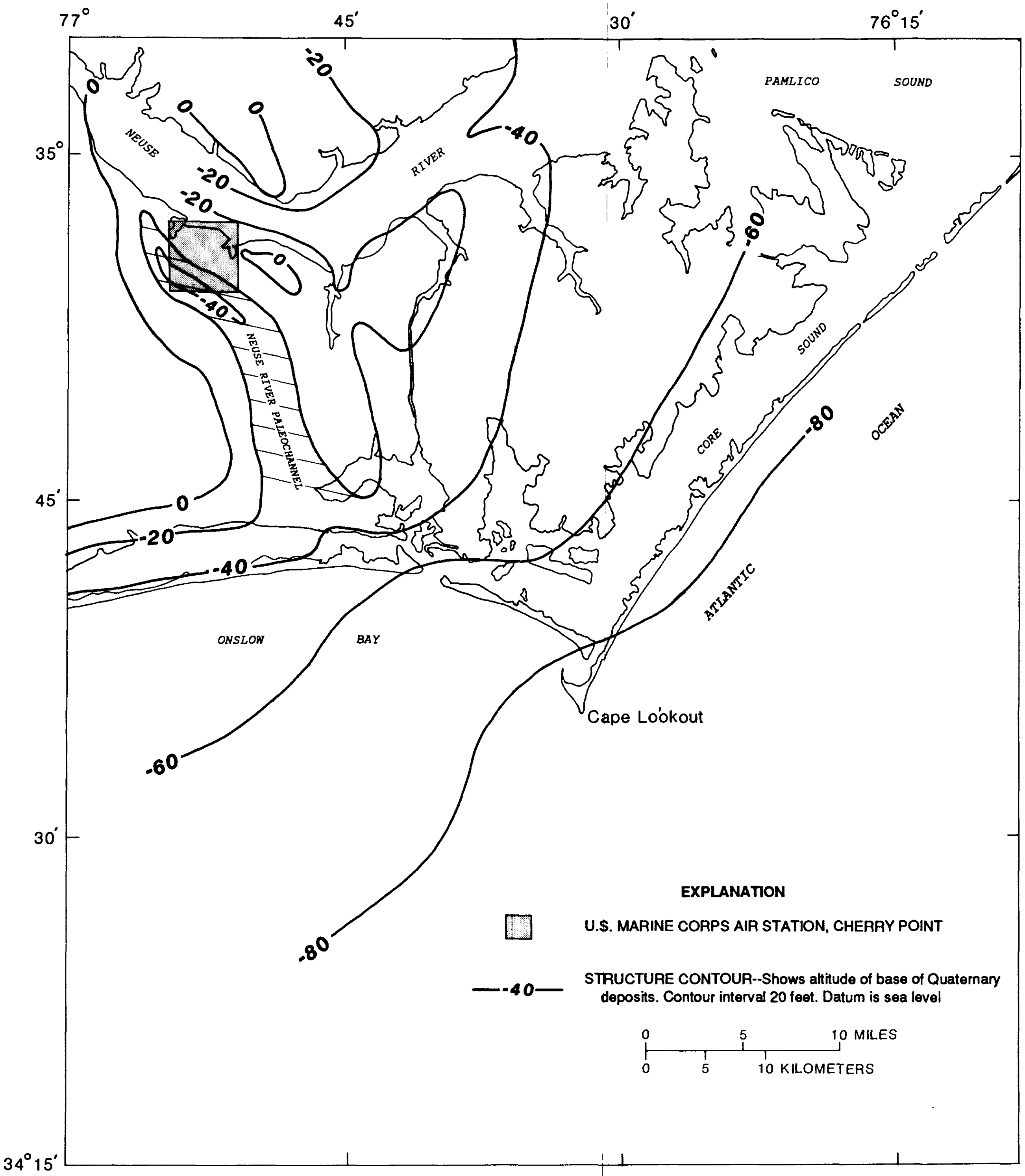


Figure 7.--Relation of Pleistocene paleochannel to the U.S. Marine Corps Air Station (modified from Mixon and Pilkey, 1976).

age and the Castle Hayne Formation of middle Eocene age (Ward and others, 1978). Throughout much of the North Carolina Coastal Plain a third confining unit lies below the Pungo River Formation and above the River Bend and Castle Hayne Formations (Winner and Coble, 1987). However, geophysical logs indicate that this third confining unit is missing in the subsurface at Cherry Point. Therefore, the Castle Hayne aquifer in this report includes the lower beds of the Pungo River Formation and the underlying River Bend and Castle Hayne Formations. The Castle Hayne aquifer extends from a depth of approximately 110 ft below land surface to at least 300 ft below land surface.

Lithologic and Geophysical Logs

Generalized lithologic logs depicting textural changes in the sediments that underlie the four well-cluster sites are shown on hydrogeologic sections A-A' and B-B' (figs. 8 and 9, respectively). The upper 50 to 55 ft of each log was interpreted from a microscopic examination of sediment samples collected during construction of the stainless steel cased well in the surficial aquifer. The remaining section of each log was interpreted from samples collected during construction of the well screened within the Yorktown aquifer. Detailed lithologic descriptions used to prepare the generalized logs are shown in table 8 beginning on page 53 of this report. Sediments examined with a microscope and estimated to contain less than 5 percent of silt and clay-sized grains are called "sands" on the hydrogeologic sections. Sediments estimated to contain 5 to 10 percent of silt and clay-sized grains are called "slightly silty to slightly clayey sands," and sediments estimated to contain greater than 10 percent silt and clay-sized material are called "silty to clayey sands" to "sandy clays."

Natural gamma-ray logs, made in the wells that penetrate the Yorktown aquifer, are shown adjacent to the lithologic logs to supplement textural interpretations. The gamma-ray log run in supply well 97 (MCAS Well 14) during the initial phase of the USGS ground-water study, is included on hydrogeologic section A-A' (fig. 8) to aid in interpretation of the subsurface stratigraphy between well-cluster sites 2 and 3. These logs are records of the amount of naturally occurring gamma-ray radiation emitted by

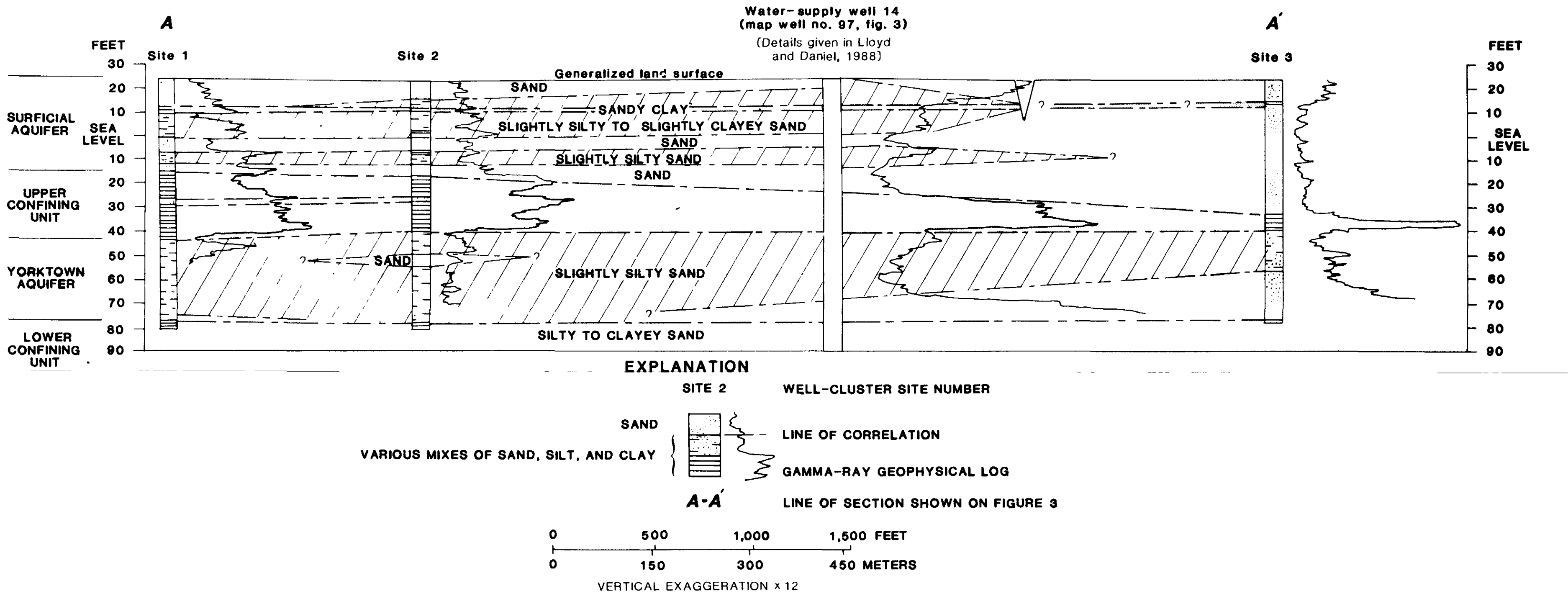


Figure 8.--Hydrogeologic section A-A'.

the sediments and are used to help distinguish between clayey confining material and more permeable sands. In general, clay emits more gamma radiation than does sand. The higher the gamma-ray radiation, the farther to the right the log deflection. Apparent inconsistencies between the lithologic and gamma-ray logs are due to the presence of collophanite, a phosphate mineral found in the Yorktown and the Pungo River Formations that occurs beneath the Air Station (Lloyd and Daniel, 1988). This mineral emits a substantial amount of gamma radiation (Kimrey, 1965), and without corresponding lithologic logs, it is possible that phosphatic sand layers could be mistaken for clay layers on gamma-ray logs.

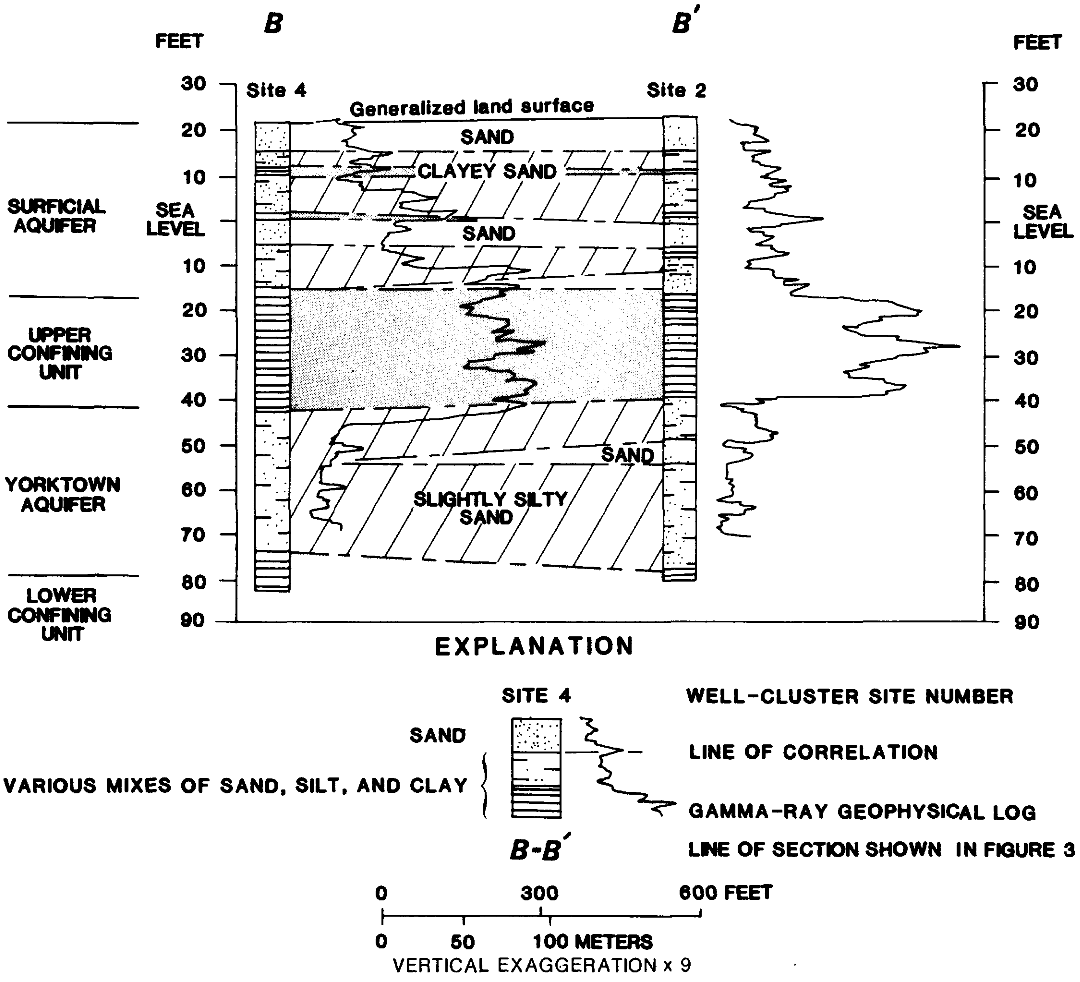


Figure 9.--Hydrogeologic section B-B'.

In general, the extent and hydrogeologic character of aquifers and confining units identified from the lithologic and geophysical logs depicted on sections A-A' and B-B' (figs. 8 and 9, respectively) are consistent with those described in the Phase I report (Lloyd and Daniel, 1988) but renamed in this report. The subsurface strata, in sequence from ground surface to approximately 100 ft below ground surface, include the unconfined surficial aquifer, the upper confining unit of clayey sand, the Yorktown aquifer, and the lower confining unit of sandy clay.

The surficial aquifer at well-cluster sites 1, 2, and 4 consists of layers of clean sands interspersed with layers of slightly silty to slightly clayey sands. The presence of silt and clay in the finer-grained layers at these sites impedes downward movement of water in the aquifer and promotes lateral movement through the more permeable layers of clean sands in the direction of decreasing hydraulic head. Previous studies have shown that water in the surficial aquifer in the vicinity of the well-cluster sites moves in a westerly direction toward Slocum Creek (Lloyd and Daniel, 1988).

In contrast, the surficial aquifer at well-cluster site 3 is comprised of relatively clean sands with very little silt and clay. A possible explanation for the contrast is that the layers of fine-grained sediments present at well-cluster sites 1, 2, and 4 have been eroded away at site 3 and replaced by cleaner sands deposited in the Neuse River paleochannel (Mixon and Pilkey, 1976). The hydraulic conductivity of the surficial aquifer at well-cluster site 3 is expected to be substantially higher than that at the other sites as evidenced by the loss in circulation of drilling mud during well construction at site 3.

A thin layer of sandy clay present at all four well-cluster sites at a depth of approximately 10 to 15 ft below ground surface is not considered to be a confining unit because no perched water table was identified above this stratum during the drilling operations. Also, static water levels measured in the surficial aquifer (discussed later in this report) occurred several feet below this stratum.

The upper confining unit of silty sand to sandy clay underlies the surficial aquifer at each of the four well-cluster sites. The depth to this stratum ranges from 39 ft below ground surface at site 1 to 55 ft below ground surface at site 3. Thickness of this unit decreases in a southerly direction (fig. 8) from 28 ft at site 1 to only 7 ft at site 3. Natural gamma-ray logs depicted in the Phase I report (Lloyd and Daniel, 1988) showed that this confining unit is absent at water-supply well 100 (MCAS Well 16) and less than 10 ft thick at water-supply well 103 (MCAS Well 17). Erosion in the Neuse River paleochannel, which appears to be deepest in the vicinity of site 3, may be responsible for the thinning of this unit.

The Yorktown aquifer is composed mostly of slightly silty sand interbedded with thin layers of sand and silty sand. Some of these layers are very dense and (or) cemented, which made sample recovery in this aquifer difficult. The top of this aquifer averages about 65 ft below land surface at the four sites. Thickness of the aquifer is fairly uniform (fig. 8), averaging approximately 35 ft.

The lower confining unit of silty sand to sandy silt that underlies the Yorktown aquifer dips to the east (fig. 9). Phosphatic sands found near the bottom part of the aquifer at well-cluster site 3, and not clay, are probably responsible for the deflection shown on the gamma-ray log at that interval. During drilling operations, it was noted that the sediments in the bottom part of the aquifer consist of clean sand.

Mineralogical Analysis of Fine-Grained Sediments

Fine-grained sediment samples collected from the upper and lower confining units were analyzed by X-ray diffraction to identify constituent minerals present in the units. Results are used to help assess the potential for attenuation of contaminants present in water flowing through these confining units. Adsorption of trace metals onto the surfaces of clay minerals and other fine-grained sediments is well documented (Sanks and others, 1975). Organic contaminants tend to be much more mobile in ground water and are not as readily adsorbed by clay minerals. Organic matter in soils and sediments is a much more effective adsorbent for these organic compounds than are the mineral constituents (Mortland, 1985). Both trace metals and organic compounds have been previously detected in the surficial aquifer at the Air Station (NUS, 1987).

The X-ray diffraction analyses were performed on samples collected during construction of the wells at well-cluster sites 1, 2, and 4. Only that fraction of each sample passing the U.S. Standard sieve no. 200 (grain diameter of less than 0.074 millimeter) was analyzed. Most of the samples collected from the confining units and examined with a microscope were estimated to contain from 10 percent to greater than 50 percent of silt and clay-sized particles. Results of the analyses are presented in table 2.

Table 2.--*Results of mineralogical analyses on fine-grained sediments collected during construction of U.S. Geological Survey monitoring wells*

Sample extracted during construction of well no.	[1]S1W4	[1]S1W4	S2W1	S2W2	S4W1	S4W2
Depth of tested sample (feet below ground surface)	49 feet	102 feet	101 feet	46 feet	96 feet	41 feet
Stratum from which sample was taken (see fig. 6)	Upper confining unit	Lower confining unit	Lower confining unit	Upper confining unit	Lower confining unit	Upper confining unit
Mineral identified in sample by X-ray diffraction analyses (from the most to the least abundant)[2]	smectite illite kaolinite quartz pyrite apatite orthoclase microcline	smectite illite quartz pyrite apatite orthoclase calcite aukerite microcline	smectite illite quartz pyrite apatite orthoclase calcite aukerite microcline	smectite illite quartz pyrite orthoclase microcline calcite hematite vaterite?	smectite illite kaolinite quartz pyrite apatite orthoclase microcline	smectite illite kaolinite quartz pyrite apatite orthoclase microcline

[1] Well S1W4 was constructed in March 1988 at well-cluster site 1 as part of a separate U.S. Geological Survey study at the Air Station (L.C. Murray, U.S. Geological Survey, written commun., 1989).

[2] Only that fraction of the sample passing the U.S. Standard sieve #200 (grain-size diameter less than 0.074 millimeter) was analyzed.

The minerals identified in each sample are listed in order of decreasing abundance. Smectite and illite, the two most abundant minerals identified in the samples from both confining units, are clay minerals of similar structure but of different chemical composition (Bolt and Bruggenwert, 1978). The structure and composition of these two clay minerals, particularly those of smectite, are conducive to adsorption of relatively high amounts of trace metals (Bolt and Bruggenwert, 1978). The amount of metals removed by these clays is unknown and is dependent upon many physical and chemical factors that are beyond the scope of this study to address. However, these clays can be expected to attenuate (and immobilize) metal ions dissolved in ground water moving vertically through either of the two confining units at the Air Station and, thus, afford some protection to the underlying aquifers. At well-cluster site 3, where the confining units have been found to be thin and discontinuous, this potential for attenuation of trace metals is less than at the other three sites. Once the adsorptive capacities of the clay minerals have been exceeded, however, metals in solution will no longer be immobilized by the clays but will be free to migrate with the ground water in the surficial aquifer.

A third clay mineral, kaolinite, is identified in three of the six samples. The structure of kaolinite is different than smectite and illite, and its affinity to adsorb trace metals is somewhat less than either smectite or illite (Sanks and others, 1975). Other minerals found in less abundance in the fine-grained sediments include fine-grained quartz, pyrite (a sulfide), apatite (a phosphate), orthoclase (a silicate), calcite (a carbonate), and hematite (an iron oxide). Some of these minerals may be expected to adsorb trace metals, but not as much as the clay minerals.

WATER LEVELS

The water-level data were collected in order to define the hydraulic heads, hydraulic gradients, and the directions of flow within and between the surficial, Yorktown, and Castle Hayne aquifers. The ground water that saturates these aquifers and the confining units between them moves through these units in response to differences in hydraulic head. The rate and direction of this movement and, hence, the potential for contaminant movement are controlled by the hydraulic conductivity and the effective porosity of the units, which is their ability to transmit water, and by the hydraulic gradient, which is the difference in the hydraulic head per unit distance within and between the aquifers. Ground water flows from areas where hydraulic head is high to areas where it is low.

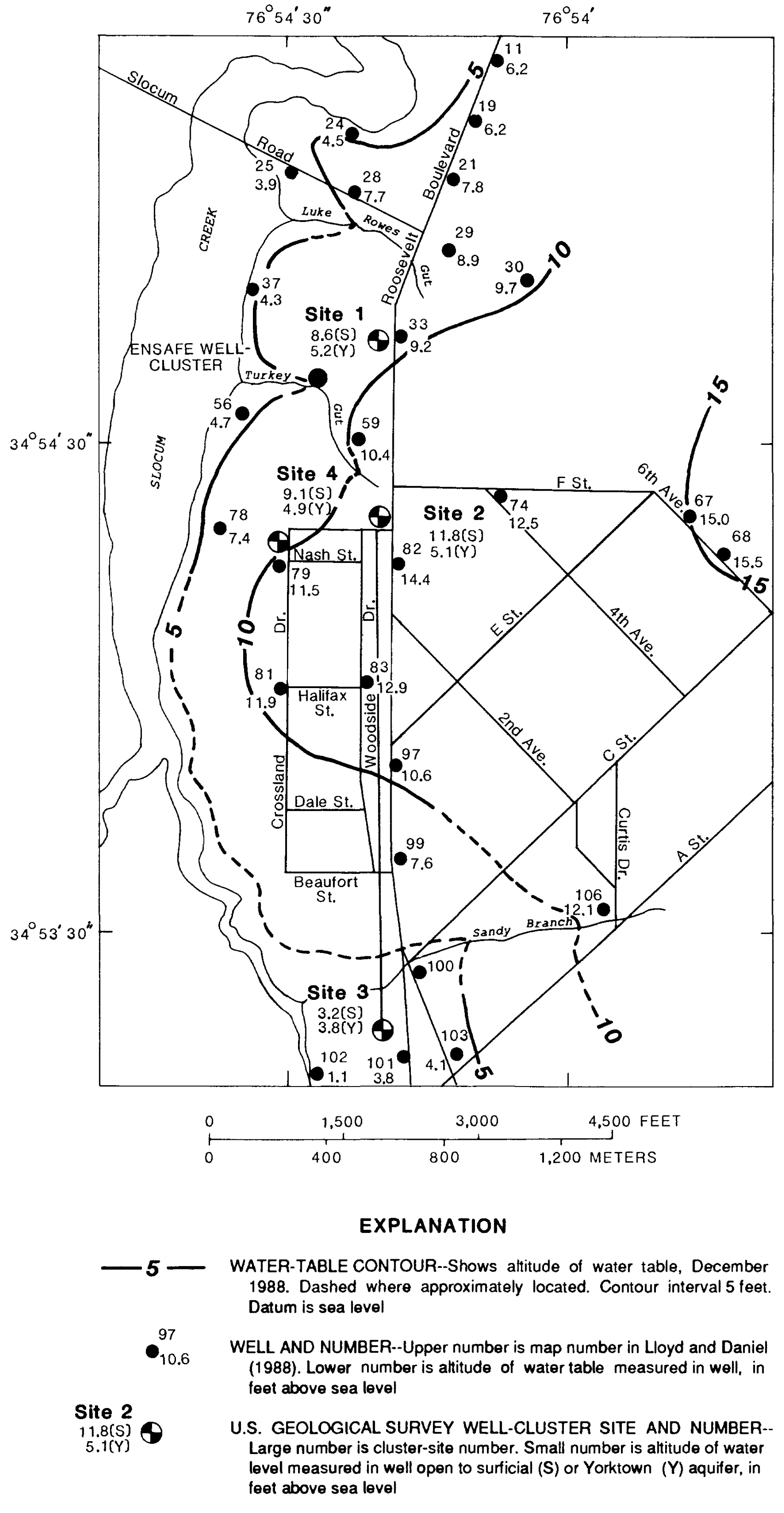
The water-level data presented and discussed in this report are divided in two sections. The first section presents data used to evaluate the spatial variability in hydraulic head between and within the surficial, Yorktown, and Castle Hayne aquifers. The temporal variability in the hydraulic head between and within the aquifers is discussed in the second section.

Spatial Variability in Hydraulic Head

Water-level data collected from 96 wells at the Air Station over the period December 5-9, 1988, were used to evaluate the spatial variability in the hydraulic head between and within the surficial, Yorktown, and Castle Hayne aquifers. These data included measurements from the 12 USGS cluster wells, from 24 surficial aquifer wells installed adjacent to each of the water-supply wells by the USGS in September 1987, from 57 surficial aquifer wells previously installed by private consulting firms, and from the 3 wells installed by Ensafe, Inc., at waste-disposal site 10.

Contours showing the approximate altitude of the water table (top of the zone of saturation in the surficial aquifer) within the area encompassing the USGS well-cluster sites are shown in figure 10. Not all of the surficial aquifer water-level measurements are plotted on this illustration because many measurements were made in wells near one another and had very similar head values. The water-table altitudes range from approximately 15 ft near the eastern part of the study area to approximately 1 ft at Slocum Creek. These differences in hydraulic head induce ground water in the surficial aquifer to flow west toward Slocum Creek, with localized flow toward Luke Rowes Gut, Turkey Gut, and Sandy Branch. Contaminants introduced into the surficial aquifer from waste-disposal site 10 will move with the ground water toward Slocum Creek and locally to Turkey Gut (fig. 10). Preferential flow paths created by the layered system of relatively permeable sands described earlier in this report may exert a controlling influence on rates and direction of contaminant movement.

For comparative purposes, the altitude of the potentiometric surface (represented by the level to which water will rise in a tightly cased, nonpumping well screened in an aquifer) of the Yorktown aquifer is shown at each of the four USGS well-cluster sites and at the Ensafe cluster site. The five points of data for the Yorktown aquifer shown in figure 10 are not



EXPLANATION

—5— WATER-TABLE CONTOUR--Shows altitude of water table, December 1988. Dashed where approximately located. Contour interval 5 feet. Datum is sea level

97 ● 10.6 WELL AND NUMBER--Upper number is map number in Lloyd and Daniel (1988). Lower number is altitude of water table measured in well, in feet above sea level

Site 2 11.8(S) 5.1(Y) U.S. GEOLOGICAL SURVEY WELL-CLUSTER SITE AND NUMBER--Large number is cluster-site number. Small number is altitude of water level measured in well open to surficial (S) or Yorktown (Y) aquifer, in feet above sea level

Figure 10.--Approximate altitude of the water table and water levels in the Yorktown aquifer at the well-cluster sites.

sufficient for construction of potentiometric surface contour lines across the area. In the northern half of the area, however, where four of the clusters are located, water in the Yorktown aquifer appears to move to the west toward Slocum Creek. The relatively low altitude of the water level measured at well-cluster site 3 (3.8 ft) indicates that, at some point between well-cluster sites 2 and 3, the direction of flow in the Yorktown aquifer is to the south or southwest toward Sandy Branch and Slocum Creek and probably nearly parallel to flow in the surficial aquifer.

The vertical distribution of hydraulic head between the surficial, Yorktown, and Castle Hayne aquifers from Slocum Road south to well-cluster site 3 is shown on section C-C' (fig. 11). The hydraulic heads in these aquifers are clearly separated along most of the section, such that a potential is created for vertical movement of ground water and contaminants from the surficial aquifer to the Yorktown and Castle Hayne aquifers. However, separation of these hydraulic heads also implies that the upper and lower confining units act as confining units that inhibit the vertical movement of water and dissolved contaminants into the Yorktown and Castle Hayne aquifers.

The water levels in the surficial, Yorktown, and Castle Hayne aquifers as shown in figure 11 converge in the southern part of the study area and appear to intersect near well-cluster site 3. At this site, the altitude of the water level measured in the Yorktown aquifer (3.8 ft) is actually higher than the altitude of the water table (3.2 ft). The altitude of the potentiometric surface in the Castle Hayne aquifer increases to the south and was measured at 3.9 ft in water-supply well 100 (MCAS Well 16) located approximately 600 ft to the northeast of site 3. These water levels indicate that this is in a discharge area for the Castle Hayne aquifer, where upward flow of ground water occurs from the Castle Hayne aquifer through the Yorktown aquifer and into the surficial aquifer.

Several factors probably contribute to the convergence of the water levels in these aquifers near well-cluster site 3. The altitude of the water table decreases with topography toward Sandy Branch, an area of localized discharge for the surficial aquifer. The increase in the altitude

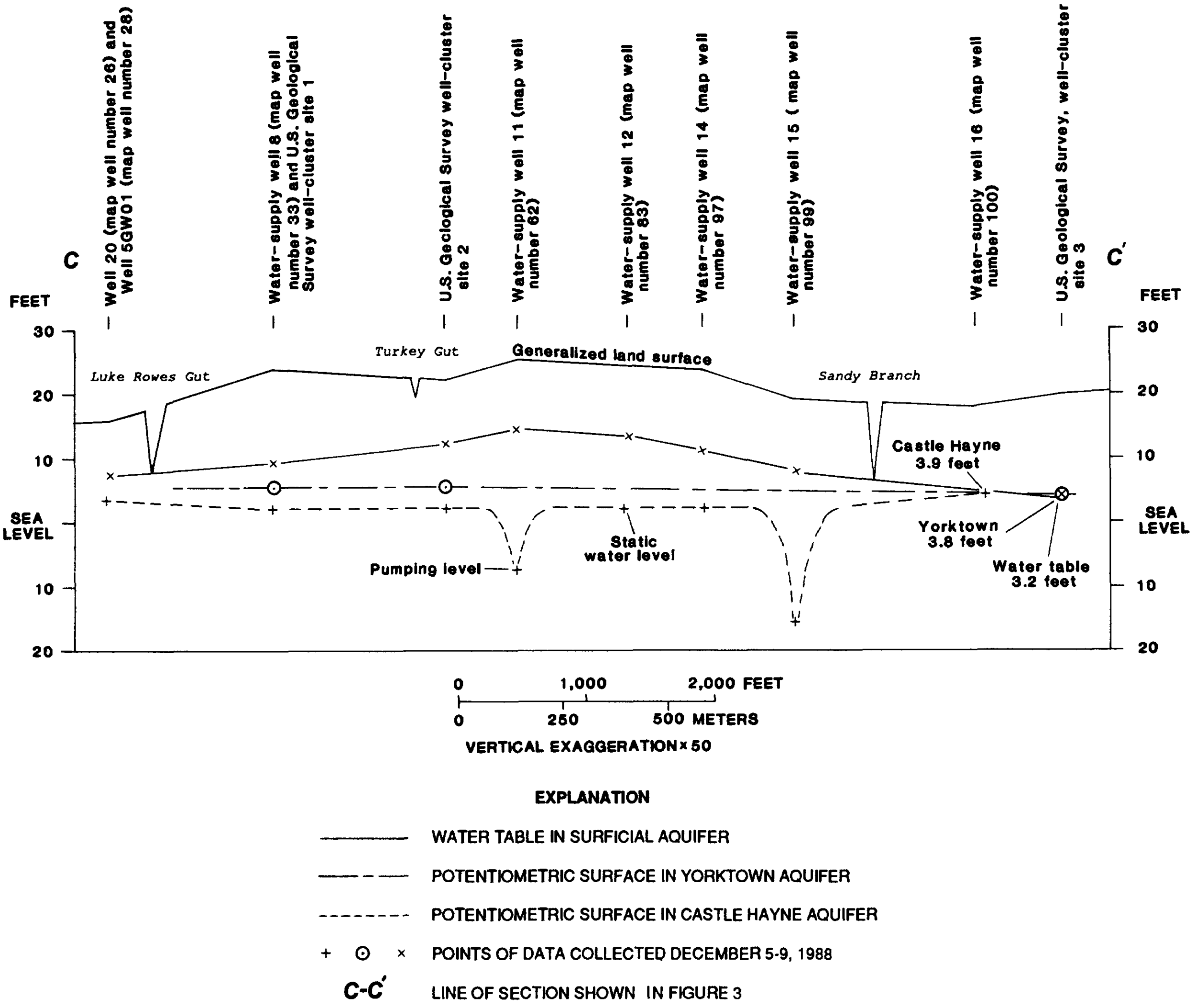


Figure 11.--Cross section C-C' depicting spatial relation between water levels in the surficial, Yorktown, and Castle Hayne aquifers measured December 5-9, 1988.

of the potentiometric surface of the Castle Hayne aquifer in the southern part of the study area may, in part, be the result of discontinued pumping at water-supply wells 100 and 103 (MCAS Wells 16 and 17, respectively). These wells were shut down after benzene was detected in water samples during the Phase I study. Converging water levels in the three aquifers correspond with the thinning and absence of the confining units between them. The upper confining unit is absent at water-supply well 100 (MCAS Well 16), while the lower confining unit is absent at water-supply well 103 (MCAS Well 17). The absence of the confining units, together with the convergence of the water levels in the three aquifers at these locations, indicates that both the Yorktown and Castle Hayne aquifers are less confined and more hydraulically connected in the southwestern part of the Air Station than in the area around well-cluster sites 1, 2, and 4. Additional data are needed to determine the lateral extent of this condition south and west of well-cluster site 3. To the northeast, however, a natural gamma-ray log run in well 106 (MCAS Well 26) shows that both confining units are present at this location (Lloyd and Daniel, 1988). The water table and potentiometric surface in the Castle Hayne aquifer at well 106 were measured at 12.1 ft and 3.9 ft, respectively, on December 8, 1988.

Temporal Variability in Hydraulic Head

Hydrographs depicting water-level fluctuations in the surficial and Yorktown aquifers at the four well-cluster sites from May 18, 1988, to December 8, 1988, are shown on figure 12. In general, the difference in hydraulic head between these aquifers remained constant over the period of record. The net decline seen in the water levels over this period can be attributed to natural discharge from the ground-water system and to increased ground-water withdrawals at the Air Station. The abrupt increase in the water-table altitude from early August to early September 1988 coincides with several rainstorms (greater than 2 inches recorded for August 7, 9, 10, 24, and 31) during that period (U.S. Marine Corps Weather Service, August 1989).

At well-cluster site 3, water-level fluctuations in the surficial and Yorktown aquifers are very similar. Because the hydraulic head between these aquifers (fig. 11) indicates that ground water flows upward from the Castle Hayne aquifer to the surficial aquifer, the potential for advective movement of contaminants from the surficial aquifer into the Castle Hayne aquifer is small, even though the confining units between these two aquifers are thin or absent at and near well-cluster site 3. Contaminants in the surficial aquifer at and near site 3 would most likely migrate laterally and discharge into Sandy Branch and Slocum Creek.

Two potential avenues for downward migration of contaminants in this area do exist. Molecular diffusion of contaminants in the direction of decreasing concentration could cause contaminants to move from the surficial

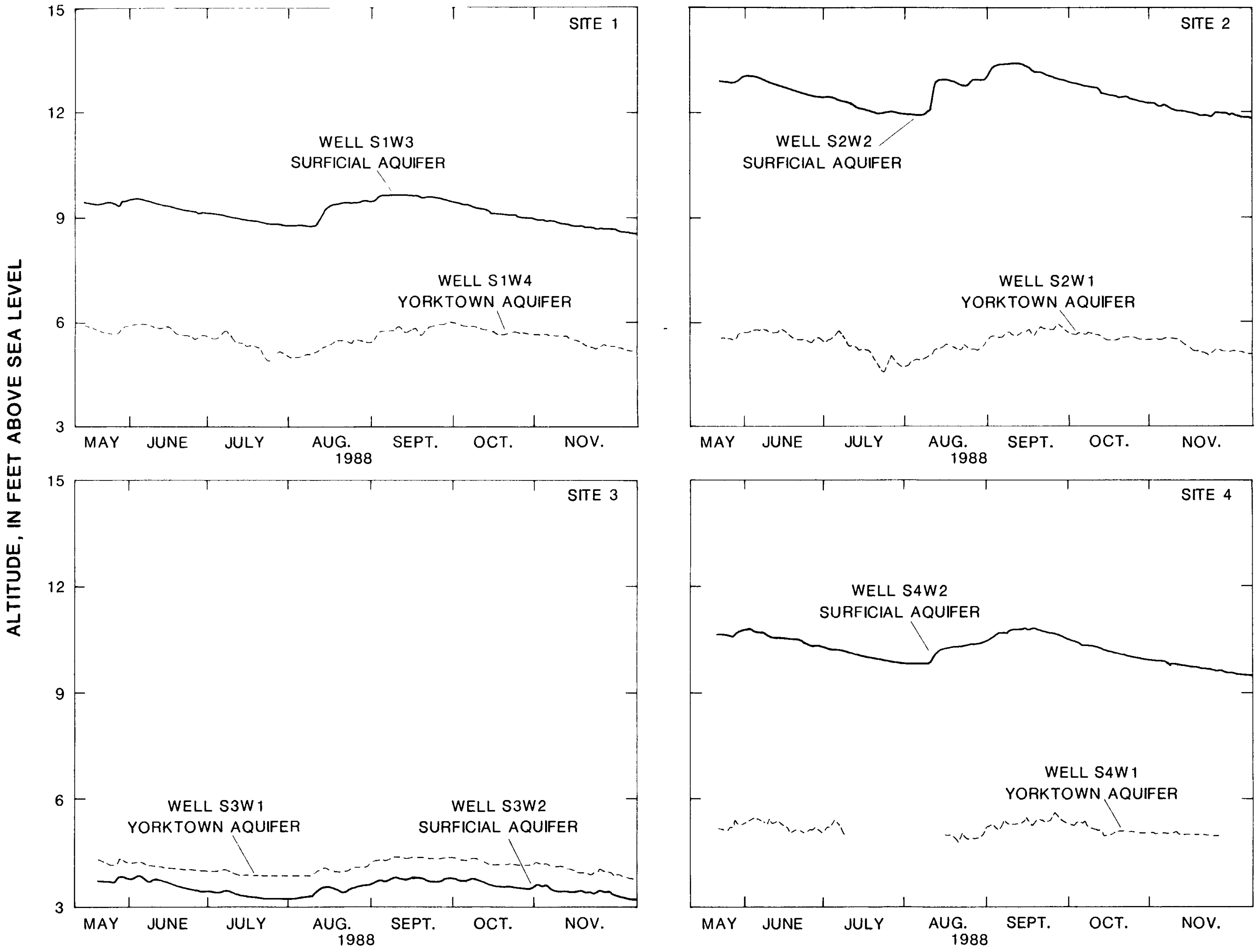


Figure 12.--Hydrographs of wells in the surficial and Yorktown aquifers at the well-cluster sites.

aquifer to the Castle Hayne aquifer. The rate of diffusion would be dependent on the source concentration of the contaminant, physical properties of the porous media, chemical interactions, and other factors. By comparison, a more immediate threat would be posed by any future pumping of the water-supply wells in this area (specifically wells 100 and 103) (MCAS Wells 16 and 17). Pumping these wells may substantially lower the potentiometric surface of the Castle Hayne aquifer and thus reverse the direction of head differential between the Castle Hayne, Yorktown, and surficial aquifers in the area near waste-disposal site 16. The potential for downward movement of ground-water from the surficial to the Castle Hayne aquifer would then be dependent upon the degree to which the potentiometric surface in the Yorktown aquifer declined with pumping from the supply wells. If the potentiometric surface in the Yorktown aquifer was unaffected by drawdown in the Castle Hayne aquifer, then the higher hydraulic head in the Yorktown aquifer would act as a "divide," and flow would be from the Yorktown to the surficial and Castle Hayne aquifers. This condition might occur if the volume of water pumped from supply wells 100 and 103 (MCAS Wells 16 and 17) was small and the wells were pumped for a short period of time. However, continued pumping from these wells will cause the hydraulic head in the Yorktown aquifer to fall below the water table. The relative heads in these three aquifers would then create the potential for downward migration of contaminants.

Insufficient data exist at this time to quantitatively assess the impact of pumpage from the Castle Hayne aquifer on the potentiometric surface in the Yorktown aquifer at any of the well-cluster sites. However, short-term fluctuations in the abandoned Castle Hayne aquifer water-supply well 26 (MCAS Well 20), caused by pumping of nearby water-supply wells and tidal and barometric fluctuations, do appear to coincide with short-term fluctuations seen in well S1W4 in the Yorktown aquifer at well-cluster site 1 (fig. 13). Well-cluster site 1 is the closest of the four cluster sites to well 26 (MCAS Well 20), the only Castle Hayne aquifer well equipped with a recording device. Based on this observation, it is reasonable to assume that the sensitivity of the hydraulic head in the Yorktown aquifer to pumping in the Castle Hayne aquifer would be greater at and near well-cluster site 3, where the lower confining unit between these aquifers is thin and discontinuous.

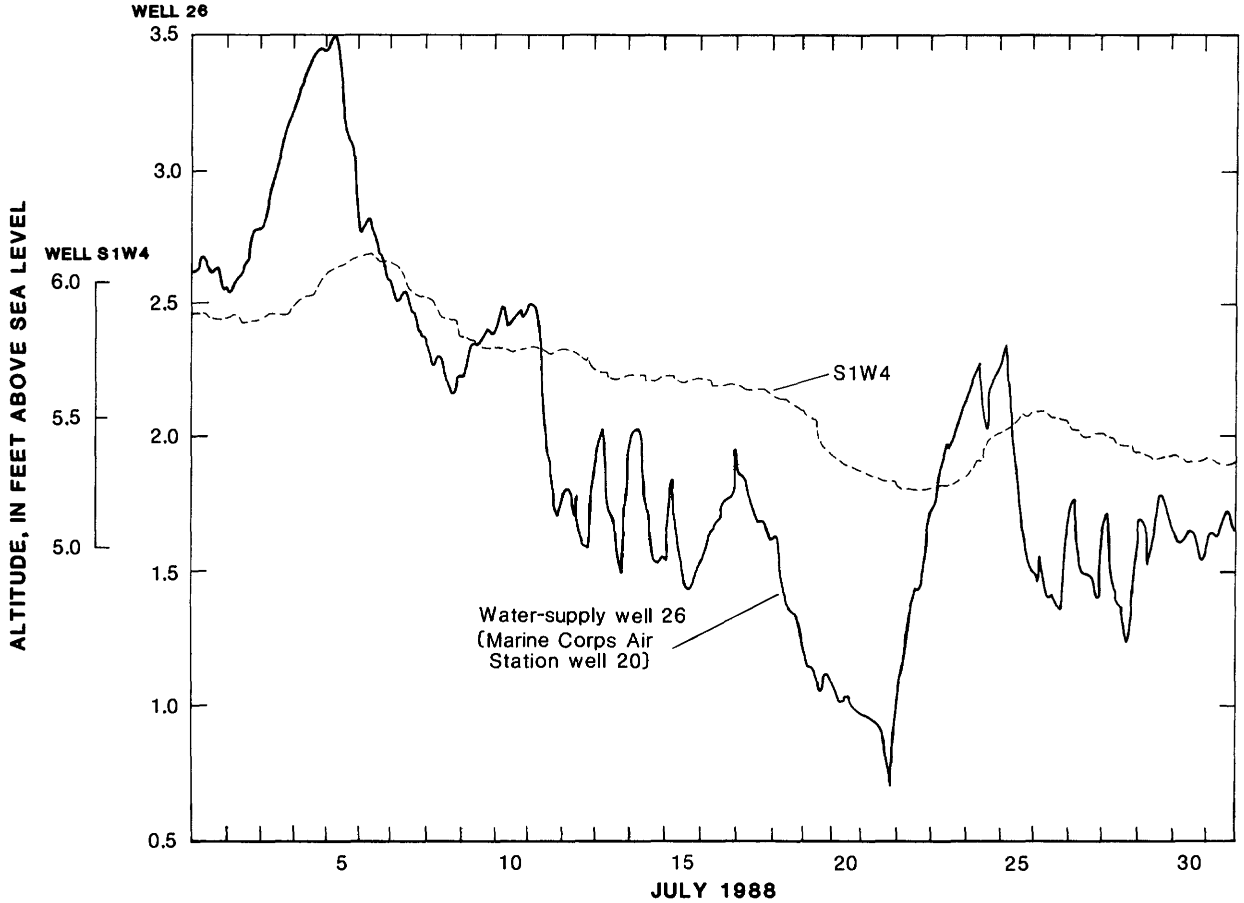


Figure 13.--Hydrographs of well S1W4 and of water-supply well 26.

QUALITY OF WATER FROM MONITORING WELLS

Sample Collection and Analyses

Ground-water samples were collected from the 12 USGS cluster wells between October 21, 1987, and November 5, 1987, and submitted to laboratories for chemical analyses. Each sample was analyzed for U.S. Environmental Protection Agency (EPA) priority pollutants, in addition to major cations and anions, physical properties and characteristics, nutrients, organics, and other constituents. These analyses are consistent with those performed on samples collected from the water-supply wells during the previous phase of the ground-water study (Lloyd and Daniel, 1988). Procedures used to collect and analyze the water samples from the cluster wells are the same as those previously used to collect and analyze water samples from the water-supply wells. These procedures are described by Lloyd and Daniel (1988) and will not be repeated in this report.

Results of the analyses of water samples from the USGS cluster wells are presented in table 9 beginning on page 71 of this report. Included in table 9 are all but seven of the substances listed in the EPA list of priority pollutants (table 3). The seven substances for which analyses were not performed are: acrolein; acrylonitrile; bis(chloromethyl) ether; 2,4-dimethylphenol; 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD); thallium; and asbestos (fibrous). Analyses were not performed for these substances for a variety of reasons such as the extreme toxicity of the substance which precluded having analytical standards (for example 2,3,7,8-tetrachlorodibenzo-p-dioxin), instability of the standards, or other reasons. In the case of 2,4-dimethylphenol, the absence of an analysis for the compound is probably a moot point because the analyses for total phenols, which were run on samples from all wells, gave results less than the detection limit of 5 µg/L.

Computerized library searches were performed for unidentified organic substances detected during analyses for acid extractable, base/neutral extractable, and purgeable organic compounds. These library searches were made using spectral data available for nearly 39,000 known organic compounds. These libraries are maintained by the National Bureau of Standards (NBS) and by the U.S. Environmental Protection Agency--National Institute of Health (EPA-NIH). The library search for purgeable organic compounds conducted by personnel of the U.S. Geological Survey Central Laboratory used the NBS library, and the search to identify acid extractable and base/neutral extractable compounds conducted by personnel of the Tennessee Valley Authority laboratory used the EPA-NIH library. Results of the searches and the compounds tentatively identified are not given in table 9 but are presented and discussed in a later section of this report.

Table 3.--*U.S. Environmental Protection Agency list of priority pollutants*

[The 129 substances listed in the table below were compiled from U.S. Environmental Protection Agency (1979a, 1979b).]

PURGEABLE ORGANICS

Acrolein[1]
Acrylonitrile[1]
Benzene
Toluene
Ethylbenzene
Carbon tetrachloride
Chlorobenzene
1,2-Dichloroethane
1,1,1-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethylene
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
Chloroethane
2-Chloroethyl vinyl ether
Chloroform
1,2-Dichloropropane
1,3-Dichloropropene
Methylene chloride
Methyl chloride
Methyl bromide
Bromoform
Dichlorobromomethane
Trichlorofluoromethane
Dichlorodifluoromethane
Chlorodibromomethane
Tetrachloroethylene
Trichloroethylene
Vinyl chloride
1,2-trans-Dichloroethylene
bis(Chloromethyl) ether[1]
1,2-Dibromoethylene

BASE/NEUTRAL EXTRACTABLE ORGANICS

1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachloroethane
Hexachlorobutadiene
Hexachlorobenzene
1,2,4-Trichlorobenzene
bis(2-Chloroethoxy) methane
Naphthalene
2-Chloronaphthalene
Isophorone
Nitrobenzene
2,4-Dinitrotoluene
2,6-Dinitrotoluene
4-Bromophenyl phenyl ether
bis(2-ethylhexyl) phthalate
Di-n-octyl phthalate
Dimethyl phthalate
Diethyl phthalate
Di-n-butyl phthalate
Acenaphthylene
Acenaphthene
Butyl benzyl phthalate
Fluorene
Fluoranthene
Chrysene
Pyrene
Phenanthrene
Anthracene
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-c,d)pyrene
Dibenzo(a,h)anthracene
Benzo(g,h,i)perylene
4-Chlorophenyl phenyl ether
3,3'-Dichlorobenzidine
Benzidine
bis(2-Chloroethyl) ether
1,2-Diphenylhydrazine
Hexachlorocyclopentadiene
N-Nitrosodiphenylamine
N-Nitrosodimethylamine
N-Nitrosodi-n-propylamine
bis(2-Chloroisopropyl) ether

ACID EXTRACTABLE ORGANICS

Phenol
2-Nitrophenol
4-Nitrophenol
2,4-Dinitrophenol
4,6-Dinitro-o-cresol
Pentachlorophenol
p-Chloro-m-cresol
2-Chlorophenol
2,4-Dichlorophenol
2,4,6-Trichlorophenol
2,4-Dimethylphenol[1]

PESTICIDES/PCB'S

α-Endosulfan
β-Endosulfan
Endosulfan sulfate
α-BHC
β-BHC
δ-BHC
γ-BHC (Lindane)
Aldrin
Dieldrin
4,4'-DDE
4,4'-DDD
4,4'-DDT
Endrin
Endrin aldehyde
Heptachlor
Heptachlor epoxide
Chlordane
Toxaphene
Aroclor 1016
Aroclor 1221
Aroclor 1232
Aroclor 1242
Aroclor 1248
Aroclor 1254
Aroclor 1260
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)[1]

METALS AND OTHER INORGANIC ELEMENTS

Antimony
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium[1]
Zinc

MISCELLANEOUS

Asbestos (fibrous)[1]
Total cyanides
Total phenols

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[1] Substances for which analyses were not made during this study.

Inorganic Constituents

A summary of selected water-quality characteristics that include major cations and anions, physical properties and characteristics, nutrients, and other constituents is given in table 4. This table is a synthesis of the inorganic constituents and other selected water-quality characteristics listed in table 9.

Major Cations and Anions

The concentrations of the major cations and anions in the water from the cluster wells indicate that the water in both the surficial and Yorktown aquifers is a calcium-bicarbonate type that contains moderate amounts of dissolved silica. Mean calcium concentrations measured in water from the surficial and Yorktown aquifer wells are 51 milligrams per liter (mg/L) and 43 mg/L, respectively; for silica, the mean concentrations are 19 mg/L and 26 mg/L, respectively. Chloride concentrations range from 5.3 mg/L at well S1W3 to 20 mg/L at wells S3W1 and S3W2 and are consistently higher in both aquifers at site 3 than at sites 1, 2, and 4.

Equivalent proportions of the major cations and anions are fairly constant in the samples from both aquifers except for two of the Yorktown aquifer wells, S1W1A and S4W1. This is illustrated on the trilinear plot shown on figure 14. Water from wells S1W1A and S4W1 have lower percentages of calcium and higher combined percentages of sodium and potassium than water from the other wells. By comparison, water analyzed from the Castle Hayne aquifer during the previous investigation was also found to be a calcium-bicarbonate type. A source of calcium in the water of the Castle Hayne aquifer is the limestone (calcium carbonate) that comprises much of the aquifer matrix. A source of calcium in the surficial and Yorktown aquifer wells is the layers of shell hash and shell fragments identified during examination of the sediments. Locations and depths to this material at the well sites are found in the lithologic logs provided in table 8.

Table 4.--*Water-quality results for selected constituents in water from U.S. Geological Survey monitoring wells (October 21, 1987-November 5, 1987)*

[mg/L, milligram per liter; NA, not analyzed; cm, centimeter; µg/L, microgram per liter]

Constituent	Yorktown aquifer wells					Surficial aquifer wells							
	S1W1A	S2W1	S3W1	S3W1 (Duplicate)	S4W1	S1W2	S1W3	S2W2	S2W3	S3W2	S3W3	S4W2	S4W3
Major cations													
Calcium, dissolved (mg/L as Ca)	13.0	59.0	83.0	84.0	16.0	49.0	40.0	62.0	69.0	60.0	56.0	21.0	NA
Magnesium, dissolved (mg/L as Mg)	.36	1.3	3.1	3.1	.39	2.1	1.3	2.4	2.5	1.4	1.3	1.1	NA
Potassium, dissolved (mg/L as K)	8.2	4.2	4.6	4.3	4.2	1.3	1	1.6	1.1	1.1	1.1	1.5	NA
Silica, dissolved (mg/L as SiO_2)	22	28	36	36	19	13	17	19	21	22	21	18	NA
Sodium, dissolved (mg/L as Na)	17	8.8	7.6	7.8	13	4.5	6.9	8.1	9	8.8	9	8.1	NA
Major anions													
Bicarbonate, total, field (mg/L as HCO_3)	269	278	287	NA	110	156	162	195	220	200	162	78	49.0
Chloride, dissolved (mg/L as Cl)	7.3	8.2	15	20	7.3	4.6	5.3	7.8	6.4	20	12	12	NA
Fluoride, dissolved (mg/L as F)	.30	.20	.20	.20	.20	.20	.20	.10	.10	.40	.10	.10	NA
Sulfate, dissolved (mg/L as SO_4)	10	4.3	3.9	3.9	12	14	11	27	20	2	1.7	13	NA
Physical properties and characteristics													
Alkalinity, total, field (mg/L as $CaCO_3$)	221	228	235	NA	90	128	133	160	180	164	133	64	40
Alkalinity by titration to pH 4.5, lab (mg/L as $CaCO_3$)	57	164	202	184	46	126	116	149	177	149	146	47	NA
Color (Platinum-cobalt units)	6	2	13	62	2	1	2	2	3	25	1	3	NA
Hardness, total (mg/L as $CaCO_3$)	34	150	220	220	42	130	110	160	180	160	150	57	NA
pH, field (units)	9.57	8.14	7.39	NA	9.98	6.68	6.30	7.12	7.21	6.80	6.80	6.13	5.98
Specific conductance, field (microsiemens/cm)	178	320	435	NA	NA	255	225	318	370	325	302	160	130
Specific conductance, lab (microsiemens/cm)	152	346	458	456	139	303	256	364	386	347	329	176	NA
Temperature, field (degrees Celsius)	18.5	19	19.5	NA	19	18.5	18.5	19	19	19.5	19.5	19	20
Turbidity (nephelometric turbidity units)	40	23	26	37	1.9	61	63	23	21	66	48	23	NA

Table 4.--*Water-quality results for selected constituents in water from U.S. Geological Survey monitoring wells (October 21, 1987-November 5, 1987)*--Continued

[mg/L, milligram per liter; NA, not analyzed; cm, centimeter; µg/L, microgram per liter]

Constituent	Yorktown aquifer wells					Surficial aquifer wells							
	S1W1A	S2W1	S3W1	S3W1 (Duplicate)	S4W1	S1W2	S1W3	S2W2	S2W3	S3W2	S3W3	S4W2	S4W3
Nutrients													
Ammonia nitrogen, dissolved (mg/L as N)	0.115	0.30	0.20	0.30	0.084	0.060	0.056	0.086	0.058	0.126	0.254	0.029	0.123
Ammonia plus organic nitrogen, dissolved (mg/L as N)	.70	.354	.685	.665	.30	.60	1.1	1.4	2.1	.60	1.2	.50	.20
Nitrate nitrogen, dissolved (mg/L as N)	<.001	.026	.013	.018	.018	.102	.022	.014	.013	.019	.008	.012	.007
Nitrite nitrogen, dissolved (mg/L as N)	.009	.004	.003	.003	.003	.004	<.001	<.001	<.001	.002	.002	<.001	.003
Nitrite plus nitrate nitrogen, dissolved (mg/L as N)	.009	.030	.016	.021	.021	.106	.022	.014	.013	.021	<.01	.012	<.01
Phosphorous, ortho, dissolved (mg/L as P)	.008	.074	.003	.003	.003	.053	.211	.010	.003	.001	.004	.025	.055
Other constituents													
Boron, dissolved (µg/L as B)	20	20	20	20	20	20	20	40	20	20	20	30	30
Carbon dioxide, dissolved (mg/L as CO_2)	0	2.3	16	18	0	51	113	22	21	46	45	67	0
Cyanide, total (mg/L as CN)	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Dissolved oxygen (mg/L as O_2)	1.25	.55	.75	NA	1.20	.80	.75	.55	.65	.65	.65	.60	NA
Dissolved solids, sum of constituents (mg/L)	110	210	280	270	100	160	150	220	240	210	190	115	NA
Dissolved solids residue at 180 °C (mg/L)	113	207	292	286	93	163	141	209	237	204	191	104	NA
Methylene blue active substance (mg/L as MBAS)	.01	.03	.01	.01	.03	.01	.01	.01	.01	.02	.02	.01	.01
Organic carbon, dissolved (mg/L as C)	2.9	2.4	6.3	6.4	3.2	1.2	1.3	1.1	1.1	1.9	1.3	1.0	1.3

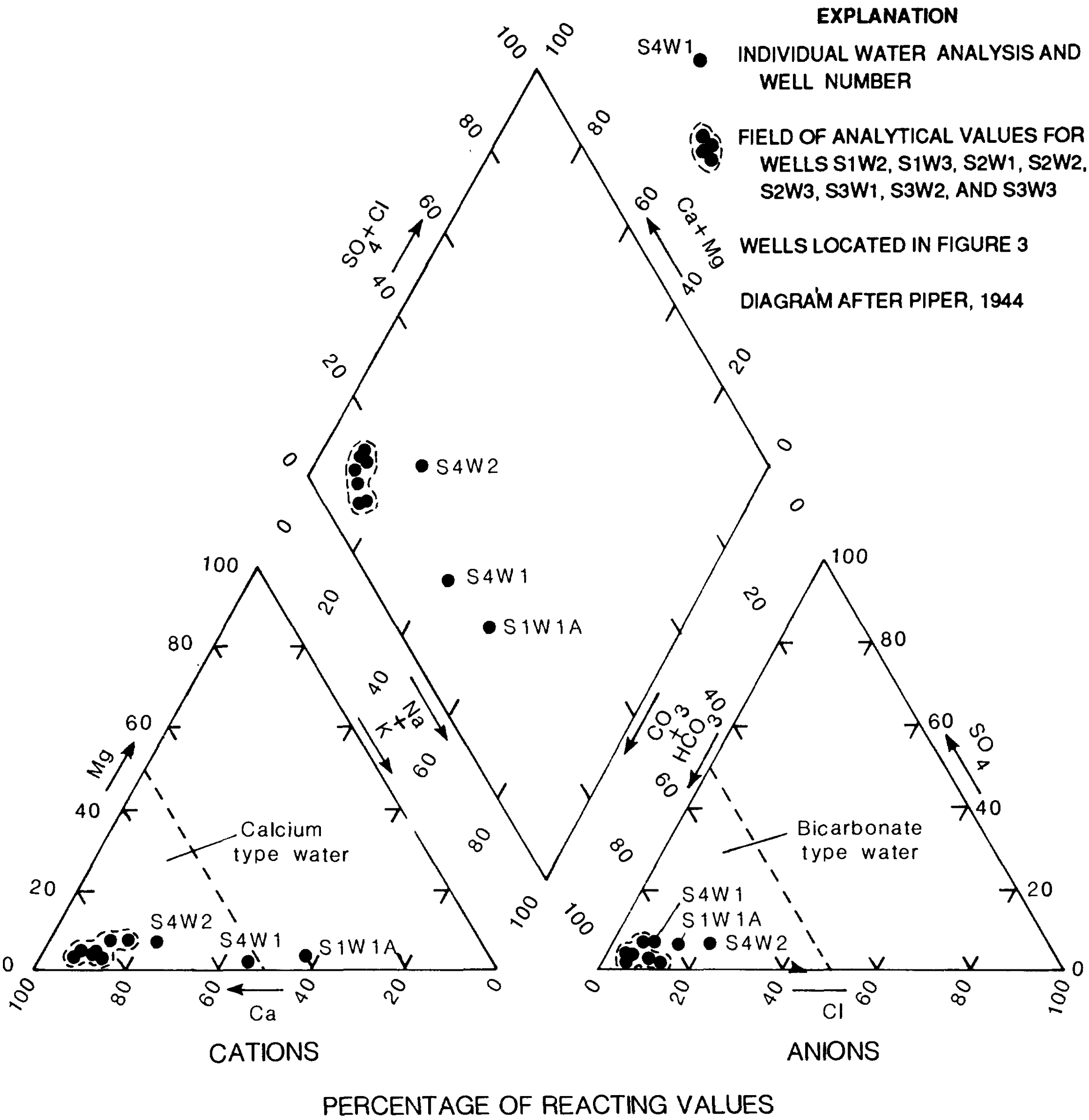

Figure 14.--Trilinear diagram of major cations and anions in water from U.S. Geological Survey monitoring wells.

Physical Properties and Characteristics

Large differences in pH between water samples collected from the two aquifers were found. Values determined in the field for the samples taken from the surficial wells ranged from 5.98 (at S4W3) to 7.21 (at S2W3) and were all lower than the pH values measured in water from the Yorktown aquifer wells. The pH of water in three of the four wells in the Yorktown aquifer exceeded 8.0. The pH of the water in two of these wells, S1W1A and S4W1, had unusually high pH values of 9.57 and 9.98, respectively. Most ground waters found in the United States have pH values ranging from 6.0 to 8.5 (Hem, 1970).

The pH of water in all four wells in the Yorktown aquifer also exceeded the median pH of 7.25 previously determined for water in wells in the Castle Hayne aquifer at the Air Station (Lloyd and Daniel, 1988). Because the water in the aquifers above and below the Yorktown aquifer both have lower pH values, the relatively high pH values determined for water collected from the Yorktown aquifer wells are suspect and may not be representative of the water in the aquifer. These samples may have been contaminated by "bleed water" released from the cement grout. Recall that this grout, composed primarily of calcium carbonate with a naturally high pH, was poured to form a plug at the bottom of the 8-inch pit casing in each Yorktown aquifer well prior to extending the borehole into the Yorktown aquifer. Because the grout was poured inside of the casing, the potential exists for bleed water to move down the casing toward the well screen. No grout was poured inside of the casing during construction of the surficial wells. For these wells, grout was poured only in the annular space between the outside of the casing and the borehole.

Support for this explanation is provided by comparing the pH at well S1W1A (9.57, as given in table 4) with those values measured later at two other wells in the Yorktown aquifer, S1W4 and S1W6A, constructed at well-cluster site 1 during a separate investigation (L.C. Murray, U.S. Geological Survey, written commun., 1989). Bentonite clay, not cement, was used to grout these wells. The pH of water from S1W4 and S1W6A was measured at 7.4 (on April 6, 1988) and 7.5 (on September 17, 1988), respectively. These values are consistent with the pH values measured in the surficial and Castle Hayne aquifers, indicating that the high pH values seen in wells S1W1A, S2W1, and S4W1 may have been influenced by the cement grout.

The pH of 7.39 measured at well S3W1 is much lower than those measured for the other three wells in the Yorktown aquifer and is close to the median pH of 7.25 previously measured in the Castle Hayne aquifer. This observation is significant because it provides evidence that, as inferred from the hydrogeologic data previously discussed, water in the Castle Hayne aquifer flows upward in this area of the Air Station where the confining units are thin and discontinuous and mixes with the waters in the Yorktown and surficial aquifers. This upward movement of water in the Castle Hayne aquifer is probably responsible for preventing downward migration of the cement grout bleed water toward the well screen where the sample was collected.

Nutrients

Organic nitrogen and ammonia nitrogen are the predominant forms of nitrogen found in water from both the surficial and Yorktown aquifers. Combined concentrations range from 0.20 mg/L at well S4W3 to 2.1 mg/L at well S2W3 (table 4). Combined nitrate and nitrite nitrogen are present in smaller concentrations, from 0.009 mg/L at well S1W1A to 0.106 mg/L at well S1W2. Phosphate concentrations range from 0.001 mg/L at well S3W2 to 0.211 mg/L at well S1W3.

Metals

Of all the metals for which analyses were made, only iron and manganese exceeded standards listed in the EPA ambient water-quality criteria (U.S. Environmental Protection Agency, 1986). Concentrations of iron (up to 1,400 µg/L in well S4W2) and manganese (up to 99 µg/L in well S3W3) exceeded maximum amounts recommended for secondary drinking-water standards (0.3 and 0.05 mg/L, respectively) in 6 of 11 water samples (table 5). In general, water samples collected from the surficial-aquifer wells contained higher concentrations of these metals than did the samples collected from the Yorktown aquifer wells.

Trace metals listed by the EPA as priority pollutants detected in samples from both aquifers include zinc (up to 60 µg/L, total recoverable), chromium (up to 36 µg/L, total recoverable), nickel (up to 34 µg/L, total recoverable), copper (up to 25 µg/L, total recoverable), and lead (up to 18 µg/L, total recoverable). Total recoverable concentrations account both for metals originally present in the dissolved form in the unfiltered sample and for metals removed from sediment surfaces by a weak acid digestion. By comparison, dissolved metal concentrations (filtered samples) constitute only a fraction of the total recoverable concentrations--lead (up to 6 µg/L), nickel (up to 4 µg/L), and copper (up to 2 µg/L). These results

Table 5.--*Priority pollutant trace metals and inorganic elements detected in water from U.S. Geological Survey monitoring wells*

[All constituent concentrations given in micrograms per liter. Y, well screened in Yorktown aquifer; S, well screened in surficial aquifer. --, analysis run but result below detection limit]

Map well number (fig. 3)	USGS well number	Aquifer	Antimony, total	Arsenic, total	Beryllium, total recoverable	Cadmium, total recoverable	Chromium, total recoverable	Copper total recoverable	Copper, dissolved	Iron, dissolved	Lead, total recoverable	Lead, dissolved	Manganese, dissolved	Nickel, total recoverable	Nickel, dissolved	Silver, total recoverable	Zinc, total recoverable
116	S1W1A	Y	--	2	--	--	13	13	2	8	18	5	<1	10	1	--	10
117	S1W2	S	--	6	--	3	7	22	--	8	11	--	39	31	3	--	50
118	S1W3	S	1	11	--	3	--	13	1	580	5	--	47	7	1	--	50
119	S2W1	Y	--	--	--	--	31	18	1	6	15	--	24	34	--	--	20
120	S2W2	S	--	6	--	3	24	10	--	580	5	--	62	28	4	--	50
121	S2W3	S	--	2	--	1	16	5	--	1,000	--	--	72	--	--	--	20
122	S3W1	Y	--	2	--	1	29	15	--	600	11	--	68	30	--	1	20
122	S3W1 (Duplicate)	Y	--	3	--	1	27	18	1	630	7	--	71	29	--	--	20
123	S3W2	S	2	16	--	--	36	25	--	440	14	6	83	27	--	--	50
124	S3W3	S	1	2	10	--	6	2	--	62	--	--	99	--	--	1	20
125	S4W1	Y	--	2	--	--	7	13	1	9	16	--	<1	10	--	--	60
126	S4W2	S	--	--	--	1	19	10	--	1,400	--	--	40	19	2	1	40
127	S4W3	S	--	2	--	--	29	8	--	NA	7	--	NA	5	--	--	40

are not surprising since some of the digested sediments likely contain smectite and illite, two clay minerals with relatively high adsorptive capacities for metals. These clay minerals were found to be the two most abundant minerals present in the fine-grained sediments comprising the confining units.

Organic Constituents

Priority Pollutant Organic Compounds and Organic Pesticides

Analyses of water samples collected from the cluster wells indicate the presence of 11 priority pollutant organic compounds in the aquifers underlying the Air Station. Of these 11 compounds, 9 are purgeable organic compounds, 1 is a base/neutral extractable organic compound, and 1 is a pesticide. Analyses which produced positive identifications of priority pollutant organic compounds and organic pesticides in concentrations at or above the analytical detection limit are summarized in table 6.

Nine purgeable organic compounds were detected in water samples from well-cluster site 3, near waste-disposal site 16 (fig. 2). In the surficial aquifer, the concentrations recorded for two of these compounds, trichloroethylene (3,000 µg/L for S3W2 and 4,600 µg/L for S3W3) and 1,2-dichloroethene (4,400 µg/L for S3W2 and 4,800 µg/L for S3W3) represent the maximum concentrations that could be measured by the analytical equipment. Actual concentrations may have been even higher. The maximum contaminant levels set by the U.S. Environmental Protection Agency for trichloroethylene and 1,2-dichloroethene in drinking water are 5 µg/L and 7 µg/L, respectively (U.S. Environmental Protection Agency, 1987). In a previous investigation (NUS, 1986), concentrations as high as 620 µg/L for trichloroethylene and 2,000 µg/L for 1,2-dichloroethene were detected in a monitoring well constructed in the surficial aquifer near the perimeter of waste-disposal site 16. Putnam and others (1982) report that as much as 20,000 gallons of oil may have been disposed of at this site between 1946 and 1948. Compared with trichloroethylene and 1,2-dichloroethene, the concentrations of six other purgeable organic compounds found in the surficial aquifer at well-cluster site 3 are low. Of these six, chloroethane (26 µg/L, average) and 1,1-dichloroethylene (12 µg/L, average) were the only other compounds found to exceed 5 µg/L.

Table 6.--*Priority pollutant organic compounds and organic pesticides detected in water from U.S. Geological Survey monitoring wells*

[All constituent concentrations given in micrograms per liter. Y, well screened in Yorktown aquifer; S, well screened in surficial aquifer. --, analysis run but result below detection limit]

Map well number (fig. 3)	USGS well number	Aquifer	Priority pollutant organic compounds										Organic pesticides
			Benzene	Chloroethane	Tetrachloroethylene	Toluene	Trichloroethylene	1,2-Dichloropropane	1,1-Dichloroethane	1,1-Dichloroethylene	1,2-Dichloroethene	Bis(2-ethylhexyl) phthalate	Methyl trithion
116	S1W1A	Y	--	--	--	--	--	--	--	--	--	[1]14	[2]0.03
117	S1W2	S	--	--	--	--	--	--	--	--	--	[1]15	--
118	S1W3	S	--	--	--	--	--	--	--	--	--	[1]14	--
119	S2W1	Y	--	--	--	--	--	--	--	--	--	--	--
120	S2W2	S	--	--	--	--	--	--	--	--	--	--	--
121	S2W3	S	--	--	--	--	--	--	--	--	--	--	--
122	S3W1	Y	--	--	0.3	--	16.0	--	--	--	12.0	--	--
122	S3W1 (Duplicate)	Y	0.2	--	.3	--	16.0	--	--	--	3.5	--	--
123	S3W2	S	--	27	1.7	0.5	3,000 (sat'd)	1.9	0.6	11	4,400 (sat'd)	--	--
124	S3W3	S	--	25	3.9	.8	4,600 (sat'd)	2.2	.6	13	4,800 (sat'd)	--	--
125	S4W1	Y	--	--	--	.5	1.4	--	--	--	--	--	--
126	S4W2	S	--	--	--	--	.2	--	--	--	--	--	--
127	S4W3	S	--	--	--	--	--	--	--	--	--	--	--

[1] The phthalates found in the site 1 samples may have come from small shavings, seen floating in the collected samples, that were scraped from the polyvinylchloride (PVC) pipe used to develop the wells. None of these shavings were detected in the samples collected at sites 2 and 3.

[2] The concentration of the pesticide methyl trithion found in the sample from well S1W1A is questionable because it was also detected at the same concentration in the blank sample.

(sat'd) Concentration represents the maximum concentration of the compound that could be measured by the laboratory instrumentation; actual concentration in the sample may have exceeded this value.

The areal extent of a contaminant plume near well-cluster site 3 in the surficial aquifer has not been determined, but it would most likely extend downgradient from waste-disposal site 16 to the west and north in the direction of ground-water flow toward Slocum Creek and Sandy Branch. As long as water-supply wells 100 (MCAS Well 16) and 103 (MCAS Well 17) are not pumped, the advective lateral movement of these compounds from this site eastward toward the water-supply wells is unlikely.

Trichloroethylene (up to 16 µg/L) and 1,2-dichloroethene (up to 12 µg/L) were also detected in water samples from the Yorktown aquifer at well-cluster site 3. These compounds may have migrated from the surficial aquifer into the Yorktown aquifer during the period when water-supply wells 100 (MCAS Well 16) and 103 (MCAS Well 17) were pumped.

No priority pollutant, purgeable organic compounds were detected at well-cluster sites 1 and 2; both of these sites are located to the east and upgradient of waste-disposal site 10. Trichloroethylene (1.4 µg/L) and toluene (0.5 µg/L) were detected in the Yorktown aquifer at well-cluster site 4, the site constructed near the southern perimeter of waste-disposal site 10. The presence of these compounds indicates that, in spite of the appearance that contaminants would tend to move laterally toward Slocum Creek, some of these contaminants may have entered the Yorktown aquifer at or upgradient from this site. Resampling is needed to verify these results.

The results of analyses for two of the organic compounds listed in table 6 are questionable. The presence of bis(2-ethylhexyl) phthalate, an extractable organic compound, detected in water collected from well-cluster site 1 (up to 15 µg/L) may have been caused by small PVC shavings seen floating in the collected samples. This material was probably scraped from the PVC pipe used to develop the wells. None of these shavings were seen in the samples collected from well-cluster sites 2, 3, or 4. The occurrence of the organic pesticide, methyl trithion, in water from well S1W1A (0.03 µg/L) is questionable because the pesticide was also detected at this same concentration in the blank sample during the laboratory analysis.

Nonpriority Pollutant Organic Compounds

During the analyses for priority pollutant organic compounds (purgeables and extractables), which utilizes a gas chromatograph-mass spectrophotometer (GC/MS) to detect organic substances of different molecular structure and weight, a number of compounds were detected that were not on the priority pollutant list (table 3). In an effort to identify these compounds, a comparison, or library search, was made between the spectra of the unknown compounds produced by the GC/MS and a compilation of approximately 39,000 available spectra of known compounds. Libraries of available spectra are maintained by the National Bureau of Standards (NBS) and the Environmental Protection Agency with the National Institute of Health (EPA-NIH).

The results of the library search and spectral comparisons are given in table 7. Nearly all of the unknown compounds have been tentatively identified with a high percentage probability of identification. Water from three wells (S1W1A, S1W2, and S3W1) contains one or more purgeable organic compounds that could not be identified. Purgeable organic compounds that were tentatively identified in the search include 5-methyl-1,2,3-thiadiazol, 1-methyl-4-(1-methylethyl)cyclohexadiene, dimethyl disulfide, and hydrazine metabolite. The concentrations of these compounds are small (less than 5 μg/L) in all of the samples.

Three extractable organic compounds not listed as priority pollutants were detected. One of the compounds, tentatively identified as 2-ethyl hexanol, is a fuel derivative found in the water sample from well S1W1A. This well is located near the eastern perimeter of waste-disposal site 10 (fig. 2), where petroleum oils and lubricants were disposed of (Putnam and others, 1982). The other organic compounds tentatively identified are dodecanoic acid and octacanoic acid, both saturated fatty acids common to fats and oils from a variety of plants and animals (Weast, 1975, p. D216-D217). These compounds were identified in water samples taken from both the surficial and Yorktown aquifers at well-cluster site 3, and in the Yorktown aquifer at well-cluster site 4. Well-cluster sites 3 and 4 are located near the perimeters of waste-disposal sites (10 and 16) known to contain

Table 7.--*Nonpriority pollutant organic compounds detected in water from U.S. Geological Survey monitoring wells*

[Compounds identified by a U.S. Environmental Protection Agency--National Institute of Health or National Bureau of Standards library search of approximately 39,000 available spectra. µg/L, microgram per liter; Y, well screened in Yorktown aquifer; S, well screened in surficial aquifer]

Map well number (fig. 3)	USGS well number	Aquifer	Acid and base/neutral extractable compounds: Compound	Percent probability of identification[1]	Approximate concentration (µg/L)	Purgeable organic compounds: Compound	Approximate concentration (µg/L)
116	S1W1A	Y	2-Ethyl hexanol	40	2	5-Methyl-1,2,3-Thiadiazol	2.5
						1-Methyl-4-(1-Methylethyl cyclohexadiene)	1
						Dimethyl disulfide	Trace
						One unidentified	Trace
						One unidentified--acetone?	1
117	S1W2	S	None	--	--	One unidentified--acetone?	1
118	S1W3	S	None	--	--	None	--
119	S2W1	Y	None	--	--	None	--
120	S2W2	S	None	--	--	None	--
121	S2W3	S	None	--	--	None	--
122	S3W1	Y	Dodecanoic acid	90	7	One unidentified	Trace
			Octanoic acid	70	2		
122	S3W1 (Duplicate)	Y	None	--	--	One unidentified	Trace
123	S3W2	S	Dodecanoic acid	90	11	Hydrazine metabolite	1.6
			Octanoic acid	80	5		
124	S3W3	S	None	--	--	Hydrazine metabolite	2
125	S4W1	Y	Dodecanoic acid	90	49	5-Methyl-1,2,3-Thiadiazol	2
126	S4W2	S	None	--	--	None	--
127	S4W3	S	None	--	--	None	--

[1] Reported by Tennessee Valley Authority, Laboratories Branch.

municipal-type refuse, a likely source of these compounds. Fatty acids are moderately soluble in water (Weast, 1975) and have a fairly low attraction for clays and other sedimentary particles and can thus be expected to be somewhat mobile in ground water.

Other Constituents

Concentrations of dissolved organic carbon (DOC) were consistently higher in water from wells in the Yorktown aquifer (averaging 3.5 mg/L) than in water from wells in the surficial aquifer (averaging 1.3 mg/L). By comparison, the majority of all ground waters have concentrations of DOC below 2 mg/L (Barcelona, 1984). The higher DOC concentrations in the Yorktown aquifer may be due to the upward movement of water from the Castle Hayne aquifer, where the mean DOC concentration was previously determined at 7.2 mg/L (Lloyd and Daniel, 1988). At well-cluster site 3, the concentration of DOC in the Yorktown aquifer well was measured at 6.4 mg/L, twice as high as that measured in any of the other three wells in the Yorktown aquifer and much closer to the mean value measured in the Castle Hayne aquifer. Again, this can be attributed to the fact that the area around well-cluster site 3 is a discharge area for the Castle Hayne aquifer.

SUMMARY AND CONCLUSIONS

Twelve wells were constructed by the U.S. Geological Survey at four sites (three wells per site) in May through June 1987 between unlined hazardous-waste disposal sites and water-supply wells at the U.S. Marine Corps Air Station at Cherry Point, North Carolina. Well-cluster sites 1, 2, and 4 were constructed near waste-disposal site 10, the largest of the hazardous-waste sites. Well-cluster site 3 was constructed in the southwestern part of the Air Station between waste-disposal site 16 and several water-supply wells previously found to contain small concentrations of benzene.

Together with lithologic and geophysical logs, water-level data collected at each of the four well-cluster sites indicate that the hydrogeologic conditions at well-cluster sites 1, 2, and 4 (near waste-disposal site 10) are similar but differ markedly from conditions at well-cluster site 3 (near waste-disposal site 16). Differences in hydraulic head measured between the surficial, Yorktown, and Castle Hayne aquifers at and near well-cluster sites 1, 2, and 4 indicate a potential for downward movement of ground water as well as any contaminants introduced into the surficial aquifer. However, such downward movement is impeded by two confining units (the upper and lower confining units) of silty to clayey sand that separate these three aquifers. Lithologic and geophysical logs indicate that the upper confining unit (which separates the surficial and Yorktown aquifers) at sites 1, 2, and 4 has an average thickness of 26 ft. Hydraulic head relations and lithologic data indicate that dissolved contaminants are likely to move laterally westward toward Slocum Creek in the direction of major ground-water flow in the surficial and Yorktown aquifers.

The upper confining unit thins toward the south and is only about 7 ft thick at well-cluster site 3. Geophysical logs of nearby water-supply wells 100 (MCAS Well 16) and 103 (MCAS Well 17) indicate that both the upper and lower confining units are much thinner or discontinuous in the southwestern part of the Air Station. Layers of slightly silty to slightly clayey sand present in the surficial aquifer at well-cluster sites 1, 2, and 4 are absent at well-cluster site 3. At site 3, the surficial aquifer consists of clean, highly-permeable sand. A possible explanation for the lithologic contrast between site 3 and sites 1, 2, and 4 is that the confining units (or portions thereof) and the fine-grained material present in the surficial aquifer at sites 1, 2, and 4 have been eroded away at site 3 and replaced by cleaner sands deposited in the Neuse River paleochannel. The deepest part of this paleochannel lies within the southwestern part of the Air Station near site 3 and water-supply wells 100 (MCAS Well 16) and 103 (MCAS Well 17).

The hydraulic heads in the surficial, Yorktown, and Castle Hayne aquifers converge toward the south between well-cluster sites 2 and 3. At well-cluster site 3, the altitude of the potentiometric surface in the Yorktown aquifer (3.8 ft) was higher than that in the surficial aquifer

(3.2 ft). The altitude of the potentiometric surface in the Castle Hayne aquifer measured at nearby water-supply well 100 (MCAS Well 16) was 3.9 ft, which indicates that both the Yorktown and Castle Hayne aquifers discharge into the surficial aquifer in this area. Under these hydraulic-head conditions, little potential exists for advective migration of contaminants from the surficial aquifer near waste-disposal site 16 downward into the Castle Hayne aquifer. However, pumping from supply wells 100 (MCAS Well 16) and 103 (MCAS Well 17) could reverse the hydraulic head relations and increase the potential for contaminant migration in the Castle Hayne aquifer.

Water-quality analyses of samples collected from the 12 cluster wells indicate that the water in the surficial and Yorktown aquifers is a naturally hard, calcium-bicarbonate type with moderate amounts of dissolved silica. Concentrations of iron (up to 1,400 μg/L) and manganese (up to 99 μg/L) exceeded EPA secondary drinking-water standards in roughly half of the water samples. Water samples collected from the surficial aquifer wells generally contained higher concentrations of these metals than did those collected from the Yorktown aquifer wells.

Trace metals detected in both aquifers include zinc (up to 60 μg/L), chromium (up to 36 μg/L), nickel (up to 34 μg/L), copper (up to 25 μg/L), and lead (up to 18 μg/L). Only a small proportion of these total recoverable concentrations, however, were dissolved and mobile in the ground water at the time of sampling.

Nine EPA priority pollutant, purgeable organic compounds were detected in water samples collected from well-cluster site 3, the site constructed in the southwestern part of the Air Station near waste-disposal site 16. Eight of these compounds were detected in water samples from the surficial aquifer. The two purgeable organic compounds detected in highest concentrations in the surficial aquifer at this site were trichloroethylene (4,600 μg/L) and 1,2-dichloroethene (4,800 μg/L). Because these concentrations represent the maximum concentrations that could be measured by the analytical equipment in the laboratory, actual concentrations of these compounds in the samples may have been even higher. Maximum contaminant levels set by the EPA for these compounds in drinking water are 5 μg/L and 7 μg/L, respectively. Six other purgeable organic compounds including chloroethane, tetrachloroethylene, toluene, 1-2-dichloropropane, 1,1-dichloroethane, and 1,1-dichloroethylene were also detected in the surficial aquifer at site 3 but in smaller concentrations (less than 30 μg/L).

The contaminants detected at well-cluster site 3 can be expected to move laterally within the surficial aquifer and discharge into Slocum Creek and Sandy Branch. Under nonpumping hydraulic-head conditions, all the aquifers are discharging in this area, and little potential exists for advective movement of these contaminants downward into the Castle Hayne aquifer.

Trichloroethylene and 1,2-dichloroethene (up to 16 and 12 μg/L, respectively) were the contaminants detected in greatest concentrations in the Yorktown aquifer; both of these compounds were found at well-cluster site 3. It is likely that these compounds migrated into the Yorktown aquifer over the period of time when water-supply wells 100 (MCAS Well 16) and 103 (MCAS Well 17) were operating.

No priority pollutant, purgeable organic compounds were detected at well-cluster sites 1 and 2; both of these sites are located to the east and upgradient of waste-disposal site 10. However, two purgeable compounds, trichloroethylene (1.4 μg/L) and toluene (0.5 μg/L), were detected in the Yorktown aquifer samples at well-cluster site 4 near the southern perimeter of waste-disposal site 10. The presence of these compounds indicates that, in spite of the appearance that most contaminants move laterally toward Slocum Creek, some contaminants have entered the Yorktown aquifer at this site or upgradient from this site. Resampling is needed to verify these water-quality results.

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Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4	
Soil	0-1
SAND, quartz, fine, well sorted, angular, very pale orange (10 YR 8/2), twigs present at base, no fossils observed	1-10
Sandy CLAY; medium gray (N5); few sand interlaminations and lenses; sand fine, well sorted, subangular to angular, dark yellowish orange (10 YR 6/6)	10-12.5
Sandy CLAY, light gray (N5)	12.5-12.7
SAND and SILT, top 5 inches is coarse silt to fine sand; sand is moderately sorted, subangular to angular, very pale orange (10 YR 8/2), some dark iron oxide staining present; bottom 6 inches is sand, fine, moderately sorted, subangular to angular, very pale orange (10 YR 8/2)	12.7-13.6
No sample recovery	13.6-14
SAND, fine, moderately sorted, subangular to angular, very pale orange, (10 YR 8/2); clay interlaminations and clasts, dark yellowish orange (10 YR 6/6)	14-15
No sample recovery	15-16
SAND, fine, moderately sorted, subangular, very pale orange (10 YR 8/2); mottled with clay lenses and a few clay clasts, medium gray (N5); twigs at base	16-16.8
No sample recovery	16.8-18
SAND, fine, very pale orange (10 YR 8/2); with small clay lenses, dark yellowish orange (10 YR 6/6)	18-19.8
No sample recovery	19.8-20.5
SAND, fine, well sorted, angular, medium gray (N5); 5 percent silt present	20.5-21.6
No sample recovery	21.6-22.7

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4--Continued	
Clayey SAND; sand fine, quartz, well sorted, angular, medium gray (N5) to medium dark gray (N4); bottom 4 inches is sand, quartz, bimodal with 65 percent very fine to fine and 35 percent medium, subrounded to angular, yellowish gray (5 Y 8/1)	22.7-23.5
No sample recovery	23.5-24
Silty SAND, top 3 inches fine sand, quartz, dark yellowish orange (10 YR 6/6); 1-inch layer of clay, dark gray (N3); bottom 8 inches is sand, coarse, moderately sorted, subrounded to subangular, medium dark gray (N4); with clay lenses	24-25
No sample recovery	25-26
SAND, quartz, medium, moderately sorted, subrounded; very light gray (N8) to medium light gray (N6)	26-27.8
No sample recovery	27.8-28
SAND, quartz, fine, well sorted, angular; very pale orange (10 YR 8/2); sparse very coarse subrounded quartz grains; twigs at base	28-29.4
No sample recovery	29.4-30
SAND, top 5 inches fine to medium, poorly sorted, subangular to angular; very light gray (N8); middle 6 inches is slightly granular sand, bimodal with 70 percent medium (0.5 mm) subrounded sand and 30 percent coarse to very coarse subrounded to rounded sand; medium gray (N5); phosphatic pebbles, shell fragments; bottom 1 inch increases in silt	30-31.3
No sample recovery	31.3-33
Pebbly silty SAND; sand medium size, poorly sorted, angular, olive gray (5 Y 4/1); 20 percent pebbles, glauconite, phosphate and quartz pebbles, subrounded; shell fragments, angular; 15 percent silt; thin black carbonized lenses	33-33.75

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4--Continued	
No sample recovery	33.75-34
Slightly silty SAND, sand fraction is 90 percent and contains 90 percent quartz and 10 percent phosphatic sand, medium sand size, well sorted, subangular to angular, olive gray (5 Y 6/1), 5 to 10 percent silt and clay, phosphate and quartz pebbles, thin black carbonized lenses	34-34.5
Pebbly SAND; sand fraction is 90 percent and contains 95 percent quartz; 3 percent phosphate, and 2 percent shell fragments; coarse sand size (0.6 mm), poorly sorted, rounded to subrounded; gravel fraction is 10 percent and contains quartz, shell fragments, and phosphate pebbles; light gray (N8) to light olive gray (5 Y 6/1); dark carbonaceous layers	34.5-35.4
SAND; 95 percent quartz and rare phosphate, glauconite, and sand-sized shell fragments; bimodal, 65 percent medium (0.25 mm) and 35 percent coarse (0.7 mm) sand; moderately sorted, subround to subangular; very light gray (N8); rare pebble-sized shell fragments	35.4-35.8 36-37
Pebbly slightly silty SAND; 80 percent sand, medium, light olive gray (5 Y 6/1) to medium light gray (N6); 10 percent silt and clay; 10 percent quartz and phosphate pebbles, shell fragments	37-37.75
No sample recovery	37.75-38
Pebbly SAND; 85 percent sand, medium, very light gray (N8); 15 percent quartz and phosphate pebbles, shell fragments	38-39
Sandy CLAY with 30 percent silt size and 40 percent clay size; 30 percent sand fraction is 30 percent and contains 95 percent quartz and 5 percent phosphate, sand fine, moderately sorted, subangular, olive gray (5 Y 4/1) to dark greenish gray (5 GY 4/1); rare mica flakes	39-40 40.6-41.8

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4--Continued	
Silty SAND; sand fraction is 70 percent and contains 90 percent quartz and 10 percent phosphatic sand, fine sand, poorly sorted, angular; dark greenish gray (5 GY 4/1); 30 percent silt and clay	41.8-44.4
Silty SAND; sand fraction is 70-80 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, moderately sorted, angular, dark greenish gray (5 GY 4/1); 20-30 percent silt and clay	44.4-46 46.4-48 48-49.4 50.8-52
SAND; 90 percent quartz, 6 percent phosphate, and 4 percent sand-sized shell fragments; fine to coarse sand, very poorly sorted, subrounded, light olive gray (5 Y 6/1); phosphate pebbles, shell fragments	52-53
Slightly silty SAND; sand fraction is 90 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, well sorted, subangular; dark greenish gray (5 GY 4/1); 10 percent silt and clay; quartz and phosphate pebbles	53-54
No sample recovery	54-54.25
Silty SAND; sand fraction is 80 percent and contains 90 percent quartz, 10 percent phosphatic and glauconitic sand; fine sand, moderately sorted, angular; dark greenish gray (5 GY 4/1); 20 percent silt and clay	54.25-58
Silty SAND to sandy SILT; 40-50 percent silt and clay; 50-60 percent sand contains 95 percent quartz; 5 percent phosphatic and glauconitic sand; dark greenish gray (5 GY 4/1); phosphate pebbles	58-59.75
No sample recovery	59.75-60.25
Silty SAND; sand fraction is 70 percent and contains 95 percent quartz, 5 percent phosphatic and glauconitic sand; fine sand, moderately sorted, angular; greenish gray (5 GY 6/1); 30 percent silt and clay; abundant weathering and leached shells; phosphate pebbles	60.25-62

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4--Continued	
Pebbly silty SAND; sand fraction is 70-80 percent and contains 95 percent quartz, 5 percent shell fragments and phosphatic sand; coarse sand, moderately sorted, subrounded, olive gray (5 Y 4/1); 20-30 percent silt; 10 percent quartz and phosphate pebbles; shell fragments; mica flakes, possible wood chips; bottom 4 inches increases in percent silt and decreases in pebbles	62-64
Silty SAND to sandy SILT; sand fraction is 60 percent and contains 90 percent quartz and 10 percent phosphatic sand, fine to medium sand, well sorted, subangular; light olive gray (5 Y 6/1); 40 percent silt and clay	64-66.25
Slighty silty SAND; sand fraction is 90 percent and contains 95 percent quartz and 5 percent phosphate; medium sand, moderately sorted, subrounded; light olive gray (5 Y 6/1); 10 percent silt and clay; rare quartz and phosphate pebbles	66.25-67.75
No sample recovery	67.75-68
Pebbly SAND; sand fraction is 80 percent and contains 95 percent quartz and 5 percent phosphate; very coarse sand, well sorted, rounded to subrounded; yellowish gray (5 Y 8/1); 20 percent gravel fraction contains shell fragments, quartz and phosphate pebbles	68-69
Slightly pebbly, slightly silty SAND; sand fraction is 90 percent and contains 95 percent quartz, 4 percent phosphate and 1 percent shell fragments; medium sand, very well sorted, subrounded to subangular; light olive gray (5 Y 4/1); 5 percent silt; 5 percent rounded phosphate and quartz pebbles; weathered and leached out shells; base increases in grain size to coarse and very coarse slightly silty sand	69-69.75
No sample recovery	69.75-70

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4--Continued	
Silty SAND; sand fraction is 75 percent and contains 95 percent quartz and 5 percent phosphatic sand; fine sand, moderately sorted, subrounded to subangular; yellowish gray (5 Y 8/1); 20 percent silt; 5 percent quartz and phosphate pebbles; rare shell fragments	70-71
No sample recovery--refusal from semi-cemented sediments	71-75
Slightly pebbly silty SAND; sand fraction is 75 percent and contains 95 percent quartz and 5 percent phosphatic sand; medium sand size, moderately sorted, subangular to subrounded; light olive gray (5 Y 6/1); 20 percent silt; 5 percent phosphate and quartz pebbles, shell fragments	75-75.8
No sample recovery--refusal from semi-cemented sediments	75.8-80
Slightly silty SAND, slightly cemented; sand fraction is 90 percent and contains 95 percent quartz and 5 percent phosphatic sand; medium sand size, very well sorted, subrounded to subangular; light olive gray (5 Y 6/1); 10 percent silt; layer of quartz and phosphate pebbles and shell fragments at 80.25 to 80.4 feet	80-81
No sample recovery--refusal from semi-cemented sediments	81-82
Slightly silty SAND, slightly cemented; sand fraction is 90 percent and contains 95 percent quartz, 5 percent phosphatic and glauconitic sand; medium sand size, moderately sorted, rounded to subround; light olive gray (5 Y 6/1); 10 percent silt; phosphatized fish teeth	82-83
Rotary drill through lenses of semi-cemented sediments	83-89
Silty SAND, cemented with 30 percent silt; sand fraction is 70 percent and contains 80 percent quartz, 15 percent shell fragments, and 5 percent phosphatic sand; coarse sand size, poorly sorted, subrounded; light olive gray (5 Y 6/1)	89-91

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Well S1W4--Continued	
Rotary drill through sediments	91-100
SAND; quartz and rare phosphatic sand, fine to medium, moderately sorted, subangular to angular; light olive gray (5 Y 6/1); 10 percent of sand fraction is coarse to very coarse sand; 5 percent silt; mica flakes	100-101
Silty SAND; 40 percent silt; sand fraction is 55 percent and contains 90 percent quartz and 10 percent phosphatic sand, moderately sorted, angular; dark greenish gray (5 GY 4/1); 5 percent quartz and phosphate pebbles; weathered and leached out shells	101-101.25 102-104
Boring terminated at 104 feet below land surface.	
Wells S2W1 and S2W2	
Section drilled through with hollow-stem auger--no sample taken	0-5
SAND; quartz, fine, moderately sorted, angular, grayish orange (10 YR 7/4); twigs	5-6
Hollow-stem auger drilling--no sample taken	6-10
CLAY and SAND; top 5 inches clay with sand lenses, light gray (N7); middle 9 inches fine sand, 97 percent quartz and 3 percent phosphatic sand, well sorted, angular, white (N9); bottom 5 inches clay with sand lenses, grayish orange (10 YR 7/4)	10-11.6
Portion of split-spoon sample not recovered	11.6-12
Hollow-stem auger drilling--no sample taken	12-15
CLAY and SAND; fine sand, 94 percent quartz, 5 percent phosphatic sand and 1 percent glauconitic sand, very well sorted, angular, light gray (N7); clay clasts and lenses common	15-17
Hollow-stem auger drilling--no sample taken	17-20
Portion of split-spoon sample not recovered	20-20.4

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S2W1 and S2W2--Continued	
CLAY and SAND; top 3 inches clay, medium light gray (N6); middle 12 inches fine to coarse sand, quartz, poorly sorted, subrounded to angular, light gray (N7), few clay lenses several centimeters thick, rare carbonized wood chips and twigs; bottom 4 inches fine sand, 98 percent quartz and 2 percent phosphate, very well sorted, angular, white (N9)	20.4-22
Hollow-stem auger drilling--no sample taken	22-25
SAND; fine, 98 percent quartz and 2 percent phosphate, very well sorted, angular, white (N9); with clay clasts and lenses, medium light gray (N6); twigs	25-26.4
Silty SAND; fine, sand fraction is 65 percent and contains 98 percent quartz and 2 percent phosphate, moderately sorted, subrounded to angular, light gray (N7); 35 percent silt	26.4-27
Hollow-stem auger drilling--no sample taken	27-31
Slightly silty SAND; sand fraction is 90 percent and contains 97 percent quartz and 3 percent phosphatic sand, bimodal, fine subangular to coarse rounded sand, poorly sorted, rounded to subangular; light olive gray (5 Y 6/1); rare clay interlaminations	31-32.3
Pebbly SAND; sand fraction is 70 percent and contains 60 percent quartz, 30 percent shell fragments and 10 percent phosphatic sand, coarse to very coarse sand size, moderately sorted, rounded to subrounded; light olive gray (5 Y 6/1); 5 percent silt; gravel fraction is 25 percent and contains rounded phosphate and quartz pebbles, and shell fragments, zone is 3 inches thick; bottom 5 inches is sand, fine to medium, quartz and rare phosphatic sand, moderately sorted, subrounded to angular, dusky yellow (5 Y 6/4); abundant sand and fine pebble-sized shell fragments	32.3-33
Hollow-stem auger drilling--no sample taken	33-35
SAND; top 5 inches medium sand, shell fragments, light gray (N7); middle 5 inches pebbly sand, medium to coarse sand rounded fine quartz and phosphate pebbles, weathering shells and shell fragments, yellowish gray (5 Y 7/2)	35-36

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S2W1 and S2W2--Continued	
Portion of split-spoon sample not recovered	36-37
Hollow-stem auger drilling--no sample taken	37-38
Sandy SILT; sand fraction is 50 percent and contains quartz and shell fragments, very fine to fine sand, well sorted, subangular; yellowish gray (5 Y 7/2); 45 percent silt; weathered and leached out shells	38-40
Silty SAND; sand fraction is 80 percent and contains 85 percent quartz, 10 percent shell fragments and 5 percent phosphatic sand, medium sand size, moderately sorted, subrounded; gravel fraction is 20 percent and contains rounded fine quartz and phosphate pebbles, and angular shell fragments; 10 percent silt; yellowish gray (5 Y 7/2); bottom 10 inches decrease in pebble fraction to 5 percent, color change to olive gray (5 Y 5/2)	40-42
Hollow-stem auger drilling--no sample taken	42-45
Sandy SILT to silty SAND; sand fraction is 40 percent and contains 90 percent quartz and 3 percent phosphatic and 7 percent glauconitic sand, fine sand size, well sorted, angular; 60 percent silt; light olive gray (5 Y 5/2); no fossils observed; silt fraction decreases to 15 percent at bottom	45-47
Hollow-stem auger drilling--no sample taken	47-50
Silty SAND; sand fractions is 65 percent and contains 95 percent quartz, 3 percent phosphatic and 2 percent glauconitic sand, fine sand size, well sorted, angular; light olive gray (5 Y 5/2); 35 percent silt; rare phosphate pebbles, no fossils observed	50-52
Mud-rotary drilling--no sample taken	52-55
Portion of split-spoon sample not recovered	55-57
Mud-rotary drilling--no sample taken	57-60
Silty SAND; quartz and rare phosphatic sand, coarse sand, moderately sorted, subrounded; 20 percent silt; yellowish gray (5 Y 7/2); few quartz and phosphate pebbles, shell fragments	60-61

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S2W1 and S2W2--continued	
Portion of split-spoon sample not recovered	61-62
Mud-rotary drilling--no sample taken	62-65
Portion of split-spoon sample not recovered	65-67
Mud-rotary drilling--no sample taken	67-70
SAND, quartz and phosphatic sand, coarse sand, moderately sorted, subrounded, very light gray (N8); few quartz and phosphate pebbles, shell fragments	70-71
Portion of split-spoon sample not recovered	71-72
Mud-rotary drilling--no sample taken	72-75
SAND, semi-indurated, coarse sand, quartz and rare phosphatic sand, moderately sorted, subrounded; 5 percent silt; very light gray (N7) to light gray (N8); shells molds and weathered shells	75-75.2
Portion of split-spoon sample not recovered	75.2-76
Mud-rotary drilling--no sample taken	76-80
Slightly pebbly silty SAND; sand fraction is 55 percent quartz, coarse to very coarse sand, poorly sorted, subrounded to rounded; 40 percent silt; 5 percent fine quartz and phosphate pebbles; shell fragments; very light gray (N8)	80-81
Portion of split-spoon sample not recovered	81-82
Mud-rotary drilling--no sample taken	82-85
Silty SAND; top 1 inch is composed of semi-indurated sand, then 3 inches of olive gray (5 Y 3/2) muddy sand bottom 8 inches is silty sand, medium, sand fraction is 80 percent and contains quartz and phosphatic sand, well sorted, subrounded; 20 percent silt; very light gray (N8); few shell fragments	85-86
Portion of split-spoon sample not recovered	86-87

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S2W1 and S2W2--Continued	
Mud-rotary drilling--no sample taken	87-90
SAND; semi-indurated, very fine to very coarse, quartz and phosphatic sand, poorly sorted; shell fragments; very light gray (N8)	90-90.3
Portion of split-spoon sample not recovered	90.3-91
Mud-rotary drilling--no sample taken	91-95
Portion of split-spoon sample not recovered	95-97
Mud-rotary drilling--no sample taken	97-100
Sandy SILT; 55 percent silt; sand fraction is 45 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, very well sorted, angular; light olive gray (5 Y 5/2); weathering and leached mollusk shells	100-102
Boring terminated at 102 feet below land surface.	
Wells S3W1 and S3W2	
Section drilled through with hollow-stem auger--no sample taken	0-5
SAND; quartz, medium, moderately sorted, angular; very pale orange (10 YR 8/2)	5-6.4
Portion of split-spoon sample not recovered	6.4-7
Hollow-stem auger drilling--no sample taken	7-10
MUD and SAND; top 4 inches mostly mud, very light gray (N8), with medium sand lenses, very pale orange (10 YR 8/2); bottom 8 inches sand, medium, well sorted, subrounded to subangular, very pale orange (10 YR 8/2)	10-11
Portion of split-spoon sample not recovered	11-12
Hollow-stem suger drilling--no sample taken	12-15

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S3W1 and S3W2--Continued	
SAND; quartz and rare phosphatic sand, medium sand, moderately sorted, subrounded; very pale orange (10 YR 8/2); thin (1 mm) mud lenses, very light gray (N8); few twigs	15-17
Hollow-stem auger drilling--no sample taken	17-20
SAND; quartz, bimodal with 50 percent angular fine sand (0.18 mm) and 50 percent subrounded medium sand (0.4 mm); pale yellowish orange (10 YR 8/2); clay clasts at top, very light gray (N8); grain size increases towards base to medium sand, well sorted, subrounded	20-22
Hollow-stem auger drilling--no sample taken	22-25
SAND; quartz, fine to medium, moderately sorted, subrounded to angular; very pale orange (10 YR 8/2); clay clasts and quartz fine pebbles near top; similiar to interval described above	25-26
Portion of split-spoon sample not recovered	26-27
Hollow-stem auger drilling--no sample taken	27-30
SAND; quartz and rare phosphatic sand, fine to medium sand, moderately sorted, subrounded; very pale orange (10 YR 8/2)	30-31
Portion of split-spoon sample not recovered	31-32
Hollow-stem auger drilling--no sample taken	32-35
SAND; quartz, medium sand, moderately sorted, subrounded, very pale orange (10 YR 8/2); few wood fragments at base	35-36
Portion of split-spoon sample not recovered	36-37
Hollow-stem auger drilling--no sample taken	37-40
SAND; quartz, medium sand, moderately sorted, subrounded to angular; very pale orange (10 YR 8/2); rare wood fragments; sand size fine to medium towards base	40-42
Hollow-stem auger drilling--no sample taken	42-45

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S3W1 and S3W2--Continued	
SAND; quartz, fine to medium sand, well sorted, subrounded to angular; very pale orange (10 YR 8/2); thin (1 mm) mud lense at 46 feet, medium gray (N5)	45-47
Hollow-stem auger drilling--no sample taken.	47-50
SAND; quartz, medium sand, well sorted, subrounded to subangular; very pale orange (10 YR 8/2); rare mud clasts	50-52
Hollow-stem auger drilling--no sample taken	52-55
SAND; quartz ane rare phosphatic sand, bimodal with 75 percent medium and 25 percent very coarse sand, poorly sorted, rounded to subrounded; very pale orange (10 YR 8/2); twigs rare	55-56
Transition zone: Iron-oxidized zone 1-inch thick	56-56.1
Silty SAND; sand fraction is 90 percent, medium to coarse sand, poorly sorted, subrounded to subangular; highly organic peaty zone; dark gray (N3); carbonaceous cypress twigs, sparse quartz pebbles; 10 percent silt size organic matter	56.1-56.7
Pebbly muddy SAND; sand fraction is 70 percent and contains 90 percent quartz, 7 percent glauconitic and 3 percent phosphatic sand, fine sand, well sorted, angular; 20 percent mud containing 65 percent silt and 35 percent clay; 10 percent gravel fraction contains quartz and phosphate pebbles; olive gray (5 Y 4/1); highly organic-rich zone, wood fragments	56.7-57
Portion of split-spoon sample not recovered	57-58
Mud-rotary drilling--no sample taken	58-61
Silty SAND; sand fraction is 60 percent and contains 95 quartz and 5 percent phosphatic sand, medium sand, moderately sorted, subrounded to angular; 40 percent silt; leached and weathered out mollusk shells; phosphatized fish teeth. Wash?	61-62.4
Portion of split-spoon sample not recovered	62.4-63

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S3W1 and S3W2--Continued	
Mud-rotary drilling--no sample taken	63-65
Slightly silty SAND; sand fraction is 85 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, well sorted, angular; 10 percent silt; pale olive (10 YR 6/2); weathered and leached mollusk shells	65-66
Portion of split-spoon sample not recovered	66-67
Mud-rotary drilling--no sample taken	67-70
Portion of split-spoon sample not recovered	70-72
Mud-rotary drilling--no sample taken	72-75
Slightly silty SAND; sand fraction is 85 percent and contains 93 percent quartz and 3 percent phosphatic sand, fine sand, well sorted, angular; 10 percent silt; yellowish gray (5 Y 7/2) to light olive gray (5 Y 5/2); weathered and leached out mollusk shells display darker color bands	75-77 81-81.25
Portion of split-spoon sample not recovered	81.25-82
Mud-rotary drilling--no sample taken	82-85
SAND; semi-indurated, fine to medium; quartz and rare phosphatic and glauconitic sand, phosphate pebbles; medium dark gray (N4)	85-85.3
Silty SAND; sand fraction is 75 percent and contains 90 percent quartz and 10 percent phosphatic sand, medium sand, moderately sorted, angular; 25 percent silt; light olive gray (5 Y 5/2); quartz pebbles common, weathered mollusk shells	85.3-85.6
Portion of split-spoon sample not recovered	85.6-87
Mud-rotary drilling--no sample taken	87-90
Portion of split-spoon sample not recovered	90-92
Mud-rotary drilling--no sample taken	92-95
Portion of split-spoon sample not recovered	95-97

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S3W1 and S3W2--Continued	
Mud-rotary drilling--no sample taken	97-100
Sandy SILT; 70 percent silt; sand fraction is 30 percent and contains 92 percent quartz, 4 percent phosphate, 3 percent glauconite, and 1 percent shell fragments, fine sand; light olive green (5 Y 5/2); weathering and leached mollusk shells	100-102
Boring terminated at 102 feet below land surface.	
Wells S4W1 and S4W2	
Section drilled through with hollow-stem auger--no sample taken	0-5
SAND, quartz, fine, well sorted, angular, yellowish gray (5 Y 5/2); few clay clasts and lenses at base	5-6.25
Portion of split-spoon sample not recovered	6.25-7
Hollow-stem auger drilling--no sample taken	7-10
CLAY, olive gray (5 Y 3/2); sand lenses and interlaminations, sand fine, very well sorted, angular, very light gray (N8); no fossils observed	10-12
Hollow-stem auger drilling--no sample taken	12-15
SAND, quartz, bimodal with 70 percent fine and 30 percent coarse sand, poorly sorted, rounded to angular, very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4); clay clasts and interlaminations	15-17
Hollow-stem auger drilling--no sample taken	17-20
Silty SAND; sand fraction is 80 percent and contains 98 percent quartz, 1 percent phosphatic and 1 percent glauconitic sand, fine sand, very well sorted, subangular to angular; 20 percent silt; yellowish gray (5 Y 7/2) to pale olive (10 YR 6/2); clay clasts and interlaminations, olive gray (5 Y 3/2)	20-22
Hollow-stem auger drilling--no sample taken	22-25

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S4W1 and S4W2--Continued	
Slightly silty SAND; sand fraction is 90 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, very well sorted, subangular to angular; 10 percent silt; yellowish gray (5 Y 7/2) to pale olive (10 Y 6/2); clay clasts	25-27
Hollow-stem auger drilling--no sample taken	27-30
Slightly silty SAND; sand fraction is 90 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, very well sorted, angular; 10 percent silt; light gray (N7); fine pebble-sized clay clasts and interlaminations; burrowing	30-32
Hollow-stem auger drilling--no sample taken	32-35
Slightly silty SAND; sand fraction is 90 percent and contains 95 percent quartz and 5 percent phosphatic sand, fine sand, very well sorted, angular; 10 percent silt; pale olive (10 Y 6/2) to light gray (N7); clay clasts	35-36
Silty SAND; 75 percent sand, medium, moderately sorted, subangular; 25 percent silt; quartz pebbles, dark organic-rich layers (1 centimeter thick); light olive gray (5 Y 5/2)	36-37
Hollow-stem auger drilling--no sample taken	37-40
Silty SAND; sand fraction is 85 percent and contains 94 percent quartz and 5 percent phosphatic sand, fine sand, very well sorted, angular; 15 percent silt; light olive gray (5 Y 5/2); quartz pebbles	40-41.25
Muddy SAND; sand fraction is 85 percent and contains 95 percent quartz and 5 percent phosphatic sand, medium sand, well sorted, subrounded to subangular; 15 percent mud containing 70 percent silt and 30 percent clay; light olive gray (5 Y 5/2); clay clasts and lenses, quartz pebbles, leached out shells, black organic rich clayey layer	41.25-42
Hollow-stem auger drilling--no sample taken	42-45

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S4W1 and S4W2--Continued	
Silty SAND; sand fraction is 85 percent and contains 90 percent quartz and 10 percent phosphatic sand, medium sand, very well sorted, angular; 15 percent silt; light olive gray (5 Y 5/2) to olive gray (5 Y 3/2)	45-47
Hollow-stem auger drilling--no sample taken	47-50
Portion of split-spoon sample not recovered	50-51
Silty SAND; top 2 inches sandy mud, fine sand, olive gray (5 Y 3/2); sand fraction is 75 percent and contains 95 percent quartz, 3 percent glauconitic and phosphatic sand, well sorted, angular; 25 percent silt; light olive gray (5 Y 5/2)	51-52
Mud, rotary drilling--no sample taken	52-60
Silty SAND; sand fraction is 80 percent and contains 90 percent quartz, 7 percent glauconitic and 3 percent phosphatic sand, fine sand, well sorted, angular; 20 percent silt; light olive gray (5 Y 5/2) to yellowish gray (5 Y 3/2); shell fragments, phosphatized fish teeth	60-61
Portion of split-spoon sample not recovered	61-62
Mud-rotary drilling--no sample taken	62-65
Pebbly Silty SAND; sand fraction is 55 percent and contains 95 percent quartz and 5 percent phosphate, medium to very coarse sand, poorly sorted, rounded to angular; 30 percent silt; 15 percent rounded quartz and phosphate fine pebbles; yellowish gray (5 Y 7/2)	65-67
Mud-rotary drilling---no sample taken	67-70
Portion of split-spoon sample not recovered	70-72
Mud-rotary drilling--no sample taken	72-75
Portion of split-spoon sample not recovered	75-77
Mud-rotary drilling--no sample taken	77-80
Portion of split-spoon sample not recovered	80-82

Table 8.--*Lithologic logs for selected U.S. Geological Survey monitoring wells*--Continued

[Estimates of grain-size fractions, sediment composition, and fossil content are based on microscopic examinations by a U.S. Geological Survey geologist. Color Code Description: Example--(10 YR 8/2) Sand, fine, moderately sorted very pale orange. See Munsell Chart. mm, millimeter]

Description	Depth below land surface (feet)
Wells S4W1 and S4W2--Continued	
Mud-rotary drilling--no sample taken	82-85
Portion of split-spoon sample not recovered	85-95
Sandy SILT; 55 percent silt; 45 percent sand, quartz, (phosphate rare) medium sand, well sorted, angular; light olive brown (5 Y 5/6) to dusky yellow (5 Y 6/4); weathered and leached mollusk shell fragments	95-97
Boring terminated at 97 feet below land surface.	

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Sample collection		Field temperature water (°C)	Turbidity (NTU)	Color (platinum-cobalt units)	Field specific conductance (µS/cm)	Lab specific conductance (µS/cm)	Field pH (standard units)	Lab pH (standard units)	Carbon dioxide, dissolved (mg/L as CO_2)	Field bicarbonate water (mg/L as HCO_3)
	Date	Time									
S1W1A	10/21/87	1230	18.5	40.0	6	178	152	9.57	9.70	0.0	270
S1W2	10/22/87	1215	18.5	61	1	255	303	6.68	7.50	51	156
S1W3	10/22/87	1115	18.5	63	2	225	256	6.30	7.30	113	162
S2W1	10/28/87	1000	19.0	23	2	320	346	8.14	8.00	2.3	278
S2W2	10/28/87	1630	19.0	23	2	318	364	7.12	7.20	22	195
S2W3	10/28/87	1800	19.0	21	3	370	386	7.21	7.20	21	220
S3W1	11/05/87	1145	19.5	26	13	435	458	7.39	7.40	16	287
S3W1 (Duplicate)	11/05/87	1245	NA	37	62	NA	456	NA	7.40	18	270
S3W2	11/04/87	1130	19.5	66	25	325	347	6.80	7.10	46	200
S3W3	11/04/87	1235	19.5	48	1	302	329	6.80	6.90	45	162
S4W1	10/29/87	1145	19.0	1.9	2	NA	139	9.98	9.40	0	110
S4W2	10/29/87	1245	19.0	23	3	160	176	6.13	6.20	67	78
S4W3	11/03/87	1310	20.0	NA	NA	130	NA	5.98	NA	0	49

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[<u>Well number</u>: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Field Alkalinity (mg/L as $CaCO_3$)	Lab Alkalinity (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 °C, dissolved (mg/L)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dissolved (mg/L as N)	Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon organic, dissolved (mg/L as C)
S1W1A	221	57	211	113	0.115	0.009	0.70	0.009	<0.001	0.008	2.9
S1W2	128	126	166	163	.060	.004	.60	.106	.102	.053	1.2
S1W3	133	116	164	141	.056	<.001	1.1	.022	--	.211	1.3
S2W1	228	164	252	207	.30	.004	.354	.030	.026	.074	2.4
S2W2	160	149	225	209	.086	<.001	1.4	.014	.014	.010	1.1
S2W3	180	177	238	237	.058	<.001	2.1	.013	.013	.003	1.1
S3W1	235	202	296	292	.20	.003	.685	.016	.013	.003	6.3
S3W1 (Duplicate)	NA	184	272	286	.665	.003	.30	.021	.018	.003	6.4
S3W2	164	149	215	204	.126	.002	.60	.021	.019	<.001	1.9
S3W3	133	146	182	191	.254	.002	1.2	<.010	<.008	.004	1.3
S4W1	90	46	126	93	.084	.003	.30	.020	.018	.003	3.2
S4W2	64	47	115	104	.029	<.001	.50	.012	--	.246	1.0
S4W3	40	--	NA	NA	.123	.003	<.20	<.010	--	.055	1.3

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Cyanide, total (mg/L as CN)	Hardness, total (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)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Arsenic, total (µg/L as As)
S1W1A	<0.010	34	13	0.36	17.0	8.2	7.3	10.0	0.30	22	2
S1W2	<.010	130	49	2.1	4.5	1.3	4.6	14	.20	13	6
S1W3	<.010	110	40	1.3	6.9	1.0	5.3	11	.20	17	11
S2W1	<.010	150	59	1.3	8.8	4.2	8.2	4.3	.20	28	<1
S2W2	<.010	160	62	2.4	8.1	1.6	7.8	27	.10	19	6
S2W3	<.010	180	69	2.5	9.0	1.1	6.4	20	.10	21	2
S3W1	<.010	220	83	3.1	7.6	4.6	15	3.9	.20	36	2
S3W1 (Duplicate)	<.010	220	84	3.1	7.8	4.3	20	3.9	.20	36	3
S3W2	<.010	160	60	1.4	8.8	1.1	20	2.0	.40	22	16
S3W3	<.010	150	56	1.3	9.0	1.1	12	1.7	.10	21	2
S4W1	<.010	42	16	.39	13	4.2	7.3	12	.20	19	2
S4W2	<.010	57	21	1.1	8.1	1.5	12	13	.10	18	<1
S4W3	<.010	NA	NA	NA	NA	NA	NA	NA	NA	NA	2

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Beryllium, total recoverable (µg/L as Be)	Boron, dissolved (µg/L as B)	Cadmium, total recoverable (µg/L as Cd)	Chromium, total recoverable (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Copper, total recoverable (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Lead, total recoverable (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Nickel, dissolved (µg/L as Ni)
S1W1A	<10	20	<1	13	2	13	8	5	18	<1	1
S1W2	<10	20	3	7	<1	22	8	<5	11	39	3
S1W3	<10	20	3	<1	1	13	580	<5	5	47	1
S2W1	<10	20	<1	31	1	18	6	<5	15	24	<1
S2W2	<10	40	3	24	<1	10	580	5	<5	62	4
S2W3	<10	20	1	16	<1	5	1,000	<5	<5	72	<1
S3W1	<10	20	1	29	<1	15	600	<5	11	68	<1
S3W1 (Duplicate)	<10	20	1	27	1	18	630	<5	7	71	<1
S3W2	<10	20	<1	36	<1	25	440	6	14	83	<1
S3W3	10	20	<1	6	<1	2	62	<5	<5	99	<1
S4W1	<10	20	<1	7	1	13	9	<5	16	<1	<1
S4W2	<10	30	1	19	<1	10	1,400	<5	<5	40	2
S4W3	<10	30	<1	29	<1	8	NA	<5	7	NA	<1

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Nickel, total recoverable (µg/L as Ni)	Silver, total recoverable (µg/L as Ag)	Zinc, total recoverable (µg/L as Zn)	Antimony, total (µg/L as Sb)	Selenium, total (µg/L as Se)	Dichlorobromomethane, total (µg/L)	Carbon tetrachloride, total (µg/L)	1,2-Dichloroethane, total (µg/L)	Bromoform, total (µg/L)	Chlorodibromomethane, total (µg/L)	Chloroform, total (µg/L)
S1W1A	10	<1	10	<1	<1	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
S1W2	31	<1	50	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S1W3	7	<1	50	1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S2W1	34	<1	20	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S2W2	28	<1	50	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S2W3	<1	<1	20	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S3W1	30	1	20	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S3W1 (Duplicate)	29	<1	20	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S3W2	27	<1	50	2	<1	<.20	<.20	<.20	<.20	<.20	<.20
S3W3	<1	1	20	1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S4W1	10	<1	60	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S4W2	19	1	40	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20
S4W3	5	<1	40	<1	<1	<.20	<.20	<.20	<.20	<.20	<.20

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Toluene, total (µg/L)	Benzene, total (µg/L)	Acenaphthylene, total (µg/L)	Acenaphthene, total (µg/L)	Anthracene, total (µg/L)	Benzo(b) fluoranthene, total (µg/L)	Benzo(k) fluoranthene, total (µg/L)	Benzo(a) pyrene, total (µg/L)	bis(2-Chloroethyl) ether, total (µg/L)	bis(2-Chloroethoxy) methane, total (µg/L)	bis(2-Chloroisoprophyl) ether, total (µg/L)
S1W1A	<0.20	<0.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S1W2	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S1W3	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S2W1	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S2W2	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S2W3	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S3W1	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S3W1 (Duplicate)	<.20	.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S3W2	.50	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S3W3	.80	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S4W1	.50	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S4W2	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0
S4W3	<.20	<.20	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0	<5.0	<5.0

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	N-Butyl benzyl phthalate, total (µg/L)	Chlorobenzene, total (µg/L)	Chloroethane, total (µg/L)	Chrysene, total (µg/L)	Diethyl phthalate, total (µg/L)	Dimethyl phthalate, total (µg/L)	1,2-diphenylhydrazine, total (µg/L)	Endosulfan sulfate, total (µg/L)	Endosulfan beta, total (µg/L)	Endosulfan alpha, total (µg/L)	Endrin aldehyde, total (µg/L)	Ethylbenzene, total (µg/L)
S1W1A	<5.0	<0.20	<0.20	<10.0	<5.0	<5.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.20
S1W2	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S1W3	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S2W1	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S2W2	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S2W3	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S3W1	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S3W1 (Duplicate)	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S3W2	<5.0	<.20	27	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S3W3	<5.0	<.20	25	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S4W1	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S4W2	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20
S4W3	<5.0	<.20	<.20	<10.0	<5.0	<5.0	<.01	<.01	<.01	<.01	<.01	<.20

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Fluoranthene, total (µg/L)	Fluorene, total (µg/L)	Hexachlorocyclopentadiene, total (µg/L)	Hexachloroethane, total (µg/L)	Indeno-(1,2,3-c,d) pyrene, total (µg/L)	Isophorone, total (µg/L)	Methyl bromide, total (µg/L)	Methyl chloride, total (µg/L)	Methylene chloride, total (µg/L)	N-Nitrosodi-n-propylamine, total (µg/L)	N-Nitrosodiphenylamine, total (µg/L)
S1W1A	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<0.20	<0.20	<0.20	<5.0	<5.0
S1W2	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S1W3	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S2W1	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S2W2	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S2W3	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S3W1	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S3W1 (Duplicate)	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S3W2	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S3W3	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S4W1	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S4W2	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0
S4W3	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0	<.20	<.20	<.20	<5.0	<5.0

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	N-Nitrosodimethylamine, total (µg/L)	Nitrobenzene, total (µg/L)	para-Chloro-meta-cresol, total (µg/L)	Phenanthrene, total (µg/L)	Pyrene, total (µg/L)	Tetrachloroethylene, total (µg/L)	Trichlorofluoromethane, total (µg/L)	1,1-Dichloroethane, total (µg/L)	1,1-Dichloroethylene, total (µg/L)	1,1,1-trichloroethane, total (µg/L)	1,1,2-trichloroethane, total (µg/L)
S1W1A	<5.0	<5.0	<30.0	<5.0	<5.0	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
S1W2	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S1W3	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S2W1	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S2W2	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S2W3	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S3W1	<5.0	<5.0	<30.0	<5.0	<5.0	.30	<.20	<.20	<.20	<.20	<.20
S3W1 (Duplicate)	<5.0	<5.0	<30.0	<5.0	<5.0	.30	<.20	<.20	<.20	<.20	<.20
S3W2	<5.0	<5.0	<30.0	<5.0	<5.0	1.7	<.20	.60	11	<.20	<.20
S3W3	<5.0	<5.0	<30.0	<5.0	<5.0	3.9	<.20	.60	13	<.20	<.20
S4W1	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S4W2	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20
S4W3	<5.0	<5.0	<30.0	<5.0	<5.0	<.20	<.20	<.20	<.20	<.20	<.20

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	1,1,2,2-Tetrachloroethane, total (µg/L)	Benzo-(g,h,i)-perylene, total (µg/L)	Benzo(a)-anthracene, total (µg/L)	1,2-Dichlorobenzene, total (µg/L)	1,2-Dichloropropane, total (µg/L)	1,2-trans-Dichloroethene, total (µg/L)	1,2,4-Trichlorobenzene, total (µg/L)	Dibenzo(a,h)-anthracene, total (µg/L)	1,3-Dichloropropene, total (µg/L)	1,3-Dichlorobenzene, total (µg/L)	1,4-Dichlorobenzene, total (µg/L)
S1W1A	<0.20	<10.0	<5.0	<0.20	<0.20	<0.20	<5.0	<10.0	<0.20	<0.20	<0.20
S1W2	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S1W3	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S2W1	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S2W2	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S2W3	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S3W1	<.20	<10.0	<5.0	<.20	<.20	12	<5.0	<10.0	<.20	<.20	<.20
S3W1 (Duplicate)	<.20	<10.0	<5.0	<.20	<.20	3.5	<5.0	<10.0	<.20	<.20	<.20
S3W2	<.20	<10.0	<5.0	<.20	1.9	4,400	<5.0	<10.0	<.20	<.20	<.20
S3W3	<.20	<10.0	<5.0	<.20	2.2	4,800	<5.0	<10.0	<.20	<.20	<.20
S4W1	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S4W2	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20
S4W3	<.20	<10.0	<5.0	<.20	<.20	<.20	<5.0	<10.0	<.20	<.20	<.20

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	2-Chloroethyl vinyl ether, total (µg/L)	2-Chloronaphthalene, total (µg/L)	2-Chlorophenol, total (µg/L)	2-Nitrophenol, total (µg/L)	Di-n-octyl phthalate, total (µg/L)	2-4-Dichlorophenol, total (µg/L)	2-4-Dinitrotoluene, total (µg/L)	2-4-Dinitrophenol, total (µg/L)	2,4,6-Trichlorophenol, total (µg/L)	2,6-Dinitrotoluene, total (µg/L)
S1W1A	<0.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S1W2	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S1W3	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S2W1	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S2W2	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S2W3	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S3W1	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S3W1 (Duplicate)	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S3W2	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S3W3	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S4W1	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S4W2	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0
S4W3	<.20	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0	<20.0	<20.0	<5.0

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	3,3'-Dichlorobenzidine, total (µg/L)	4-Bromophenyl phenyl ether, total (µg/L)	4-Chlorophenyl phenyl ether, total (µg/L)	4-Nitrophenol, total (µg/L)	4,6-Dinitro-ortho-cresol, total (µg/L)	Di-Chloro-di-fluoromethane, total (µg/L)	Aroclor 1016 PCB, total (µg/L)	Phenol (C6H-5OH), total (µg/L)	Naphthalene, total (µg/L)	1,3-trans-Di-chloropropene, total (µg/L)
S1W1A	<25.0	<5.0	<5.0	<30.0	<30.0	<0.20	<0.1	<5.0	<5.0	<0.20
S1W2	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S1W3	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S2W1	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S2W2	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S2W3	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S3W1	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S3W1 (Duplicate)	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S3W2	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S3W3	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S4W1	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S4W2	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20
S4W3	<25.0	<5.0	<5.0	<30.0	<30.0	<.20	<.1	<5.0	<5.0	<.20

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Cis-1,3-Dichloropropene, total (µg/L)	Methylene blue active substance (mg/L)	Pentachlorophenol, total (µg/L)	1,2-Dibromoethylene, total (µg/L)	bis(2-ethylhexyl) phthalate, total (µg/L)	Di-n-butyl phthalate, total (µg/L)	Benzidine, total (µg/L)	Vinyl chloride, total (µg/L)	Trichloroethylene, total (µg/L)	Naphthalenes, polychloride, total (µg/)
S1W1A	<0.20	0.01	<30.0	<0.2	14.0	<5.0	<50.0	<0.20	<0.2	<1.0
S1W2	<.20	.01	<30.0	<.2	15.0	<5.0	<50.0	<.20	<.2	<1.0
S1W3	<.20	.01	<30.0	<.2	14.0	<5.0	<50.0	<.20	<.2	<1.0
S2W1	<.20	.03	<30.0	<.2	<5.0	<5.0	<50.0	<.20	<.2	<1.0
S2W2	<.20	.01	<30.0	<.2	<5.0	<5.0	<50.0	<.20	<.2	<1.0
S2W3	<.20	.01	<30.0	<.2	<5.0	<5.0	<50.0	<.20	<.2	<1.0
S3W1	<.20	.01	<30.0	<.2	<5.0	<5.0	<50.0	<.20	16.0	<1.0
S3W1 (Duplicate)	<.20	.01	<30.0	<.2	<5.0	<5.0	<50.0	<.20	16.0	<1.0
S3W2	<.20	.02	<30.0	<.2	<5.0	<5.0	<50.0	<.20	3,000	<1.0
S3W3	<.20	.02	<30.0	<.2	<5.0	<5.0	<50.0	<.20	4,600	<1.0
S4W1	<.20	.03	<30.0	<.2	<5.0	<5.0	<50.0	<.20	1.4	<1.0
S4W2	<.20	.01	<30.0	<.2	<5.0	<5.0	<50.0	<.20	.2	<1.0
S4W3	<.20	.01	<30.0	<.2	<5.0	<5.0	<50.0	<.20	<.2	<1.0

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	4,4'-DDT, total (µg/L)	4,4'-DDD, total (µg/L)	4,4'-DDE, total (µg/L)	Aldrin, total (µg/L)	alpha-BHC, total (µg/L)	beta-Benzene hexachloride, total (µg/L)	Lindane, total (µg/L)	Chlordane, total (µg/L)	Dieldrin, total (µg/L)	Endrin, total (µg/L)
S1W1A	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.010	<0.01	<0.010	<0.010
S1W2	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S1W3	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S2W1	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S2W2	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S2W3	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S3W1	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S3W1 (Duplicate)	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S3W2	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S3W3	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S4W1	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S4W2	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010
S4W3	<.01	<.01	<.01	<.010	<.01	<.01	<.010	<.01	<.010	<.010

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Ethion, total (µg/L)	Toxaphene, total (µg/L)	Heptachlor, total (µg/L)	Heptachlor epoxide, total (µg/L)	Aroclor 1221 PCB, total (µg/L)	Aroclor 1232 PCB, total (µg/L)	Aroclor 1242 PCB, total (µg/L)	Aroclor 1248 PCB, total (µg/L)	Aroclor 1254 PCB, total (µg/L)	Aroclor 1260 PCB, total (µg/L)
S1W1A	<0.01	<0.5	<0.010	<0.010	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S1W2	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S1W3	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S2W1	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S2W2	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S2W3	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S3W1	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S3W1 (Duplicate)	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S3W2	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S3W3	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S4W1	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S4W2	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1
S4W3	<.01	<.5	<.010	<.010	<.1	<.1	<.1	<.1	<.1	<.1

Table 9.--*Chemical analyses of water from U.S. Geological Survey monitoring wells*--Continued

[Well number: Number used to identify U.S. Geological Survey wells installed May to June 1987 and located on figure 3. °C, degree Celsius; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; NA, not analyzed; <, constituent concentration is less than detection limit, as given by indicated value; --, not applicable; µg/L, microgram per liter.]

Well number	Malathion, total (µg/L)	Parathion, total (µg/L)	Diazinon, total (µg/L)	Methyl parathion, total (µg/L)	Hexachlorobenzene, total (µg/L)	Hexachlorobutadiene, total (µg/L)	Trithion, total (µg/L)	Methyl trithion, total (µg/L)	Mercury, total recoverable (µg/L as Hg)	Styrene, total (µg/L)
S1W1A	<0.01	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	0.03	<0.10	<0.2
S1W2	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S1W3	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S2W1	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S2W2	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S2W3	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S3W1	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S3W1 (Duplicate)	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S3W2	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S3W3	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S4W1	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S4W2	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2
S4W3	<.01	<.01	<.01	<.01	<5.0	<5.0	<.01	<.01	<.10	<.2