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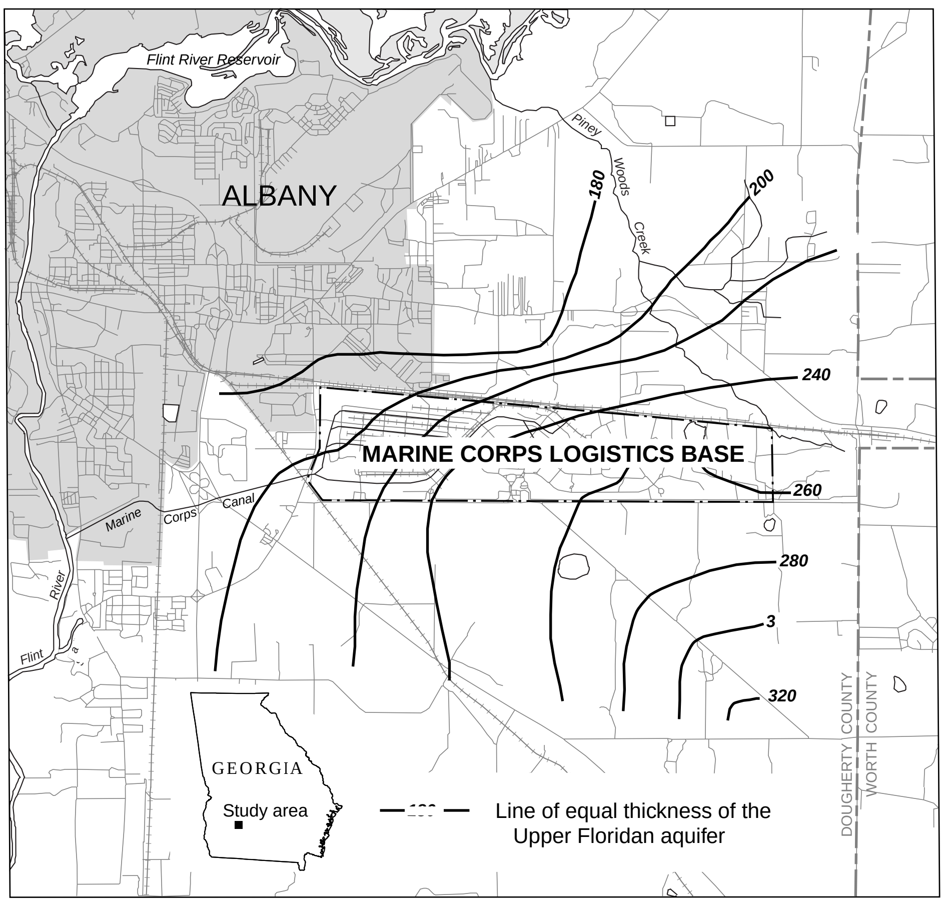
Hydrogeology of the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base near Albany, Georgia

Water-Resources Investigations Report 98-4202



Prepared in cooperation with
U.S. Department of the Navy
Southern Division Naval Facilities Engineering Command

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

HYDROGEOLOGY OF THE UPPER FLORIDAN AQUIFER IN THE VICINITY OF THE MARINE CORPS LOGISTICS BASE NEAR ALBANY, GEORGIA

By Kristen Bukowski McSwain

U.S. GEOLOGICAL SURVEY

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U.S. DEPARTMENT OF THE NAVY
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Atlanta, Georgia
1999

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
3039 Amwiler Road, Suite 130
Peachtree Business Center
Atlanta, GA 30360-2824

Copies of this report can be purchased from

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Box 25286
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CONVERSION FACTORS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.5900	square kilometer
acre	0.4047	square hectometer
	Volumetric rate	
gallon per minute (gal/min)	6.309×10^{-5}	cubic meter per second
	2.228×10^{-3}	cubic foot per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	43.86	liter per second
	Hydraulic conductivity	
feet per day (ft/d)	3.527×10^{-4}	centimeter per second
	0.3048	meter per day
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day

Temperature in degrees Celsius (° C), which can be converted to degrees Fahrenheit (° F) by using the following equation:

$$° F = 1.8 (° C) + 32$$

ABBREVIATIONS AND ACRONYMS

ABB-ES	ABB Environmental Services, Incorporated
ASTM	American Society of Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CLEAN	Comprehensive Long-Term Environmental Action, Navy
IR	Installation restoration
OU	Operable unit
PSC	Potential source of contamination
PVC	Polyvinyl chloride
RI/FS	Remedial Investigation and Feasibility Study
RI/RA	Remedial Investigation and Risk Assessment
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

VERTICAL DATUM

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

HYDROGEOLOGY OF THE UPPER FLORIDAN AQUIFER IN THE VICINITY OF THE MARINE CORPS LOGISTICS BASE NEAR ALBANY, GEORGIA

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ABSTRACT

In 1995, the U.S. Navy requested that the U.S. Geological Survey conduct an investigation to describe the hydrogeology of the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base, southeast and adjacent to Albany, Georgia. The study area encompasses about 90 square miles in the Dougherty Plain District of the Coastal Plain physiographic province, in Dougherty and Worth Counties—the Marine Corps Logistics Base encompasses about 3,600 acres in the central part of the study area.

The Upper Floridan aquifer is the shallowest, most widely used source of drinking water for domestic use in the Albany area. The hydrogeologic framework of this aquifer was delineated by description of the geologic and hydrogeologic units that compose the aquifer; evaluation of the lithologic and hydrologic heterogeneity of the aquifer; comparison of the geologic and hydrogeologic setting beneath the base with those of the surrounding area; and determination of ground-water-flow directions, and vertical hydraulic conductivities and gradients in the aquifer.

The Upper Floridan aquifer is composed of the Suwannee Limestone and Ocala Limestone and is divided into an upper and lower water-bearing zone. The aquifer is confined below by the Lisbon Formation and is semi-confined above by a low-permeability clay layer in the undifferentiated overburden. The thickness of the aquifer ranges from about 165 feet in the northeastern part of the study area, to about 325 feet in the southeastern part of the study area. Based on slug tests conducted by a U.S. Navy contractor, the upper water-bearing zone has low horizontal hydraulic conductivity (0.0224 to 2.07 feet per day) and a low vertical hydraulic conductivity (0.0000227 to 0.510 feet per day); the lower water-bearing zone has a horizontal hydraulic conductivity that ranges from 0.0134 to 2.95 feet per day.

Water-level hydrographs of continuously monitored wells on the Marine Corps Logistics Base show excellent correlation between ground-water level and stage of the Flint River. Ground-water-flow direction in the southwestern part of the base generally is southeast to northwest; whereas, in the northeastern part of the base, flow directions generally are east to west, as well as from west to east, thus creating a ground-water low. Ground-water flow in the larger study area generally is east to west towards the Flint River, with a major ground-water-flow path existing from the Pelham Escarpment to the Flint River and a seasonal cone of depression the size of which is dependent upon the magnitude of irrigation pumping during the summer months.

Calculated vertical hydraulic gradients (based upon data from 11 well-cluster sites on the Marine Corps Logistics Base) range from 0.0016 to 0.1770 foot per foot, and generally are highest in the central and eastern parts of the base. The vertical gradient is downward at all well-cluster sites.

INTRODUCTION

Historical waste-disposal practices, as well as spills of polychlorinated biphenyls, volatile organic compounds, and heavy metals, have resulted in soil and ground-water contamination at the Marine Corps Logistics Base (MCLB), Albany, Ga. Three investigations have been conducted at the MCLB to evaluate contamination related to releases and disposals of toxic and hazardous materials as a component of the Department of Defense Installation Restoration program (IR) (Envirodyne Engineers, 1995; McClelland Engineers, 1987; and Applied Engineering and Science, 1989). As a result of these investigations, the U.S. Environmental Protection Agency (USEPA) placed the MCLB on the National Priorities List of hazardous waste sites in December 1989. Sufficient data were collected by the three studies to indicate the need for a remedial response as mandated by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

At the request of the U.S. Navy, Southern Division Naval Facilities Engineering Command, the U.S. Geological Survey (USGS) began a cooperative investigation in 1995 to describe the hydrogeology of the Upper Floridan aquifer in the vicinity of the MCLB. Twenty-six potential source of contamination (PSC) areas have been identified at the MCLB and grouped into five operable units (OU's). Previous to USGS involvement, ABB Environmental Services, Inc. (ABB-ES), was contracted under the Comprehensive Long-Term Environmental Action, Navy (CLEAN) program to prepare Remedial Investigation and Feasibility Study (RI/FS) workplans, site-screening workplans, and associated planning documents for 14 RI/FS PSCs and 12 site-screening PSCs. In 1996, a sixth operable unit (OU 6) was created by the USEPA and Georgia Department of Natural Resources, Environmental Protection Division to specifically address the issue of basewide ground-water contamination in the Upper Floridan aquifer. ABB-ES has completed considerable field work for the Remedial Investigation and Risk Assessment (RI/RA) for five OU's. However, additional data were needed by the Navy to develop remediation plans and to complete the basewide characterization of the Upper Floridan aquifer, which is the shallowest widely used source of ground water for domestic use in the Albany area and a major regional water supply. The objective of this study is to provide detailed information about the hydrogeologic framework and the hydrologic characteristics of the Upper Floridan aquifer around Albany.

Purpose and Scope

This report describes the results of an investigation of the hydrogeology of the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base, located southeast and of and adjacent to Albany, Ga. The hydrogeology is described by the delineation and analysis of the hydrogeologic framework. Specifically, the hydrogeologic framework includes:

- a description of the geologic and hydrogeologic units that compose the ground-water system of the Upper Floridan aquifer;
- an evaluation of the lithologic and hydrologic heterogeneity within the Upper Floridan aquifer;
- a comparison of geologic and hydrogeologic conditions on the MCLB and in surrounding area; and
- a determination of ground-water-flow directions within the Upper Floridan aquifer.

As part of this investigation, existing geologic and hydrogeologic data were compiled, 22 additional wells were drilled, 254 wells were inventoried, and undisturbed core samples, borehole geophysical logs, and ground-water levels were collected over a two-year period from 1995 to 1997. These data were analyzed to describe the geology and hydrology of the Upper Floridan aquifer.

Description of Study Area and Marine Corps Logistics Base

The study area (fig. 1) lies on the eastern edge of the Dougherty Plain district of the Coastal Plain physiographic province (Clark and Zisa, 1976) in southwestern Georgia, about 200 miles south of Atlanta. The study area encompasses about 90 square miles southeast and adjacent to the city of Albany and the Flint River and includes parts of Dougherty and Worth Counties.

Although the study area lies totally in the Dougherty Plain District, topography in the study area is affected by the close proximity of the Pelham Escarpment, which separates the Dougherty Plain District from the Tifton Upland District to the east (fig. 1). Topography in the western part of the study area is relatively flat, because it is in the floodplain of the Flint River. The close proximity of the Pelham Escarpment causes significant topographic relief on the eastern edge of the study area, with altitudes ranging from 150 to 325 feet (ft) above sea level. The Dougherty Plain is characterized by karst topography and contains numerous sinkholes and depressional wetlands. Although no active sinkholes were identified in the study area, several depressions that seasonally contain water are present throughout the southern part of the study area.

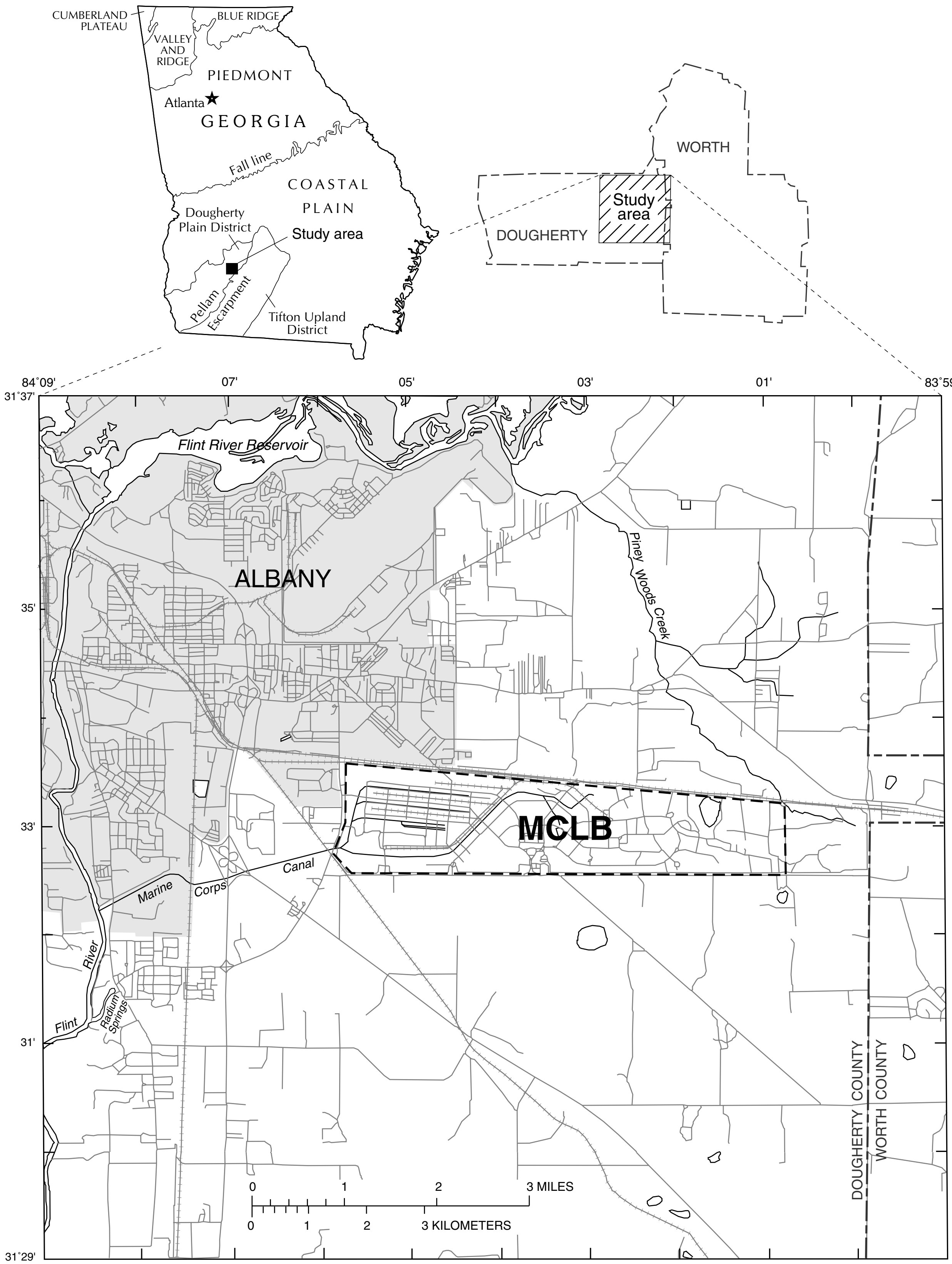


Figure 1. Location of study area and Marine Corps Logistics Base (MCLB).

Average annual rainfall for the Albany area was 50.03 inches during the period January 1931 to May 1997 and ranged from a minimum of 32.06 inches in 1954, to 70.61 inches in 1994 (Georgia State Climate Office, *accessed* July 8, 1997). In general, October and November are the driest; and March, June, and July are the wettest months.

The study area is drained by the Marine Corps Canal and Piney Woods Creek. These streams discharge to the Flint River, which is the principal surface-water drainage for the area. The Flint River is used for power generation and recreational purposes, primarily fishing. The Marine Corps Canal originates in the central part of the MCLB (fig. 1) and flows west to the Flint River. Piney Woods Creek flows northwest and discharges to the Flint River north of Albany in the Flint River Reservoir (fig. 1).

In the study area, numerous wells yield ground-water supplies for domestic, industrial, and irrigation uses. Domestic wells are typically 300 ft deep or less and withdraw water from the Upper Floridan aquifer (Torak and others, 1993). Irrigation wells also typically tap the Upper Floridan aquifer, but some are deeper and also tap the Claiborne and Clayton aquifers (Hicks and others, 1981). Industrial supply wells vary in depth and may tap aquifers beneath the Upper Floridan aquifer. Several Albany Water, Gas, and Light Company municipal supply wells are located in the study area, but these wells typically exceed 700 ft in depth and are completed below the Upper Floridan aquifer.

Land use is mainly industrial and residential, with lesser amounts of agriculture. In the northern and western parts of the study area, land use is predominantly large industrial complexes interspersed with residential housing communities. Residential housing is also located in the eastern and southern parts of the study area, but is sparse and bordered by large pecan orchards and row-crop agriculture.

The about 3,600-acre MCLB facility has been in operation since the early 1950's when it was constructed by the Marine Corps. The MCLB is centrally located in the study area and borders the southeastern city limits of Albany in Dougherty County (fig. 1). The primary responsibility of the MCLB is to coordinate the distribution of supplies to other Marine Corps facilities on the East Coast of the United States. Two divisions—the Central Repair and Facilities and Services Divisions—operate at the MCLB. The Central Repair Division rebuilds vehicles, radar, and other types of equipment; whereas, the Facilities and Services Division repairs and maintains MCLB property and equipment. Hazardous wastes are generated onsite by both divisions—through processes of electroplating, stripping, cleaning, and painting. As recently as 1988, wastes generated as part of MCLB activities were disposed of in landfills located on MCLB property (ABB-Environmental Services, Inc., 1991).

Industrial areas are located mainly in the western part of the MCLB. Base housing, playgrounds, and recreational areas are located on the eastern side of the MCLB, including a nine-hole golf course located immediately southwest of base housing (fig. 2). Additional recreational areas are located in the central part of the base. A pecan grove covering approximately 240 acres occupies the southwestern corner of the MCLB.

Water supply for the MCLB is obtained from three wells (13L018, 13L019, and 13L025, Appendix A) that primarily obtain water from the Claiborne, Clayton, and Providence aquifers. However, two of the wells (13L018 and 13L025) also are completed in the lower part of the Upper Floridan aquifer. These three wells provide potable water for the military residents and civilian employees of the base, as well as process water for MCLB industrial activities. Several surface-water bodies are located on the MCLB; however, these ponds are not used for water supply, but rather for recreational purposes.

Ground-water flow characteristics for ten potential source of contamination (PSC) areas on the MCLB were included in this investigation: PSC's 1, 2, 3, 6, 10, 11, 12, 13, 22, and 26. Locations of the PSC areas are shown in figure 2. Laboratory analyses of water samples collected by ABB-ES previous to this study (ABB-ES 1995a, b), indicate that as of September 1995, ground-water contamination existed at all PSC areas included in this investigation, with the exception of PSC 11. However, discussion of ground-water contamination on the MCLB and in the study area is beyond the scope of this report. Operable Unit 6 amalgamates all ground-water concerns into one working unit rather than treating each PSC as an individual unit.

Well-Numbering System

In this report, wells inventoried by the USGS are numbered using a system based on USGS topographic maps. Each 7½-minute topographic quadrangle map in Georgia has been assigned a number and letter designation beginning at the southwest corner of the State. Numbers increase eastward through 39, whereas letters advance northward through "Z," then double-letter designations "AA" through "PP" are used. The letters "I," "O," "II," and "OO" are not used. Wells inventoried in each quadrangle are numbered sequentially beginning with "1." Thus, the 25th well inventoried in the Albany East quadrangle (designated as 13L) in Dougherty County is designated as well 13L025. Wells installed and numbered by ABB-ES contain the prefix ALB followed by a two-digit number designating the PSC containing the well, followed by a hyphen, sequential digits, and a letter, such as ALB03-15B.

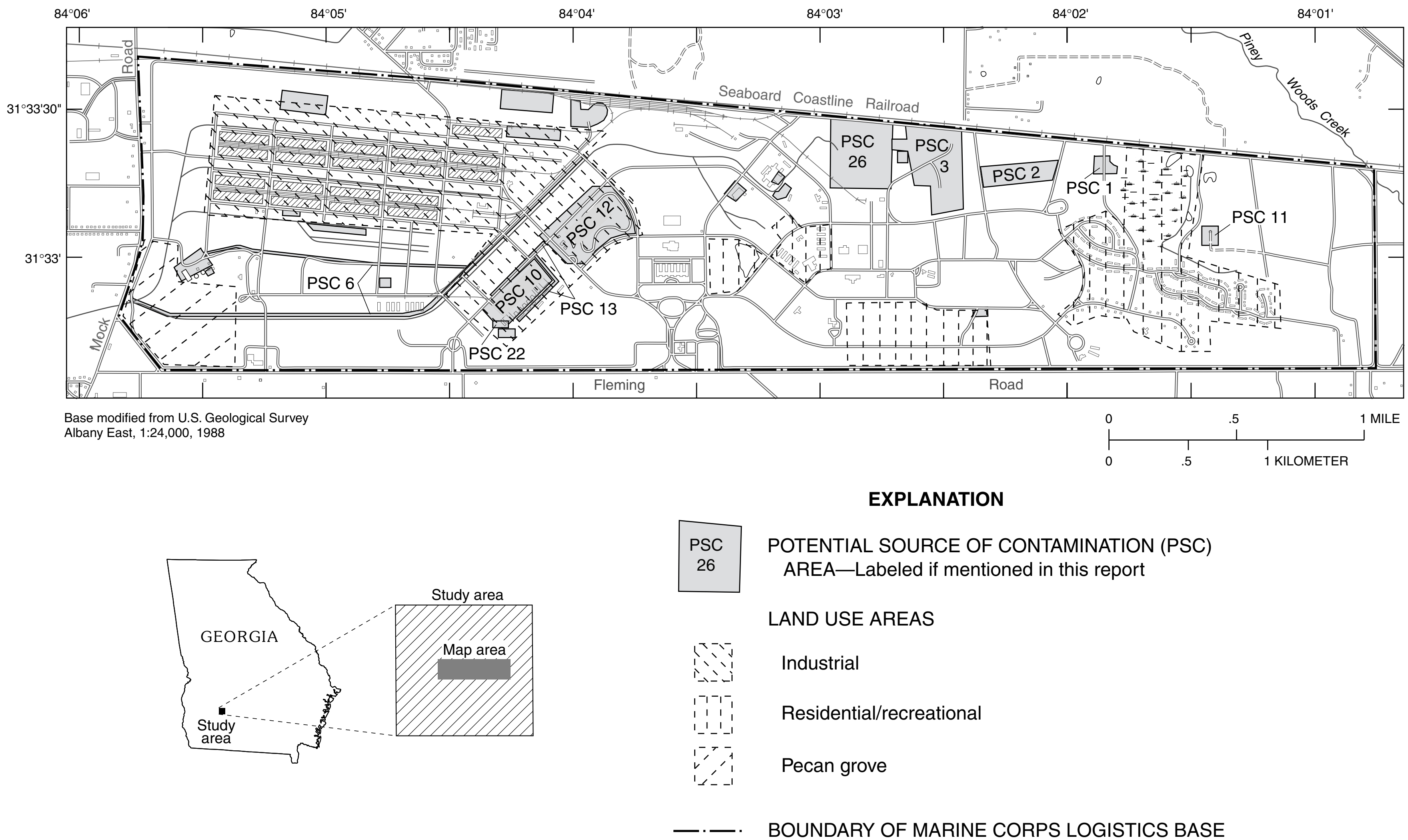


Figure 2. Locations of Marine Corps Logistics Base potential sources of contamination (PSC) and land-use areas.

Methods of Investigation

At the beginning of this study, a hydrogeologic literature review was conducted from the Dougherty County Health Department and Dougherty County Public Library. The Dougherty County Public Library is the repository for reports that describe environmental investigations conducted as part of the CERCLA process in the Albany area. Available hydrogeologic data collected by ABB-ES and previous contractors at MCLB were compiled and merged with regional data contained in the USGS National Water Information System (NWIS) database.

Data were collected for a total of 276 wells and compiled into a database for the study area. The majority of these data are from 178 monitoring wells installed on the MCLB as part of the RI/FS process. In addition to monitoring wells, 98 wells from the region surrounding MCLB within the study area were included in the database. These data were compiled and evaluated; and data gaps were identified. A listing of well data used for this report is provided in Appendixes A and B.

From September 1995 to January 1996, a preliminary examination of the subsurface lithology of the MCLB was conducted by drilling three coreholes that fully penetrated the Upper Floridan aquifer. Geologic core samples were archived in wooden core boxes and stored at the MCLB. Lithologic descriptions of collected core are provided in Appendix C.

Upon completion of each corehole, borehole geophysical logging was conducted. Natural gamma, temperature, and caliper logs were collected in each borehole. Short normal resistivity, long normal resistivity, and self-potential logs were attempted in each corehole; however, due to equipment problems, these logs were considered to be unreliable and were not used. Borehole logs and geologic cores were used to plan casing depth and open-hole intervals in each well. Each corehole was over-reamed to casing depth using either a 10- or 12-inch diameter tri-cone roller bit and mud-rotary drilling methods. Casing was installed and tremie grouted in place. After the grout cured, each well was completed by extending a tri-cone roller bit through the casing and air-rotary drilling to the final depth.

Each of the three coreholes was completed as the deep Upper Floridan aquifer monitoring well of a well-cluster site. One shallow, partially penetrating Upper Floridan aquifer monitoring well was installed within 100 ft of each corehole site to complete the cluster. Borehole geophysical logs and geologic cores were also utilized for casing and screen placement of each shallow monitoring well. Each of the three deep wells and one of the shallow wells was equipped with a continuous water-level recorder. A generalized drawing of well construction at a typical cluster site is shown in figure 3. Well-construction details are provided in table 1, and well locations are shown in figure 4.

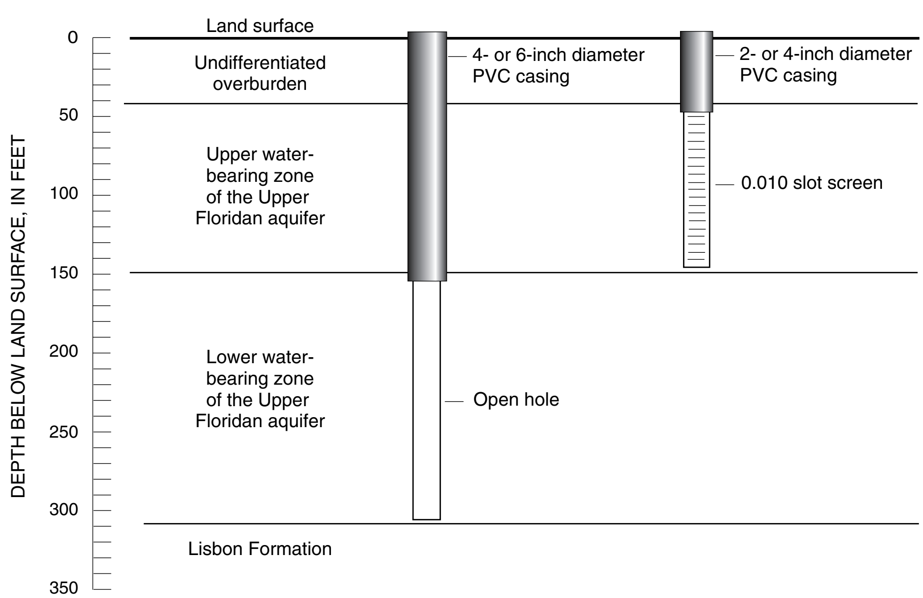
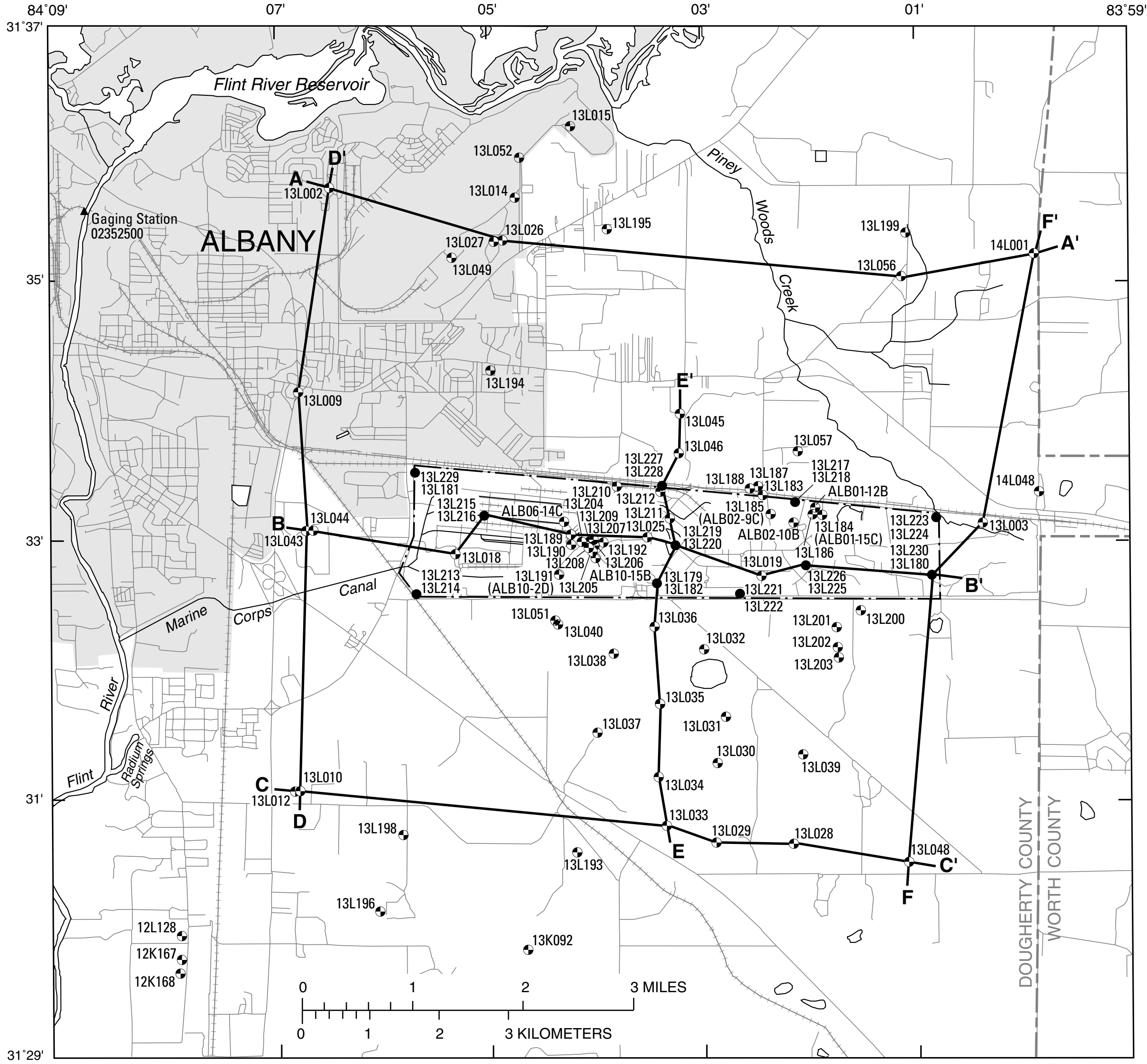


Figure 3. Generalized well construction at a typical cluster site.

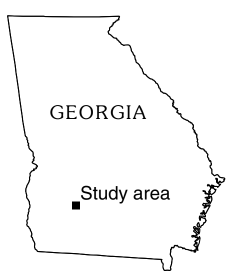
Table 1. Well construction at well-cluster sites installed at the Marine Corps Logistics Base near Albany, Georgia, from September 1995 to March 1997

[HSA, hollow stem auger; do., ditto]

Well number (figure 4)	Latitude	Longitude	Construction date	Land-surface altitude (feet)	Depth (feet below land surface)	Casing		Type of open interval	Water-bearing zone of the Upper Floridan aquifer	Drilling method
						Diameter (inches)	Depth (feet below land surface)			
13L179	31°32'46"	84°03'22"	December 1995	220.7	120.0	2	70.0	screen	upper water-bearing zone	mud/air rotary
13L180	31°32'47"	84°00'50"	October 1995	230.1	310.0	4	220.0	open hole	lower water-bearing zone	rotary coring/mud/air rotary
13L181	31°33'39"	84°05'37"	November 1995	194.2	225.0	4	140.0	open hole	do.	rotary coring/mud/air rotary
13L182	31°32'47"	84°03'19"	September 1995	219.1	270.0	6	185.0	open hole	do.	rotary coring/mud/air rotary
13L213	31°32'38"	84°05'35"	October 1996	190.8	252.0	4	186.0	open hole	do.	rotosonic/air rotary
13L214	31°32'38"	84°05'35"	January 1997	190.3	114.1	4	43.5	screen	upper water-bearing zone	HSA/mud rotary
13L215	31°33'16"	84°04'57"	October 1996	193.4	257.0	4	165.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L216	31°33'16"	84°04'57"	December 1996	193.3	124.3	4	44.3	screen	upper water-bearing zone	HSA/mud rotary
13L217	31°33'24"	84°02'05"	October 1996	224.5	302.0	4	195.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L218	31°33'24"	84°02'05"	February 1997	224.8	145.0	4	65.0	screen	upper water-bearing zone	mud rotary
13L219	31°33'04"	84°03'15"	October 1996	211.2	296.0	4	187.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L220	31°33'04"	84°03'15"	November 1996	210.9	150.0	4	60.0	screen	upper water-bearing zone	mud rotary
13L221	31°32'38"	84°02'35"	October 1996	248.8	332.0	4	235.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L222	31°32'38"	84°02'34"	February 1997	249.1	171.0	4	140.0	screen	upper water-bearing zone	mud rotary
13L223	31°33'18"	84°00'51"	November 1996	223.3	297.0	4	195.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L224	31°33'18"	84°00'50"	February 1997	223.3	155.0	4	66.0	screen	upper water-bearing zone	mud rotary
13L225	31°32'51"	84°01'57"	November 1996	255.3	318.0	4	195.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L226	31°32'52"	84°01'57"	March 1997	255.1	163.0	4	83.0	screen	upper water-bearing zone	mud rotary
13L227	31°33'30"	84°03'21"	November 1996	214.7	272.0	4	196.0	open hole	lower water-bearing zone	rotosonic/air rotary
13L228	31°33'30"	84°03'22"	January 1997	214.8	137.0	4	55.0	screen	upper water-bearing zone	mud rotary
13L229	31°33'39"	84°05'36"	November 1995	194.7	100.0	2	50.0	screen	do.	mud/air rotary
13L230	31°32'48"	84°00'50"	October 1995	230.3	150.0	2	80.0	screen	do.	mud/air rotary



Base from U.S. Geological Survey Digital Files



EXPLANATION

A —— A' LINE OF GEOLOGIC SECTION—
Sections shown in Figure 6

—·—·— BOUNDARY OF MARINE CORPS LOGISTICS BASE

12K168 WELL AND NUMBER

13L213
13L214 WELL CLUSTER AND WELL NUMBERS

Figure 4. Selected well locations and lines of geologic section.

Eight additional well clusters were installed from August 1996 to March 1997 using a combination of drilling methods that included hollow-stem auger, air rotary, mud rotary, and rotosonic. The deep Upper Floridan aquifer wells were drilled using rotosonic drilling methods and a 4-inch diameter bit. Each test hole was extended until competent limestone was penetrated. Each test hole then was over-reamed with an 8-inch diameter bit and 4-inch diameter polyvinyl chloride (PVC) casing was pressure grouted in place. After the grout cured, each well was completed as an open hole by air-rotary methods using a 3 7/8-inch diameter tri-cone roller bit. Lithologic logs of these wells are provided in Appendix C.

Shallow Upper Floridan aquifer wells were installed at the clusters after completion of the deeper wells. The first two wells were attempted at sites 13L214 and 13L216 using hollow-stem auger methods. However, lenses of competent limestone prevented drilling of these wells to the necessary depth using this method. Instead, mud-rotary methods were used to drill a 6-inch diameter pilot hole which was then over-reamed with an 8 7/8-inch tri-cone roller bit. At each well cluster, three selected undisturbed samples were obtained at random depth intervals from the upper part of the Ocala Limestone using a pitcher-barrel sampler during drilling of the pilot hole. Undisturbed samples were sent to an American Society of Testing and Materials (ASTM) certified laboratory, for geotechnical analyses. These analyses included (but were not limited to): grain size, organic content, unified soil classification, vertical hydraulic conductivity, and Atterberg limits. Well-construction details are provided in table 1 and well locations are shown on figure 4. Geotechnical analyses are summarized in table 2. Upon completion of the eight well-cluster sites, natural gamma, temperature, and caliper borehole geophysical logs were run in six of the deep wells (wells 13L213, 13L215, 13L219, 13L221, 13L225, and 13L227). These geophysical logs were correlated with core and drill cuttings to help delineate the hydrogeologic framework of the Upper Floridan aquifer.

Previous Investigations

Several studies have been conducted on the geology, hydrology, and water quality of the Upper Floridan aquifer in the Albany area. Wait (1960) described the source and quality of ground water in southwest Georgia, that included data collected in 28 towns located in 25 counties. That study correlated quality of water with rock type and geologic formation, and also reported that wells in Dougherty County that are completed in the Upper Floridan aquifer yielded about 200 to 1,700 gallons per minute (gal/min) and that the water had excellent quality.

Hicks and others (1981) discussed the hydrogeology of the Albany area by evaluating the development potential of ground-water resources. Although the main focus was on deeper aquifers, some information was provided on the Upper Floridan aquifer. Hicks and others (1981) reported that transmissivities of the Upper Floridan aquifer exceed 100,000 feet squared per day (ft^2/day) and that wells in this area produce as much as 2,000 gal/min with minimal drawdown. As of 1981, long-term water-level declines had not been observed in the Upper Floridan aquifer in the Albany area.

Hayes and others (1983) described the hydrology of the Upper Floridan aquifer in the Dougherty Plain District in southwestern Georgia. That study defined the hydrogeology of the Upper Floridan aquifer through a test-well-drilling program and utilized an existing ground-water-flow model to simulate regional water-level changes based on pumping increases. The digital model analysis concluded that during drought conditions, present demands and reduced recharge to the aquifer could result in water-supply problems.

Hicks and others (1987) described the hydrogeology of the Upper Floridan aquifer in the vicinity of Dougherty County, including an assessment of the ground-water quality and development potential. The report describes the thickness and areal extent of the Ocala Limestone and the possible effects of chemical contaminants on ground-water supply. That study was the first to recognize that the Upper Floridan aquifer is locally separated into an upper and lower water-bearing zone.

Chapman (1991) described the hydrogeologic framework of the Upper Floridan aquifer and its relation to the overlying unconsolidated sediments at an abandoned manufactured gas plant in Albany, on the western side of the Flint River. The hydrogeologic characteristics of the aquifer were described based on geologic logs and borehole geophysical logs. The hydrogeologic characteristics of the unconsolidated sediments were described from hydraulic-conductivity analyses of clay samples.

Torak and others (1993) described the geohydrologic system of the Upper Floridan aquifer and applied a digital model to evaluate its water-resource potential. Simulated hydrologic conditions tested in that report include periods of low streamflow and ground-water levels, and the effect of ground-water pumping in an area of potential ground-water development located south of the city of Albany.

Warner (1997) described the hydrogeology of the Upper Floridan aquifer in the southwestern Albany area, west of the Flint River. During that study, an aquifer test was conducted to determine hydraulic properties of the Upper

Table 2. Summary of geotechnical laboratory data analyzed from samples collected from the upper unit of the Ocala Limestone (upper water-bearing zone of the Upper Floridan aquifer

[ML, silt; SM, silty sand; CL, lean clay; SC, clayey sand; —, data not available; do., ditto]

Well number	Sample depth (feet below land surface)	Fines (percent)	Natural moisture content (percent)	Atterberg limits: Liquid limit (percent)	Atterberg limits: Plastic limit (percent)	Atterberg limits: Plasticity index (percent)	Specific gravity	Organic content (percent)	Bulk density/wet-unit weight (pounds per cubic foot)	Vertical hydraulic conductivity (centimeter per second)	Vertical hydraulic conductivity (feet per day)	Porosity	Unified soil classification	Description
13L214	54.5-57.5	59	31	26	non-plastic	non-plastic	2.72	0.3	122.7	8.90×10^{-06}	2.52×10^{-02}	0.449	ML	white gray and tan sandy silt
	79-81.5	47	29	19	do.	do.	2.70	.4	119.9	8.80×10^{-06}	2.49×10^{-02}	.450	SM	white gray and tan silty fine to medium sand
	104.5-106	48	25	22	do.	do.	2.70	.3	122.2	1.70×10^{-05}	4.82×10^{-02}	.420	SM	do.
13L216	58.5-61	73	16	22	16	6	2.69	.7	132.2	3.30×10^{-07}	9.35×10^{-04}	.320	CL	grayish white sandy clayey silt
	85-87.5	51	—	21	non-plastic	non-plastic	2.65	1.7	108.4	4.80×10^{-06}	1.36×10^{-02}	.540	ML	tan sandy silt
	115-117.5	21	39	28	do.	do.	2.66	.4	114.5	4.50×10^{-05}	1.28×10^{-01}	.504	SM	tannish gray silty fine to medium sand
13L218	55-57	50	30	22	do.	do.	2.71	.9	114.1	5.00×10^{-05}	1.42×10^{-01}	.481	ML	white sandy silt
	95-97	71	15	20	17	3	2.69	.1	117.2	1.00×10^{-07}	2.83×10^{-04}	.395	ML	do.
	135-137	75	35	28	27	1	2.70	.2	111.6	3.40×10^{-06}	9.64×10^{-03}	.509	ML	pinkish white sandy silt
13L220	55-57	56	25	22	non-plastic	non-plastic	2.71	.2	—	7.10×10^{-05}	2.01×10^{-01}	—	ML	white sandy silt
	101-103	69	29	27	23	4	2.72	.5	—	1.50×10^{-06}	4.25×10^{-03}	—	ML	do.
	137-139	51	22	23	non-plastic	non-plastic	2.71	.5	—	7.10×10^{-06}	2.01×10^{-02}	—	ML	do.
13L222	135-137	72	23	22	do.	do.	2.71	.2	—	1.10×10^{-05}	3.12×10^{-02}	—	ML	do.
	150-152	73	29	23	19	4	2.69	.3	—	5.70×10^{-06}	1.62×10^{-02}	—	ML	do.
	165-167	63	23	23	21	2	2.70	.3	—	2.20×10^{-06}	6.24×10^{-03}	—	ML	do.
13L224	55-57	49	56	74	18	56	2.70	1.9	104.7	8.00×10^{-09}	2.27×10^{-05}	.600	SC	reddish brown clayey fine to coarse sand
	105-107	49	25	27	non-plastic	non-plastic	2.69	.6	122.9	1.00×10^{-05}	2.83×10^{-02}	.412	SM	grayish brown and white silty fine to coarse sand
	150-152	65	27	34	21	12	2.70	.5	130.5	9.20×10^{-07}	2.61×10^{-03}	.389	CL	gray brown and white sandy clay
13L226	85-87	54	27	24	non-plastic	non-plastic	2.72	.3	—	4.80×10^{-05}	1.36×10^{-01}	.430	ML	white sandy silt
	120-122	59	34	24	do.	do.	2.72	.3	—	5.80×10^{-05}	1.64×10^{-01}	.488	ML	do.
	160-162	58	23	21	do.	do.	2.69	.5	—	1.50×10^{-05}	4.25×10^{-02}	.403	ML	do.
13L228	55-57	54	37	21	do.	do.	2.70	.2	—	1.80×10^{-04}	5.10×10^{-01}	—	ML	do.
	85-87	71	41	29	do.	do.	2.69	.4	—	7.60×10^{-06}	2.15×10^{-02}	—	ML	do.
	125.5-127	55	25	24	do.	do.	2.70	1.1	—	3.20×10^{-06}	9.07×10^{-03}	—	ML	do.

Floridan aquifer. Borehole geophysical techniques were used to evaluate the vertical distribution of yield from the aquifer.

Acknowledgments

Many individuals assisted in the collection and compilation of data for this report. The author extends thanks to Joel R. Sanders, project manager, U.S. Navy, Southern Division Naval Facilities Engineering Command; and to Lt. G. Allen Frantz, Environmental Officer, Marine Corps Logistics Base for their support. Appreciation also is extended to the many members of ABB Environmental Services, Inc., Tallahassee, Fla., staff who provided data collected as part of the RI/FS process and assisted with the collection of new lithologic data for this report. Special thanks also is extended to the many land owners of the Albany area who allowed access to their properties for data collection.

GEOLOGY

Coastal Plain sediments of Cretaceous to Quaternary age underlie the study area. The sediments consist of alternating units of sand, clay, limestone, dolomite, and sandstone that thicken and dip toward the southeast. Only sediments of late-middle Eocene age and younger were investigated as part of this study. These include in ascending order, the Lisbon Formation, the Ocala Limestone, the Suwannee Limestone, and the undifferentiated overburden of Quaternary age. A generalized stratigraphic sequence of the sedimentary units in the study area is provided in figure 5.

Lisbon Formation

In the study area, the Lisbon Formation of middle Eocene age consists of argillaceous limestone that is light grayish green to cream in color. The formation contains very fine to medium, clear and yellow quartz sand that is sub-angular to sub-rounded and is poorly sorted. Generally, the formation contains abundant glauconite, phosphate, and marl. The thickness of the Lisbon Formation exceeds 100 ft in the study area.

Ocala Limestone

The Ocala Limestone of late Eocene age has been subdivided into three units in the Albany area, on the basis of different lithologic and hydrologic characteristics—a lower unit, a middle unit, and an upper unit (Hicks and others, 1987). Geologic sections (see figs. 4, 6) indicate thickening of the Ocala Limestone to the east and south. The lower unit is composed of an indurated recrystallized dolomitic limestone, that contains abundant fossils (mainly bryozoa and foraminifera) and shell fragments that decrease in size and quantity with depth. The limestone is light gray to white in color and locally contains very fine to fine, sub-angular to sub-rounded clear quartz sand. The thickness of the lower unit ranges from 65 ft in the northwestern part of the study area, to 150 ft in the southeastern part. On the MCLB, the lower unit ranges in thickness from 55 to 125 ft.

The lower unit grades upward into a middle unit that is composed of a relatively impermeable whitish tan, clayey, dense, chalky limestone with trace amounts of glauconite. The middle unit of the Ocala Limestone is present continuously on geologic section F-F' and on the eastern half of sections A-A', B-B', and C-C'; discontinuously in the section E-E'; and is not present in section D-D’ (fig. 6). This suggests that the middle unit of the Ocala Limestone was eroded in the northern and western parts of the study area before deposition of the upper unit. Although it is difficult to distinguish the middle unit from adjacent units in lithologic samples, natural gamma geophysical logs display a distinct increase in natural gamma count at the base of the unit (fig. 5). The approximate location of the surface projection of the westernmost edge of the middle unit in the study area is shown in figure 7. The middle unit occurs only in a discontinuous band in the eastern part of the study area. The maximum thickness of the middle unit is about 20 ft in the study area. On the MCLB, the maximum thickness of the middle unit is about 15 ft. In areas where the middle unit is missing, the lower unit is overlain directly by the upper unit.

The upper unit of the Ocala Limestone is composed of dense, highly weathered, pale gray to white, friable, chalky limestone that contains minor sand. The upper unit is aphanitic and fossiliferous, containing some hard lenses of recrystallized limestone and fine to medium, sub-angular to sub-rounded calcareous sand. Laboratory analyses indicate that this unit has a total porosity that ranges from about 39 to 60 percent. In the study area, the thickness of the upper unit ranges from about 50 to 150 ft. On the MCLB, the upper unit ranges in thickness from 70 to 125 ft.

Suwannee Limestone

In the study area, the Ocala Limestone is overlain by the Suwannee Limestone of Oligocene age; the formation has extensively weathered and eroded and is present in the study area as remnants. The Suwannee Limestone remnants are tan to brown calcareous clay, with interspersed cobble-sized gray and white chert nodules. The Suwannee Limestone was not identified on the MCLB, and is present discontinuously in the extreme southeastern part of the study area. Geologic sections C-C', E-E', and F-F' (fig. 6) show areas where the Suwannee Limestone is present.

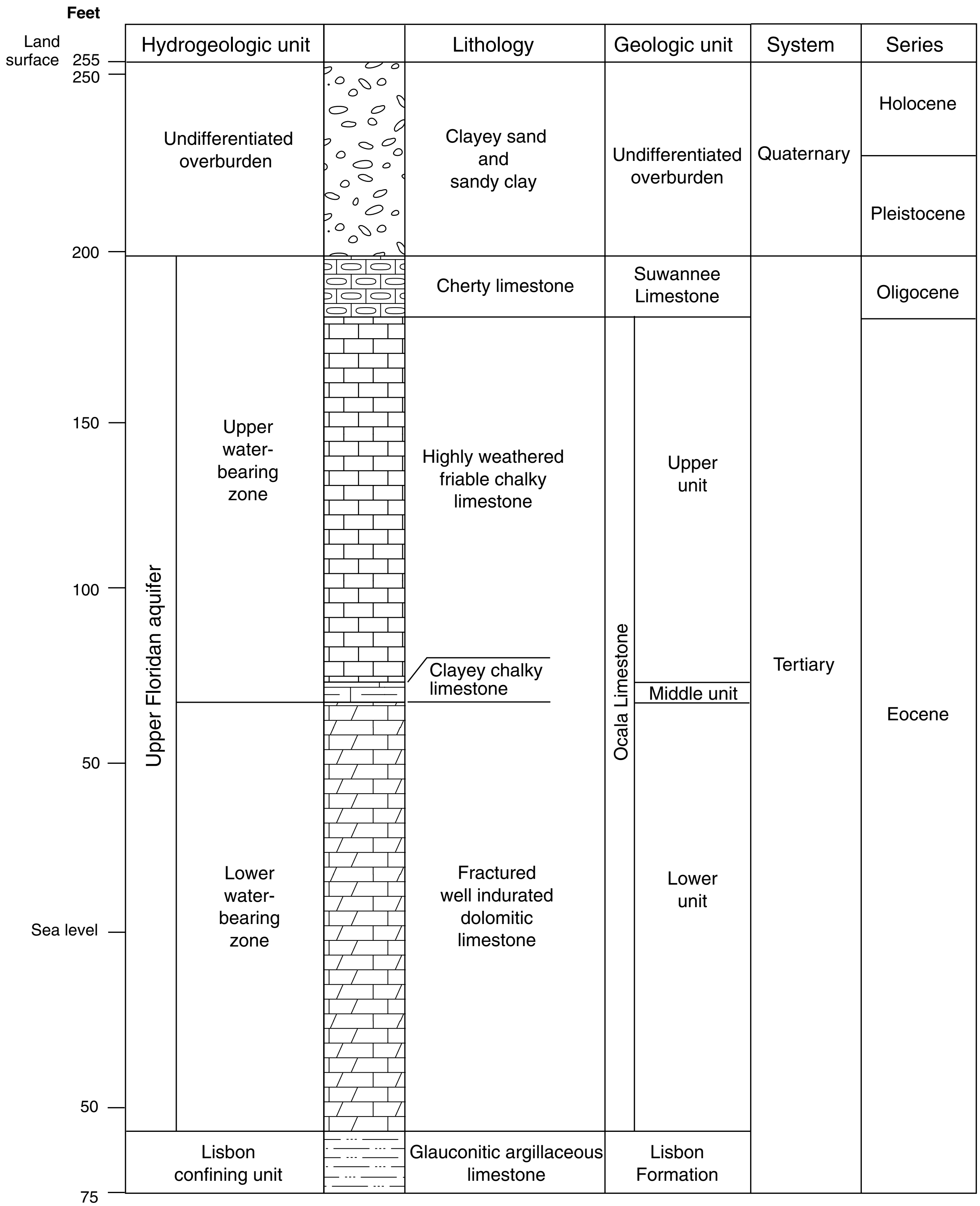


Figure 5. Generalized hydrogeology and geology in the study area; and caliper, natural gamma, and temperature logs for well 13L225.

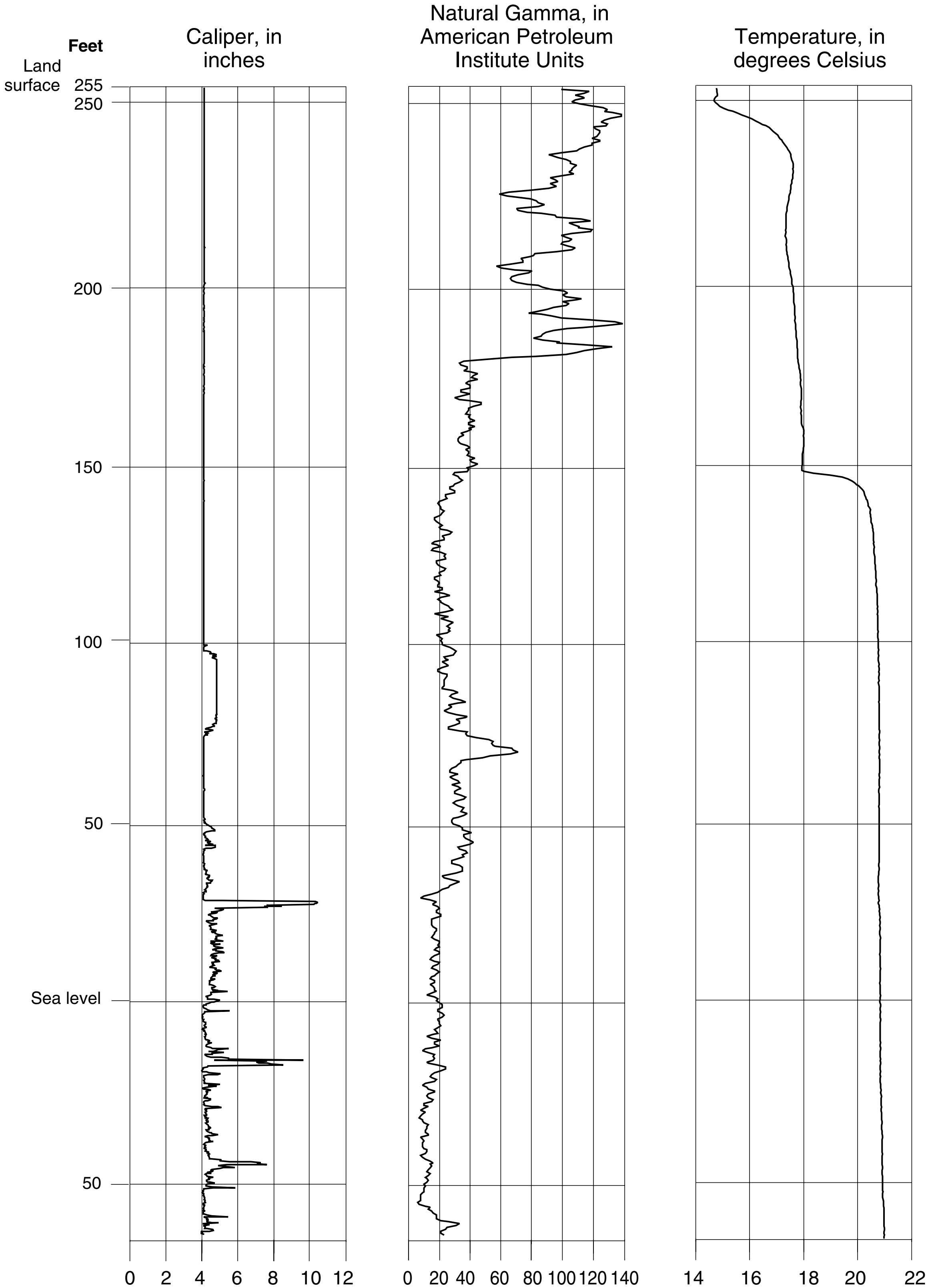


Figure 5. Generalized hydrogeology and geology in the study area; and caliper, natural gamma, and temperature logs for well 13L225—continued.

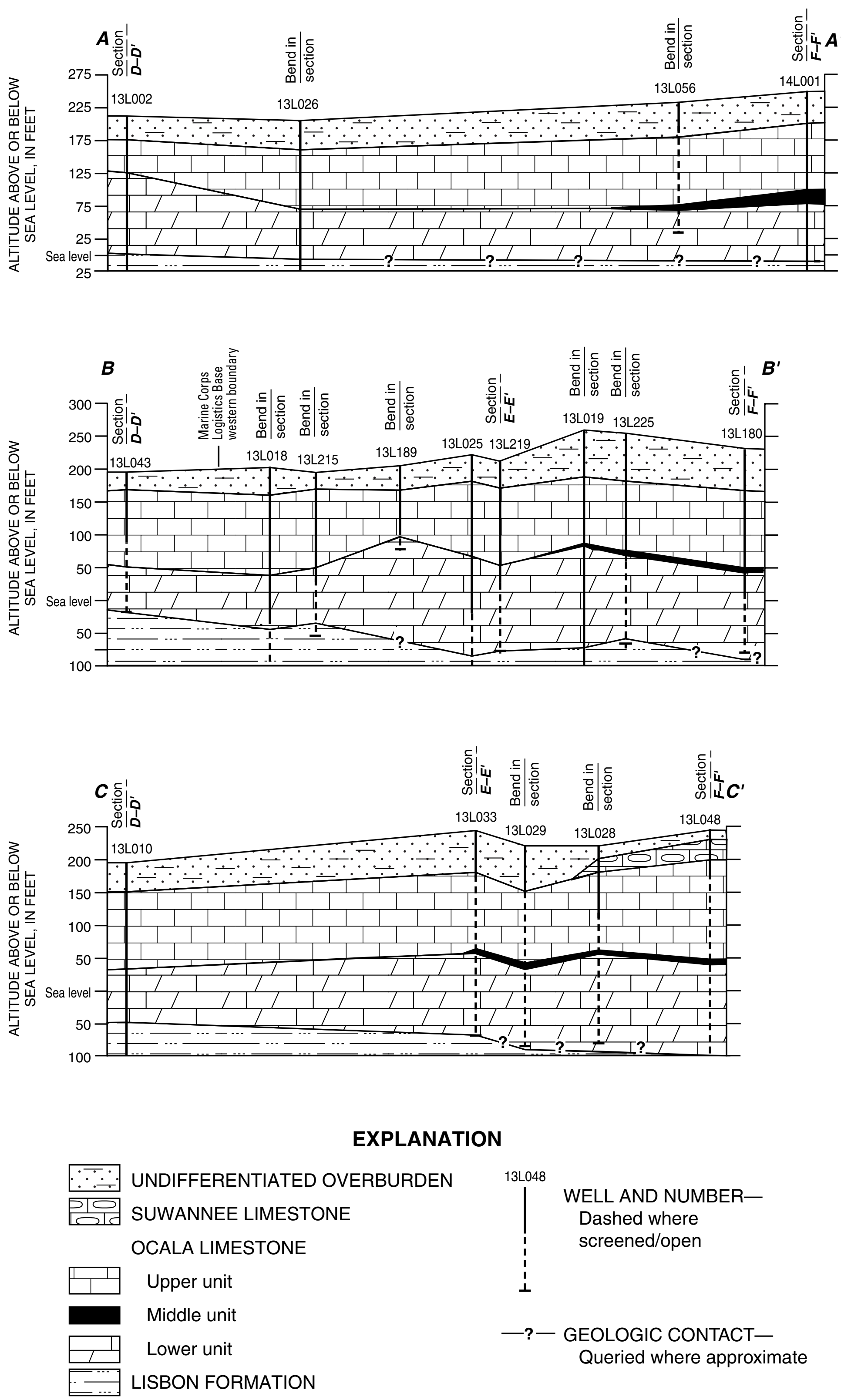
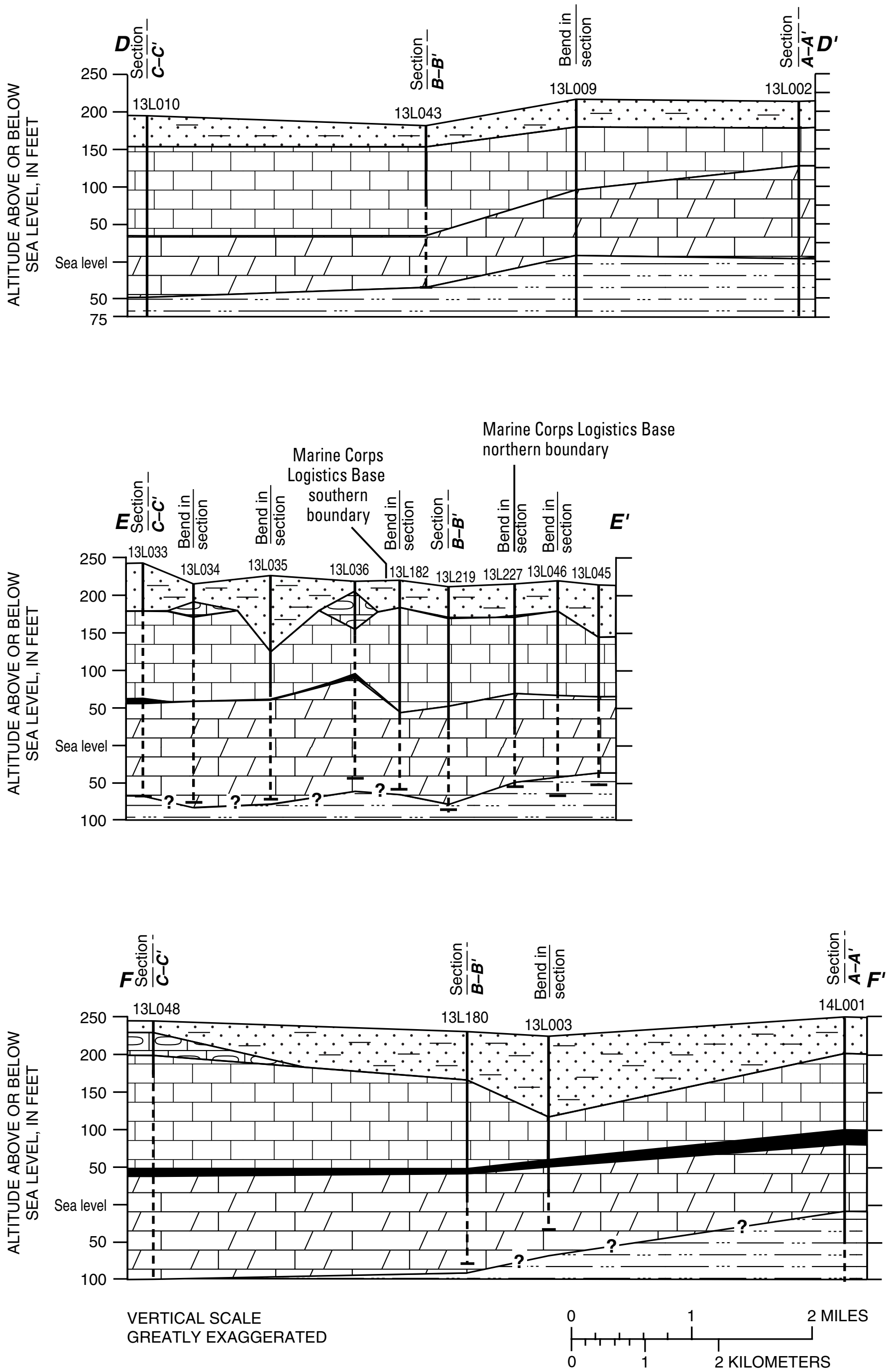
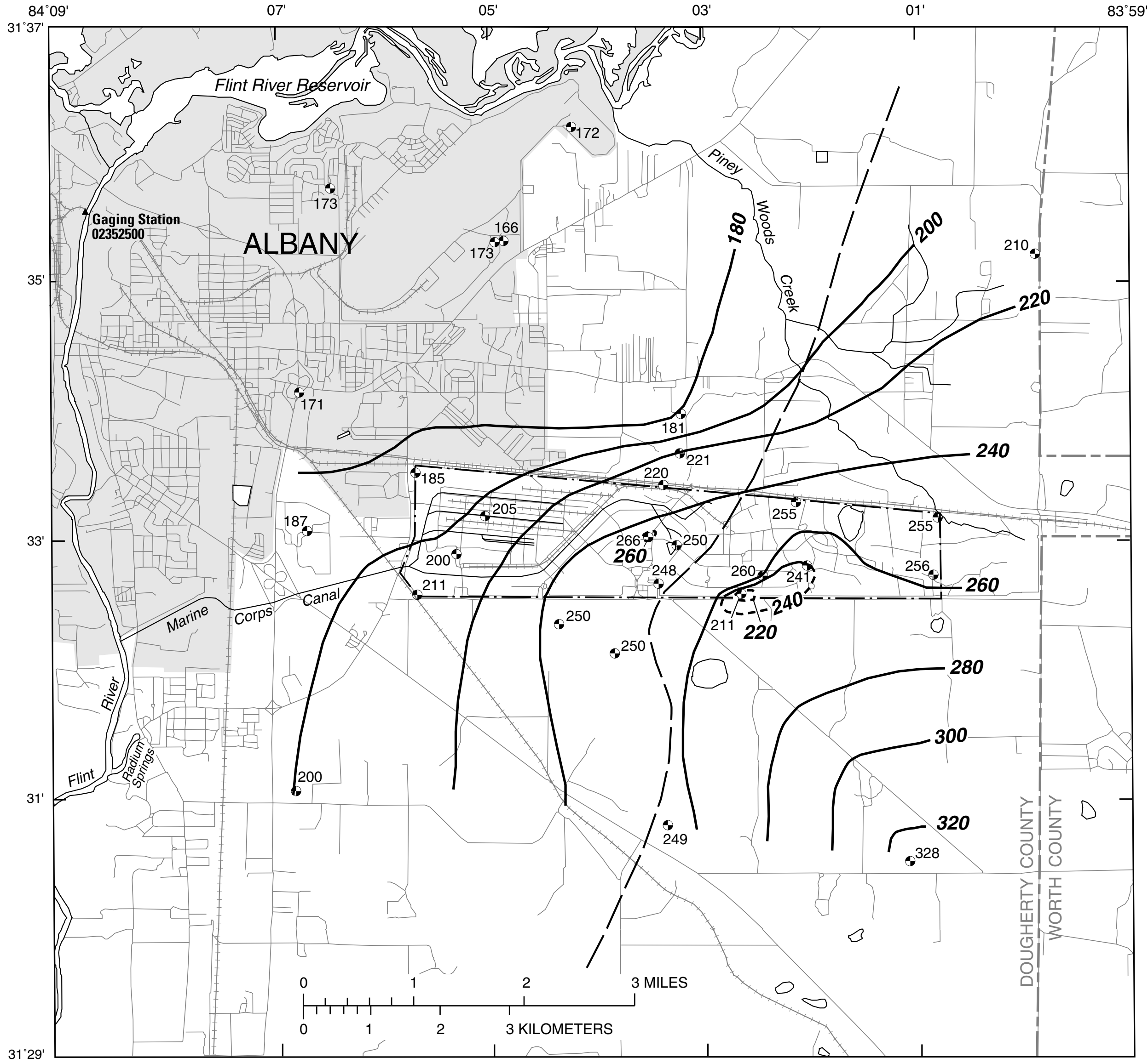


Figure 6. Geologic sections through the study area (lines of section are shown on figure 4).

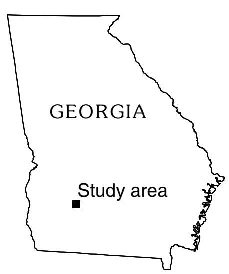


Note: Geologic sections were drawn using geophysical logs wherever possible or using drillers' logs if no geophysical logs were available. All logs are kept on file at the U.S. Geological Survey, Georgia District Office. Discrepancies in interpretation may exist between geophysical logs and drillers' logs. A list of available logs for each well is given in Appendix A.

Figure 6. Geologic sections through the study area (lines of section are shown on figure 4)—continued.



Base from U.S. Geological Survey Digital Files



EXPLANATION

—180 - - - LINE OF EQUAL THICKNESS OF THE UPPER FLORIDAN AQUIFER—Dashed where approximately located. Interval 20 feet

—— —— APPROXIMATE WESTERNMOST EXTENT OF THE MIDDLE UNIT OF THE OCALA LIMESTONE

—·—·— BOUNDARY OF MARINE CORPS LOGISTICS BASE

200 WELL—Number indicates thickness of the Upper Floridan aquifer, in feet

Note: Thickness of the Upper Floridan aquifer was measured using geophysical logs wherever possible, or using drillers' logs if no geophysical logs were available. All logs are kept on file at the U.S. Geological Survey, Georgia District Office. Discrepencies in interpretation may exist between geophysical logs and drillers' logs. A list of logs available for each well is given in Appendix A.

Figure 7. Thickness of the Upper Floridan aquifer in the study area.

Undifferentiated Overburden

The undifferentiated overburden of Quaternary age is the uppermost geologic unit in the study area. The thickness of the undifferentiated overburden in the study area and on the MCLB ranges from 15 to 105 ft, increasing markedly toward the east (fig. 6). The undifferentiated overburden consists mostly of sandy clay and clayey sand. Color varies from brown, red, purple, gray, to white. Sand in the undifferentiated overburden generally consists of clear to yellow quartz that is poorly sorted, fine to coarse grained, and angular to sub-rounded. At the base of the overburden, directly overlying the Ocala Limestone, an extensive layer of plastic, calcareous, brown clay was penetrated by drill holes; this clay is somewhat discontinuous in the western part of the study area. This clay is probably derived from the in-situ weathering of the Ocala Limestone. The thickness and lithology of the undifferentiated overburden is highly variable as a result of differential weathering, erosion, and dissolution of the underlying limestone.

HYDROGEOLOGY OF THE UPPER FLORIDAN AQUIFER

The major hydrogeologic unit in the study area is the Upper Floridan aquifer, which is composed of the Suwannee Limestone and the Ocala Limestone (fig. 5). The Upper Floridan aquifer is confined below by argillaceous limestone of the Lisbon Formation and semi-confined above by the overlying, low permeability clay layers of the undifferentiated overburden (Torak and others, 1993). For purposes of understanding hydrogeologic relations, the hydraulic characteristics of the undifferentiated overburden is included in this discussion.

Hydraulic Characteristics of the Undifferentiated Overburden

Sandy layers in the undifferentiated overburden contain ground water in localized and seasonally perched zones; however, these surficial aquifers typically are hydraulically isolated from the Upper Floridan aquifer. Although the surficial aquifers generally are separated from the Upper Floridan aquifer by regionally extensive clay layers that can exceed 10 ft in thickness, vertical leakage may occur at very low rates as a result of discontinuities or lithologic variations within the clay layers. According to Hayes and others (1983), the estimated horizontal hydraulic conductivity of the undifferentiated overburden ranges from 0.001 to 9 feet per day (ft/d) in the Albany area. On the MCLB, the horizontal hydraulic conductivity of the undifferentiated overburden ranges from 0.061 to 5.34 ft/d (ABB Environmental Services, Inc., 1997) and the vertical hydraulic conductivity of the undifferentiated overburden ranges from 0.000011 to 0.00054 ft/d (Ashok Mangla, Atlanta Testing and Engineering, written communication, February 27, 1997).

Hydraulic Characteristics of the Upper Floridan Aquifer

The Upper Floridan aquifer nearly doubles in thickness to the southeast toward the Pelham Escarpment, where the Suwannee Limestone is included as part of the aquifer. The thickness of the aquifer ranges from about 165 ft in the northeastern part of the study area, to about 325 ft in the southeastern part of the study area (fig. 7).

Hydraulically, the Upper Floridan aquifer is locally divided into two water-producing zones based on lithologic and structural differences (Hicks and others, 1987). The upper water-bearing zone is composed of the middle and upper units of the Ocala Limestone and the Suwannee Limestone (fig. 5). In the study area, wells open to this zone produce very small amounts of water, on the order of 2 gal/min. The upper water-bearing zone has low transmissivity and behaves as a leaky confining unit that separates the undifferentiated overburden from the lower water-bearing zone (Hicks and others, 1987). Variations in the thickness of the upper water-bearing zone determine the extent to which this zone behaves as a hydrologic barrier for transmitting water vertically between the lower water-bearing zone and the undifferentiated overburden (Torak and others, 1993).

Slug tests were conducted in wells located in PSC areas 1, 2, 3, 11, and 26 (fig. 2), on the MCLB by ABB-ES personnel as part of RI/RA investigations of OU’s 1 and 2 (ABB Environmental Services, Inc., 1995a). Horizontal hydraulic conductivities were calculated by ABB-ES personnel for 21 wells completed in the upper water-bearing zone. Calculated values range from 0.0278 ft/d at well ALB02-10B, to 2.07 ft/d at well ALB01-12B, with a geometric mean of 0.247 ft/d.

ABB-ES personnel also conducted slug tests in wells located in PSC areas 6, 10, 12, 13, and 22 on the MCLB as a component of RI/RA investigations on OU 4 and calculated values of horizontal hydraulic conductivity (ABB Environmental Services, Inc., 1995b). Slug tests were conducted in eight wells open to the upper water-bearing zone, with values ranging from 0.0224 ft/d at well ALB06-14C to 0.695 ft/d at well ALB10-15B, with a geometric mean of 0.106 ft/d.

Laboratory tests to determine vertical hydraulic conductivity were conducted by an ASTM certified laboratory on undisturbed geologic samples collected from the upper water-bearing zone on the MCLB (table 2). Three samples were collected at varying depth intervals during drilling of eight shallow wells of the well-cluster sites on the MCLB for a total of 24 samples. Sample locations were chosen so that one sample was taken randomly from near the top, middle, and bottom of the upper water-bearing zone. Values range from 0.0000227 ft/d at well 13L224 to 0.510 ft/d at well 13L228. The geometric mean of the vertical conductivities at all eight well locations (fig. 4) is 0.0165 ft/d.

The lower water-bearing zone is composed of the lower unit of the Ocala Limestone and is semi-confined by the overlying sediments. The limestone has undergone significant recrystallization which has resulted in low primary porosity. However, the ability of the lower water-bearing zone to transmit ground water has been significantly enhanced by the development of moldic porosity. In addition, fractures, bedding plains, and solution-enlarged joints further enhance the secondary permeability (Hicks and others, 1987). Yields from wells that tap only the lower water-bearing zone can exceed 3,300 gal/min (Warner, 1997). The lower water-bearing zone of the Upper Floridan aquifer supplies water for most irrigation, industrial, and domestic wells in the study area.

With the exception of data on the MCLB, horizontal hydraulic-conductivity data for the Upper Floridan aquifer in the study area are limited. Hayes and others (1983) estimated transmissivities from specific-capacity data from wells that tap the lower water-bearing zone in the eastern Albany area. These transmissivity estimates range from 120,000 ft^2/d at well 13L031, to 460,000 ft^2/d at well 13L045. The hydraulic conductivity can be estimated by dividing transmissivity by aquifer thickness. This method of approximation gives horizontal hydraulic conductivities that range from 520 ft/d at well 13L031 to 2,445 ft/d at well 13L043. Well locations are shown on figure 4.

On the MCLB, slug tests were conducted in two wells completed in the uppermost part of the lower water-bearing zone located in PSC areas 1, 2, 3, 11, and 26 (fig. 2), by ABB-ES personnel as part of RI/RA investigations of OU's 1 and 2 (ABB Environmental Services, Inc., 1995a). Calculated horizontal hydraulic conductivity values from these tests range from 0.0134 ft/d at well ALB02-9C, to 2.95 ft/d at well ALB01-15C, with a geometric mean of 0.286 ft/d. As a component of RI/RA investigations of OU 4, a slug test was conducted in well ALB10-2D, which is completed in the uppermost part of the lower water-bearing zone. The calculated horizontal hydraulic conductivity for well ALB10-2D is 0.325 ft/d.

Ground-Water Levels

Water levels in selected wells on the MCLB were continuously monitored with data recorders beginning in May 1996. The four wells selected for monitoring are 13L179, 13L180, 13L181, and 13L182 (fig. 4). Wells 13L180, 13L181, and 13L182 were completed using open-hole construction into the lower water-bearing zone; whereas, well 13L179 is screened in the upper water-bearing zone. Wells 13L179 and 13L182 are located in a cluster site in the central part of the MCLB. Hydrographs for the four continuously monitored wells and the Flint River at Albany (USGS gaging station 02352500) for the period May 1996 through May 1997 are shown in figure 8, along with precipitation data from the National Oceanic and Atmospheric Administration Albany 3 precipitation station.

The hydrographs (fig. 8) show excellent correlation between river stage and ground-water levels in all four wells; particularly well 13L181 which is nearest the Flint River. River stage is affected by precipitation, which subsequently affects water levels in the Upper Floridan aquifer. The magnitude of ground-water-level rise and the rate of rise in response to precipitation in the Upper Floridan aquifer is not predicable, but generally, water levels in the aquifer rise in response to this recharge.

Ground-water levels declined during the summer and early fall of 1996 as a result of increased pumping and decreased recharge to a minimum during the fall months of 1996 (fig. 8). In 1996, the Flint River reached a minimum stage of 152.49 ft ASL (above sea level) on August 25; well13L181 at 153.15 ft ASL on September 26; well 13L179 at 166.46 ft ASL on September 27; well 13L182 at 156.23 ft ASL on July 13; and well 13L180 at 177.25 ft ASL on December 22. Ground-water levels rose from the fall minimum to a maximum during the winter months of 1997 as a result of decreased pumping and increased recharge, mostly precipitation. In 1997, the Flint River reached a maximum stage of 168.15 ft ASL on February 23; well 13L181 at 168.09 ft ASL on February 26; well 13L179 at 172.86 ft ASL on March 2; well 13L182 at 170.92 ft ASL on February 26; and well 13L180 at 185.72 ft ASL on March 10.

Hydrographs of wells13L179 and13L182—completed in the upper water-bearing zone and lower water-bearing zone, respectively—show a similar water-level response to stream stage and precipitation (fig. 8). The hydrograph for well 13L182 shows a drawdown response to pumping that is not reflected in the other recorded well record—most obviously during the months of June and July 1996, and May 1997. This probably is due to irrigation pumping—mostly from the lower water-bearing zone—on a large farm located 0.4 miles south of well 13L182.

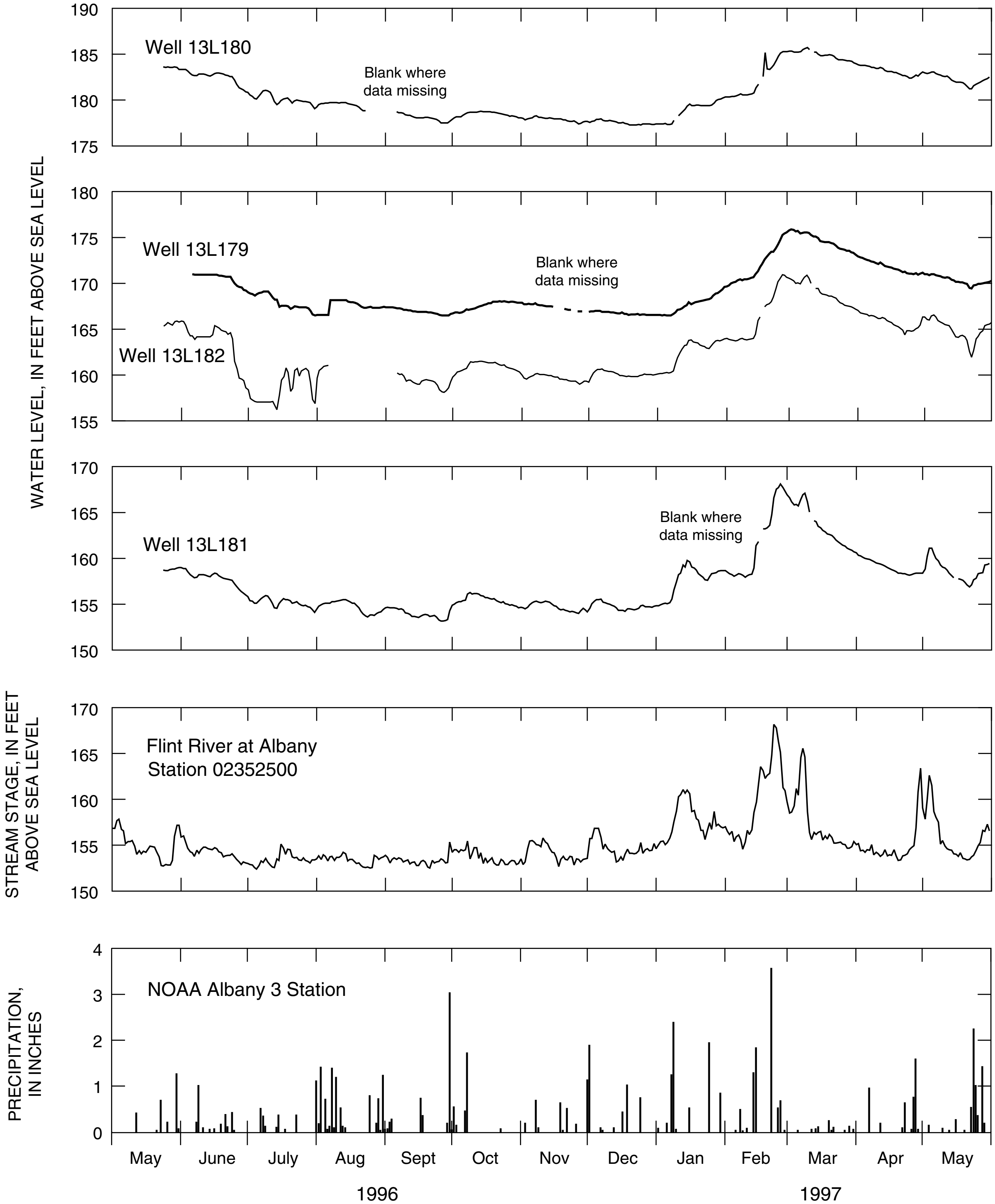


Figure 8. Daily mean ground-water levels in wells 13L180, 13L179, 13L182, and 13L181; stream stage of Flint River at Albany (USGS gaging station 02352500); and precipitation at National Oceanic and Atmospheric Administration Albany 3 station, May 1996 through May 1997.

Vertical Hydraulic Gradients

Differences in water levels between the upper and lower water-bearing zones of the Upper Floridan aquifer at the 11 cluster-well sites were used to determine the vertical hydraulic gradients between the zone (table 3). Water levels were measured over a 2-day period in September 1996, March 1997, and July 1997. The vertical gradient at each well cluster was calculated by dividing the difference in the water levels in the deep well (completed in the lower water-bearing zone) and the shallow well (completed in the upper water-bearing zone) by the difference between the centroid of the opening in the two wells. The centroid of the opening in each well was calculated by adding the depth to the top of the screen/opening to the depth to the bottom of the screen/opening and dividing by two (results are given in table 3). All 11 cluster wells had a downward (negative) vertical gradient for the measured period. Vertical gradients ranged from -0.0487 to -0.0526 foot per foot in September 1996; -0.0016 to -0.1228 foot per foot in March 1997; and -0.0040 to -0.1770 foot per foot in July 1997.

Vertical gradients in the Upper Floridan aquifer at the well-cluster sites on the MCLB are affected by seasonal and temporal changes in ground-water levels. In general, the gradients calculated using the March 1997 ground-water levels are slightly lower than those calculated using the July 1997 ground-water levels. The lower March gradient probably results from higher water levels in the lower water-bearing zone due to lower pumping rates, and in the upper water-bearing zone due to greater seasonal precipitation. The vertical hydraulic gradient between the upper water-bearing zone and lower water-bearing zone at each well-cluster site is downward throughout the year, the magnitude of which is variable. It is assumed that the vertical gradient also is generally downward elsewhere in the study area.

In general, well-cluster sites with the largest vertical gradients are located in the central and eastern parts of the MCLB (wells 13L182,13L179 and wells 13L225,13L226; fig. 4); whereas, well-cluster sites with the smallest vertical gradients are located in the western part of the MCLB (wells 13L181, 13L229 and wells 13L215, 13L216; fig. 4). This areal distribution can be correlated with areas where the middle unit of the Ocala Limestone is present or absent (fig. 7); where the middle unit is present, the vertical gradient is larger than where absent. One exception to this generalization is the well-cluster site that includes well 13L221—completed in the lower water-bearing zone, and well 13L222—completed in the upper water-bearing zone (locations shown on fig. 4). This well-cluster site consistently has the smallest vertical gradient of the 11 well-cluster sites located on the MCLB. The vertical gradient calculated at this site is lower because the upper water-bearing zone is not as thick as at other sites and the screen opening in well 13L222 is only 30 ft in length, as compared to the other upper water-bearing zone wells that have screen openings of a minimum of 50 ft in length. This smaller screen opening places the opening-centroid of well 13L222 (94 ft above sea level) approximately 20 ft below the average opening centroid of the other 10 wells (114 ft above sea level), making it appear that the calculated vertical gradient is much smaller than that calculated for the other well-cluster sites.

Ground-Water Flow in the Upper Floridan Aquifer

Ground-water flow was evaluated by constructing water-level maps of the upper water-bearing zone on the MCLB during March 1997, and of the lower water-bearing zone during September 1996, and March 1997. Ground water flows laterally downgradient from the recharge areas where water levels are highest, to discharge areas where water levels are lower, in a direction perpendicular to the water-level contours. When discharge exceeds recharge, the water-level surface is lower.

Upper water-bearing zone

Water-table maps were constructed for the MCLB in the vicinity of PSC areas 1, 2, 3, 6, 10, 12, 13, 22, and 26 (fig. 2), using water levels collected March 18, 1997. Water levels collected on the MCLB indicate that in this general area, the upper water-bearing zone of the Upper Floridan aquifer appears to behave hydraulically more as an unconfined unit rather than as a semi-confined unit as was concluded by Torak and others (1993). The Upper Floridan aquifer is unconfined as the measured water levels typically are below the top of the aquifer.

In other parts of the study area, water-level data suggests that the aquifer may act as a semi-confined unit. A basic assumption when constructing a water-table map is that ground-water flow in the aquifer is mostly horizontal, with a negligible vertical component. However, ground-water levels in the vicinity of PSC areas 1, 2, 3, and 26 are affected by the presence of large vertical gradients caused by the low permeability sediments in the upper water-bearing zone. Thus, large vertical gradients in the vicinity of these PSC areas make it difficult to construct a water-table map for this area using water-level data from all wells open to the upper water-bearing zone of the Upper Floridan aquifer. In contrast, the upper water-bearing zone is more permeable in the vicinity of PSC areas 6, 10, 12, 13, and 22, and has less pronounced vertical gradients.

Table 3. Calculated vertical head gradients at well-cluster sites for September 1996, March 1997, and July 1997

[ft/ft, foot per foot; NM, not measured, —, data unavailable; -, downward]

Well number (fig. 4)	Land-surface altitude (feet)	Opening			Date of water level	Depth to water (feet above sea level)	Date of water level	Depth to water (feet above sea level)	Date of water level	Depth to water (feet above sea level)	Vertical gradient		
		Top (feet below land surface)	Bottom (feet below land surface)	Centroid (feet below land surface)							September 1996 (ft/ft)	March 1997 (ft/ft)	July 1997 (ft/ft)
13L181	194.20	140	225	182.50	09/03/96	154.68	03/26/97	161.37	07/11/97	160.93	-0.0487	-0.0620	-0.0071
13L229	194.30	50	100	75	09/03/96	159.91	03/25/97	168.03	07/11/97	161.69			
13L182	219.10	185	270	227.50	09/03/96	160.48	03/26/97	157.50	07/11/97	167.30	-0.0526	-0.1228	-0.0432
13L179	220.80	70	120	95	09/03/96	167.45	03/26/97	173.77	07/11/97	173.02			
13L180	230.10	220	310	265	09/03/96	179.05	03/25/97	184.30	07/11/97	184.61	-0.0513	-0.0476	-0.0231
13L230	230.40	80	150	115	09/03/96	186.75	03/25/97	191.44	07/11/97	188.07			
13L213	190.80	186	252	219	NM	—	03/25/97	159.07	07/11/97	156.02	—	-0.0183	-0.0208
13L214	190.30	43.50	113.50	78.50	NM	—	03/25/97	161.64	07/11/97	158.94			
13L215	193.40	165	257	211	NM	—	03/25/97	162.10	07/11/97	158.01	—	-0.0050	-0.0180
13L216	193.30	44.25	124.25	84.25	NM	—	03/25/97	162.74	07/11/97	160.29			
13L217	224.50	195	302	248.50	NM	—	03/25/97	170.72	07/11/97	165.86	—	-0.0502	-0.0633
13L218	224.80	65	145	105	NM	—	03/25/97	177.92	07/11/97	174.95			
13L219	211.20	187	296	241.50	NM	—	03/25/97	165.86	07/11/97	161.88	—	-0.0153	-0.0185
13L220	210.90	60	150	105	NM	—	03/25/97	167.95	07/11/97	164.41			
13L221	248.80	235	332	283.50	NM	—	03/25/97	170.43	07/11/97	167.05	—	-0.0016	-0.0040
13L222	249.10	140	170	155	NM	—	03/25/97	170.64	07/11/97	167.57			
13L223	223.30	195	297	246	NM	—	03/25/97	185.50	07/11/97	181.71	—	-0.0352	-0.0296
13L224	223.30	65	155	110	NM	—	03/25/97	190.29	07/11/97	185.73			
13L225	255.30	195	318	256.50	NM	—	03/25/97	168.98	07/11/97	154.08	—	-0.0655	-0.1770
13L226	255.10	83	163	123	NM	—	03/25/97	177.72	07/11/97	177.71			

PSC areas 1, 2, 3, and 26

To reduce the effects of a large vertical gradient in the vicinity of PSC areas 1, 2, 3, and 26, wells were separated into groups by calculating the centroid of each well's screened interval. The centroid of the opening in each well was calculated by adding the depth to the top of the screen to the depth to the bottom of the screen, dividing by two, and subtracting the result from the land-surface altitude of the well (results are given in Appendix B). Two 20-ft intervals were designated for water-table mapping—one for screen centroids located between 146 to 166 ft above sea level (fig. 9), and one from 120 to 140 ft above sea level (fig. 10). These centroids were selected such that a maximum number of wells was encompassed in each group; each well was verified as being screened only in the upper water-bearing zone of the Upper Floridan aquifer.

The water-table surface for the interval 146 to 166 ft above sea level was constructed using water-level data from 18 wells measured on March 18, 1997. The water-table surface shown in figure 9 indicates that ground water generally flows from east to west across PSC's 1 and 2. However, near PSC 26, the direction of ground-water flow is from southwest to northeast. This creates a low in the water-table surface approximately located beneath PSC 3. The horizontal gradient is higher (water-table contours are more closely spaced) in the area of PSC 1 than in the areas of PSC's 2, 3, and 26. The larger gradient may be due to the close proximity of PSC 1 to Indian Lake, which may be a local recharge area, or may be due to variations in the permeability of the upper water-bearing zone.

A map showing the water-table surface for the interval 120 to 140 ft above sea level interval was constructed using water-level data from 22 wells at PSC areas, 1, 2, 3, and 26, measured on March 18, 1997 (fig. 10). The surface indicates that ground water flows in a manner similar to that of the overlying interval of 146 to 166 ft above sea level (fig. 9). Flow is east to west across PSC areas 1 and 2 and toward PSC 3 from both east and west. However, ground-water flow beneath PSC 26 is mainly to the southeast and southwest, rather than northeast, as was the case for the interval 146 to 166 ft above sea level (fig. 9). The highest horizontal gradients occur beneath PSC 1 in the vicinity of Indian Lake (fig. 10), as in the overlying interval.

Previous studies in karst terrain (Stringfield and others, 1974) have shown that the uneven distribution of permeability in carbonate rocks near the top of the saturated zone causes an uneven water-table gradient. It follows that there is a direct relation between the geometry of the water table and permeability. In areas where the permeability is high, the water table tends to be lower than a "theoretical" water table might be if uniform permeability is assumed. Conversely, areas of high permeability tend to have a small hydraulic gradient; thus, the water-table low shown in figures 9 and 10 is probably a result of an area of slightly higher permeability than the surrounding area.

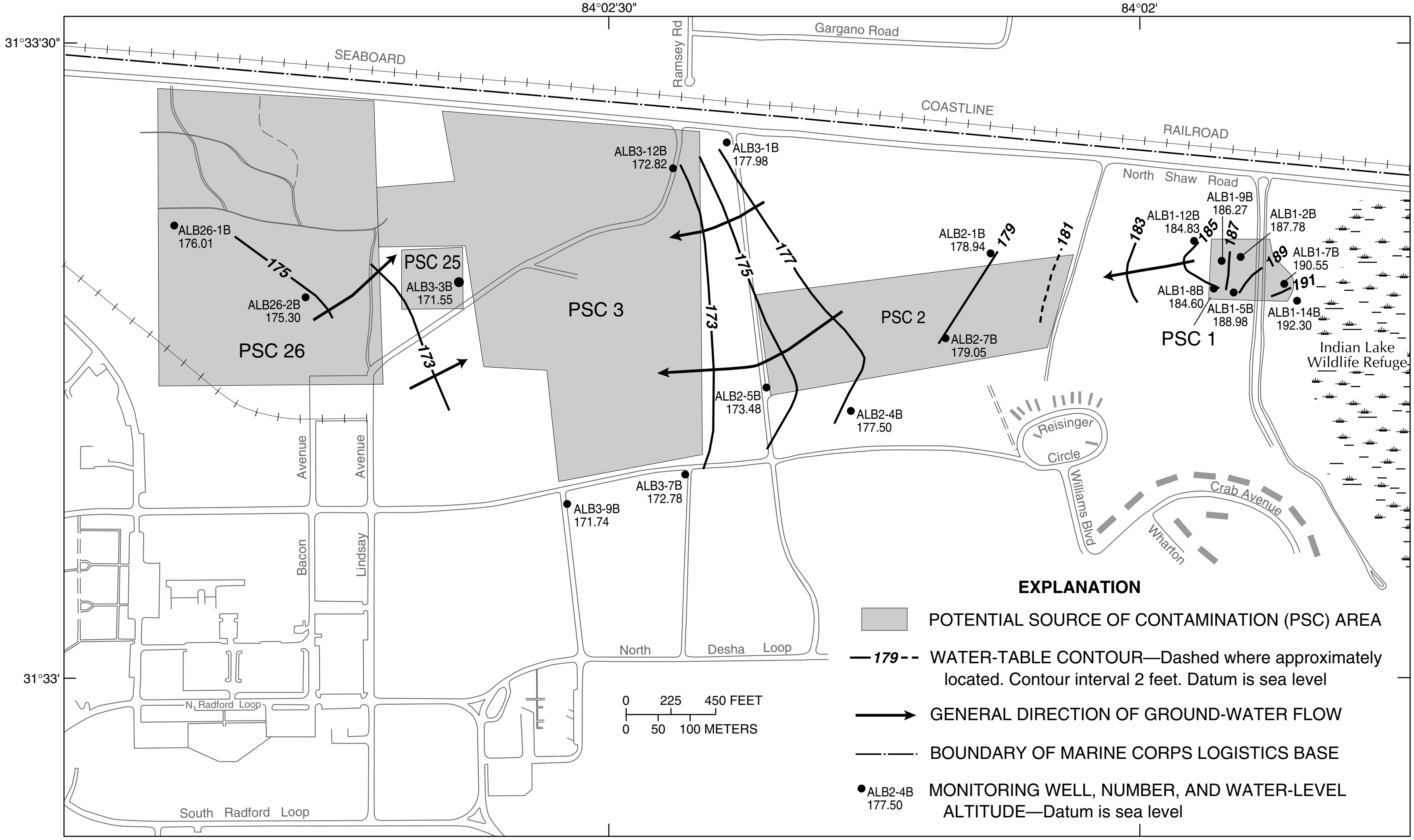
PSC areas 6, 10, 12, 13, and 22

The water-table surface in the vicinity of PSC areas 6, 10, 12, 13, and 22 on the MCLB was constructed using water-level data from 74 wells measured March 18, 1997 (fig. 11). In general, flow is from the southeast to the northwest. However, a cone of depression exists in the central part of the surface, caused by remediation efforts that are underway (1998) at the Industrial Waste Treatment Plant (IWTP). A ground-water high exists in the southeastern corner of the water-table surface in the area of well ALB10-15C. Previous studies have suggested (Stringfield and others, 1974) that local highs in the water table may indicate areas of recharge greater than that of the surrounding area, or they may indicate recharge areas having lower permeability than those in surrounding areas.

Lower water-bearing zone

Regional potentiometric-surface maps for the lower water-bearing zone of the Upper Floridan aquifer were constructed using water-level data collected from 41 wells during September 3-4, 1996, and from 59 wells during March 25-26, 1997 (figs. 12 and 13). Both potentiometric-surface maps indicate the existence of a major ground-water flow path from the Pelham Escarpment area to the Flint River (Hicks and others, 1987). This flow path is present in the northeastern part of figures 12 and 13, and trends approximately in a southwesterly direction. Flow lines in this area trend towards a series of large springs that occur along the eastern bank of the Flint River, just south of Albany. The largest of these springs is Radium Springs, which was measured at a discharge rate exceeding 70 Mgal/d during April 1982 (Hicks and others, 1987)

The September 1996 potentiometric-surface map (fig. 12) shows a large cone of depression located south of the MCLB. This cone of depression is caused by large-scale irrigation pumping that is as much as 29.5 Mgal/d (combined pumping capacity) from the Upper Floridan aquifer. A seasonal ground-water divide trends east-west along the southern boundary of the MCLB. The position of this divide is controlled by the cone of depression (fig. 12). In general, ground-water flow is from east to west, towards the Flint River. In areas near the south-central part of the study area, ground-water flow is from north to south towards the irrigation pumping; in the north-central part of the study area, flow is to the north.



Base modified from U.S. Geological Survey Albany East 1:24,000, 1988;
and ABB-Environmental Services, 1995a

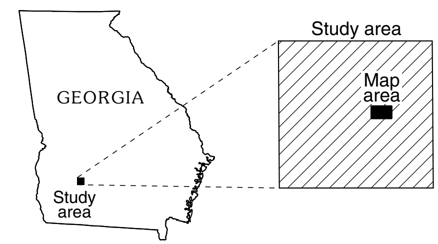
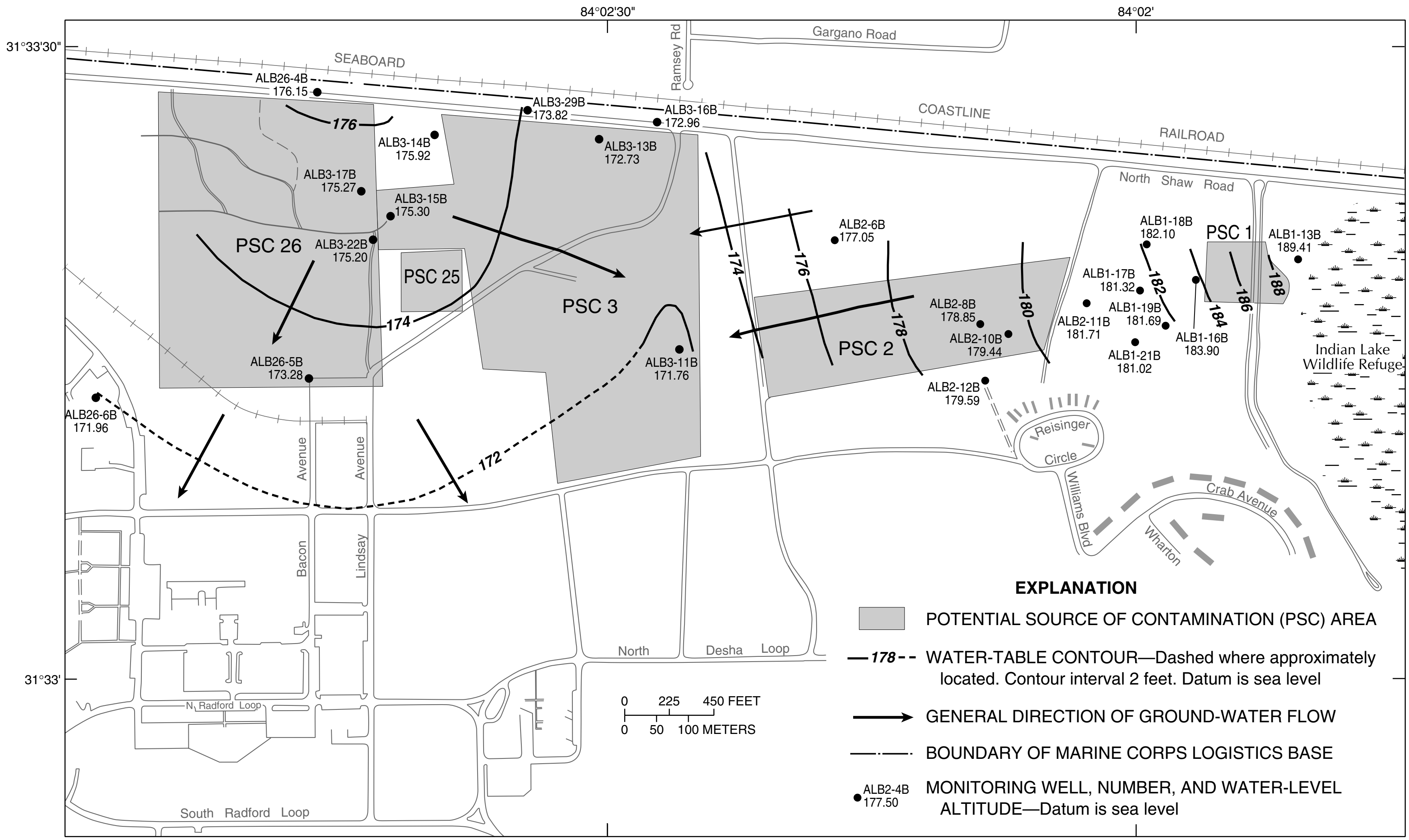


Figure 9. Water-table surface of the upper water-bearing zone of the Upper Floridan aquifer in the vicinity of potential source of contamination areas 1, 2, 3, and 26; with screen-centroid altitudes between 146 and 166 feet above sea level, March 18, 1997.



Base modified from U.S. Geological Survey Albany East 1:24,000, 1988; and ABB-Environmental Services, 1995a

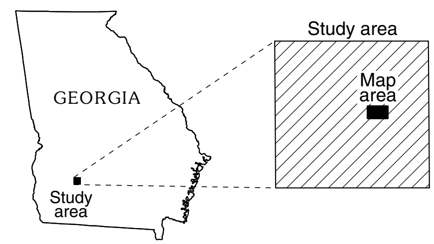


Figure 10. Water-table surface of the upper water-bearing zone of the Upper Floridan aquifer in the vicinity of potential source of contamination areas 1, 2, 3, and 26; with screen-centroid altitudes between 120 and 140 feet above sea level, March 18, 1997.

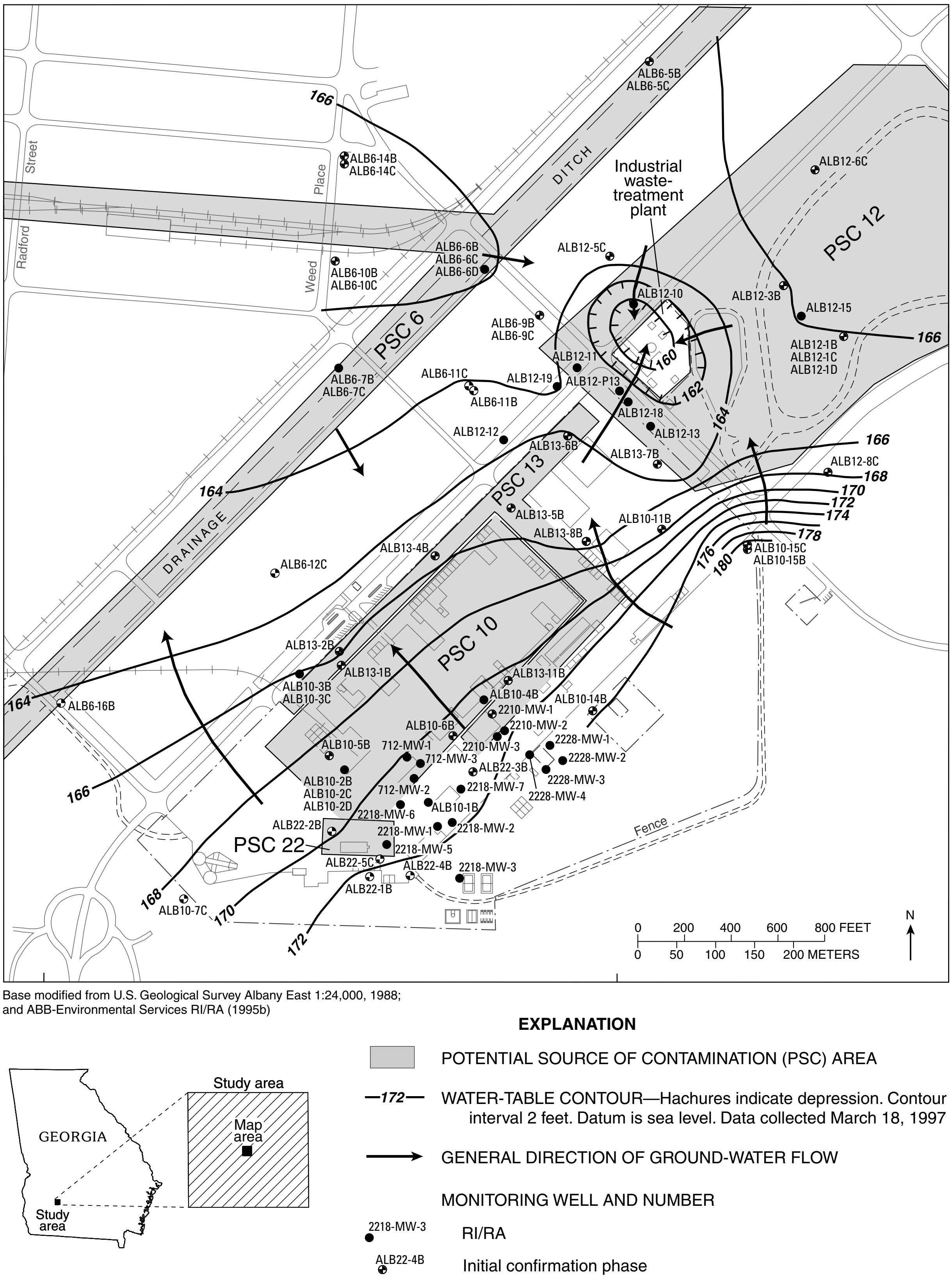


Figure 11. Water-table surface of the upper water-bearing zone of the Upper Floridan aquifer in the vicinity of potential source of contamination areas 6, 10, 12, 13, and 22, March 18, 1997.

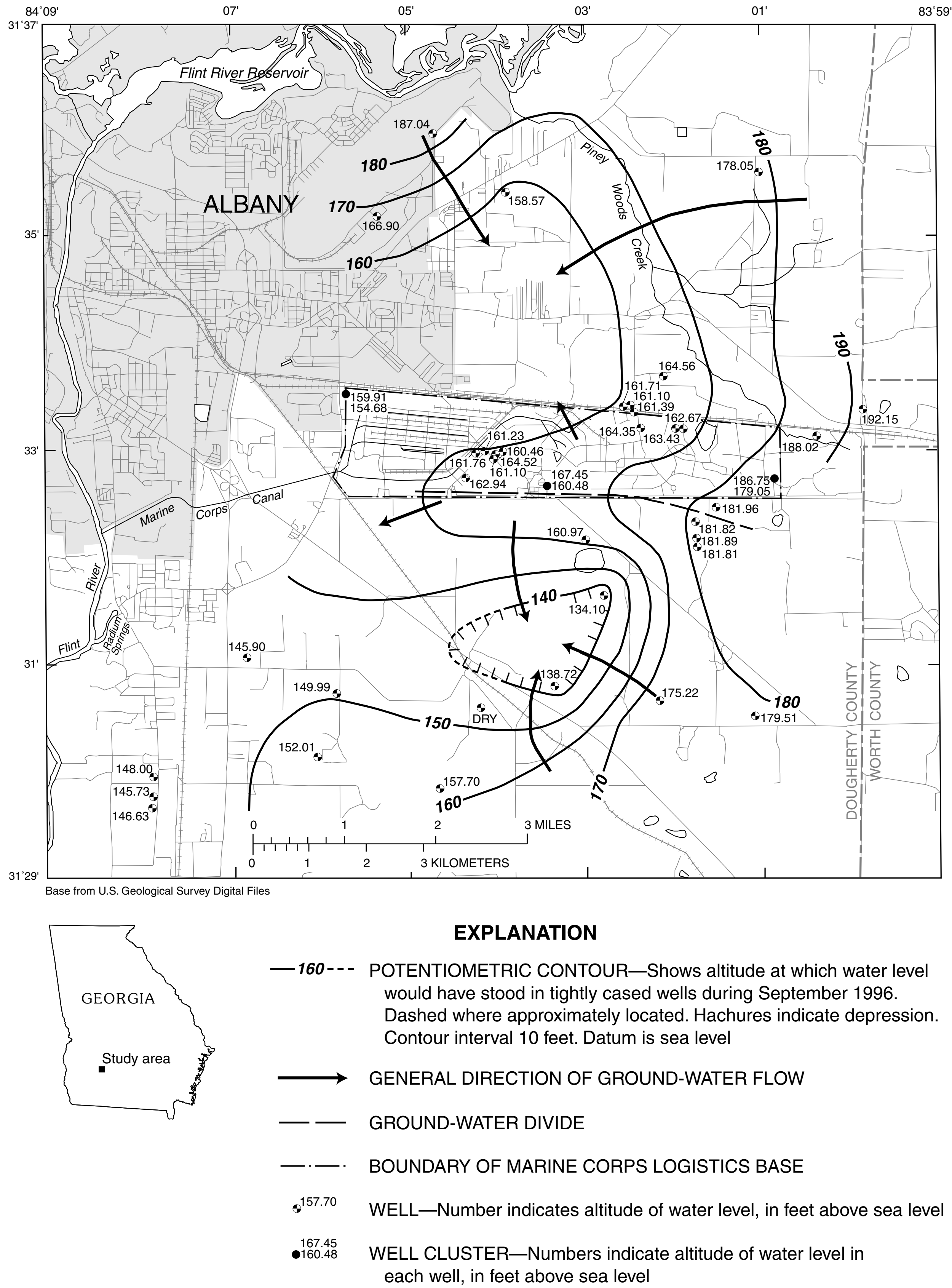
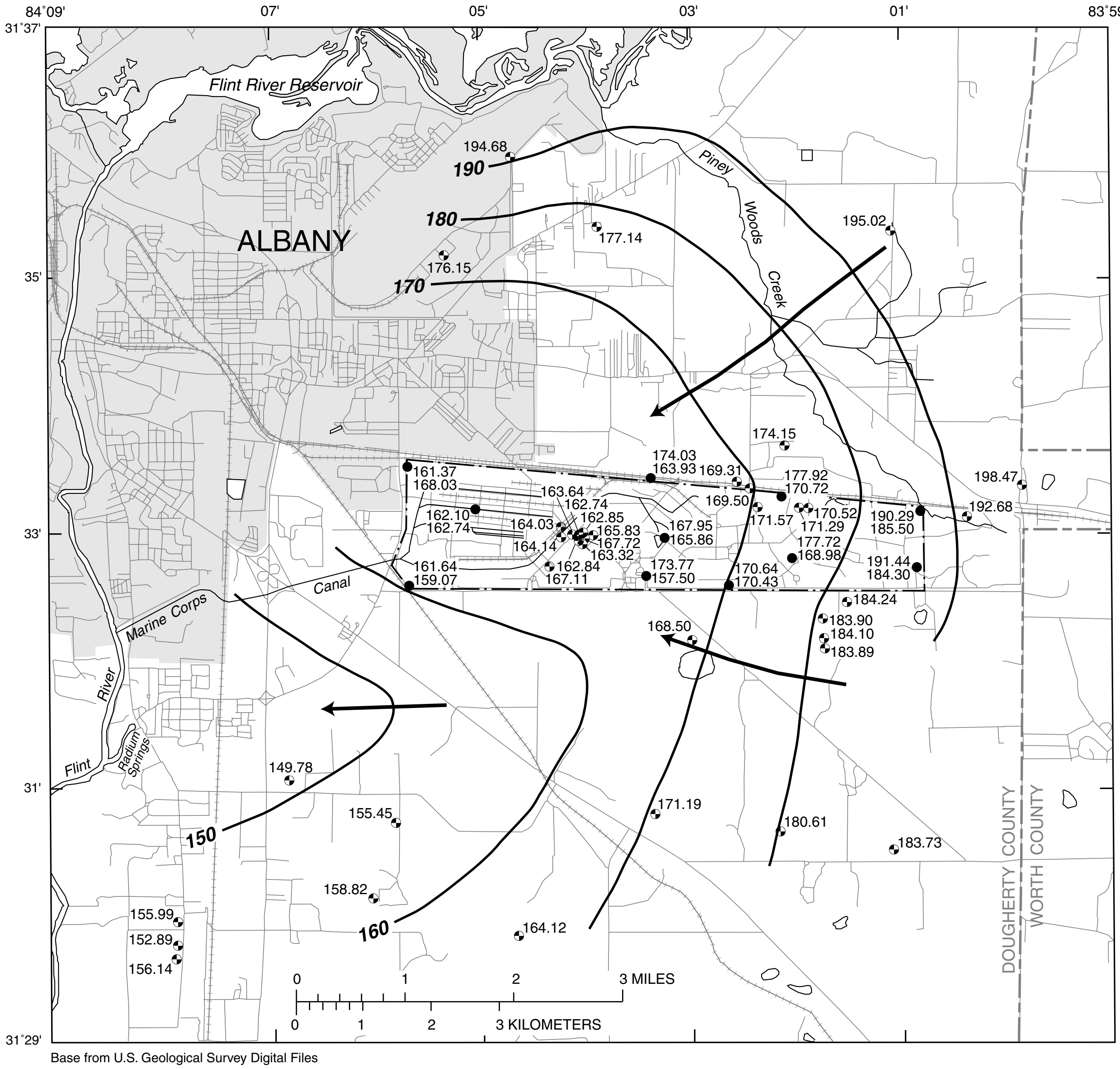
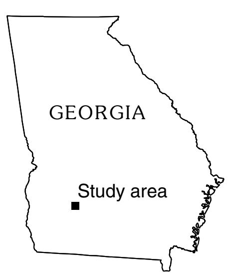


Figure 12. Potentiometric surface of the Upper Floridan aquifer in the study area, September 1996.





EXPLANATION

160 POTENTIOMETRIC CONTOUR—Shows altitude at which water level would have stood in tightly cased wells during March 1997. Contour interval 10 feet. Datum is sea level

GENERAL DIRECTION OF GROUND-WATER FLOW

BOUNDARY OF MARINE CORPS LOGISTICS BASE

164.12 WELL—Number indicates altitude of water level, in feet above sea level

170.64
170.43 WELL CLUSTER—Numbers indicate altitude of water level in each well, in feet above sea level

Figure 13. Potentiometric surface of the Upper Floridan aquifer in the study area, March 1997.

The March 1997 potentiometric-surface map (fig. 13) shows aquifer conditions during a low-stress period when irrigation pumpage in the study area is at a minimum. Ground-water flow generally is from east to west on the eastern half of the study area, northeast to southwest in the northern part of the study area, and southeast to northwest in the southwest part of the study area. In contrast to the September 1996 map (fig. 12), the March 1997 map does not have a cone of depression or ground-water divide. Also, the March 1997 water levels were slightly higher than those collected in September 1996 due to significant rainfall during the preceding winter months and subsequent recharge to the Upper Floridan aquifer, combined with minimal irrigation pumpage.

SUMMARY

The U.S. Geological Survey was requested by the U.S. Navy, Southern Division, Naval Facilities Engineering Command in 1995 to describe the hydrogeology of the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base, southeast of and adjacent to Albany, Ga. The hydrogeology of the Upper Floridan aquifer in this area was described by the delineation and analysis of the hydrogeologic framework and includes: a description of the geologic and hydrogeologic units that compose the ground-water system of the Upper Floridan aquifer; an evaluation of the lithologic and hydrologic heterogeneity within the Upper Floridan aquifer; a comparison of geologic and hydrogeologic conditions on the Marine Corps Logistics Base and in the surrounding area; and a determination of ground-water-flow directions within the Upper Floridan aquifer.

The study area lies on the eastern edge of the Dougherty Plain District of the Coastal Plain physiographic province in southwestern Georgia, about 200 miles south of Atlanta. The study area encompasses about 90 square miles and includes parts of Dougherty and Worth Counties. The Marine Corps Logistics Base is centrally located in the study area and boarders the southeastern city limit of Albany in Dougherty County.

The major hydrogeologic unit in the study area is the Upper Floridan aquifer, which is composed of the Suwannee Limestone and the Ocala Limestone. The Upper Floridan aquifer is confined below by the Lisbon Formation and semi-confined above by the overlying, low permeability clay layers present in the undifferentiated overburden. The Upper Floridan aquifer is divided into two water-bearing zones. The upper water-bearing zone is composed of the middle and upper units of the Ocala Limestone and the Suwannee Limestone. The upper water bearing zone has low transmissivity and behaves hydraulically as a leaky confining unit that separates the undifferentiated overburden from the lower water-bearing zone. In the study area, wells open to this zone produce very small amounts of water, on the order of 2 gallons per minute. The lower water-bearing zone is composed of the lower unit of the Ocala Limestone. The ability of this zone to transmit ground water has been enhanced by the development of moldic porosity and secondary permeability along joints and fractures.

Vertical hydraulic conductivities were calculated by an ASTM certified laboratory for undisturbed geologic samples collected from the upper water-bearing zone of the Upper Floridan aquifer on the Marine Corps Logistics Base. Calculated values of vertical hydraulic conductivity range from 0.000027 to 0.510 feet per day (ft/d). Slug tests were performed by a Navy contractor at potential sources of contamination areas 1, 2, 3, 6, 10, 11, 12, 13, 22, and 26 to estimate horizontal hydraulic conductivity. Values calculated for the horizontal hydraulic conductivity of the upper water-bearing zone at potential sources of contamination areas 1, 2, 3, 11, and 26 during the Remedial Investigation and Risk Assessment (RI/RA) investigation of Operable Units 1 and 2 range from 0.0278 to 2.07 ft/day; whereas potential sources of contamination areas 6, 10, 12, 13, and 22, investigated during the RI/RA investigation of Operable Unit 4 range from 0.0224 to 0.695 ft/day. In the uppermost part of the lower water-bearing zone, calculated horizontal hydraulic conductivity values have a geometric mean of 0.286 ft/d at potential sources of contamination areas 1 and 2; whereas at potential source of contamination area 10 horizontal hydraulic conductivities have a value of 0.325 ft/d.

Four wells on the Marine Corps Logistics Base were selected for continuous water-level monitoring. Hydrographs show excellent correlation between stage of the Flint River and ground-water levels in the four wells. One of the continuous monitoring well hydrographs shows a water-level low during June and July 1996, and May 1997, that is not reflected in the other three hydrographs. This water-level low is due to irrigation pumping on a large farm located south of the Marine Corps Logistics Base that obtains most of its irrigation water from the Upper Floridan aquifer.

Vertical hydraulic gradients were calculated at 11 well-cluster sites located on the Marine Corps Logistics Base for water-levels collected in September 1996, March 1997, and July 1997. Values range from 0.0487 to 0.0526 foot per foot in September 1996; 0.0016 to 0.1228 foot per foot in March 1997; and 0.0040 to 0.1770 foot per foot in July 1997. All well-cluster sites have a downward gradient, the magnitude of which is affected by seasonal and temporal changes in ground-water levels. In general, well-cluster sites with the highest vertical gradients are located on the central and eastern part of the Marine Corps Logistics Base; whereas well-cluster sites with the smallest vertical gradients occur on the western part of the Marine Corps Logistics Base.

Water-table surface maps were constructed for the Marine Corps Logistics Base area in the vicinity of potential source of contamination areas 1, 2, 3, 6, 10, 12, 13, 22, and 26, using water levels collected in March 1997. Water levels collected on the Marine Corps Logistics Base indicate that in this general area, the upper water-bearing zone of the Upper Floridan aquifer appears to behave hydraulically more as an unconfined unit rather than behaving as a semi-confined unit. The Upper Floridan aquifer is unconfined as the measured water-levels typically are below the top of the aquifer. In other parts of the study area, water-level data suggests that the aquifer may act as a semi-confined unit. Because of the presence of large vertical gradients in the potential source of contamination 1, 2, 3, and 26 areas, two separate water-table surfaces were constructed for this area. Both surfaces indicate that ground water generally flows from east to west towards the Flint River. However, across the potential source of contamination area 26 and part of the potential source of contamination area 3, flow is from west to east, creating a ground-water low. Ground-water gradients vary in magnitude across potential source of contamination areas 1, 2, 3, and 26. At potential source of contamination areas 6, 10, 12, 13, and 22 on the Marine Corps Logistics Base, the water-table surface indicates that ground-water flow is generally from the southeast to the northwest. A cone of depression in the central part of the surface is caused by remediation efforts currently (1998) underway at the Industrial Waste Treatment Plant.

Potentiometric-surface maps of the Upper Floridan aquifer were constructed for the study area using water levels collected during two time periods—September 3-4, 1996; and March 25-26, 1997. Both potentiometric-surface maps indicate the presence of a ground-water-flow path that transports water from the Pelham Escarpment area to the Flint River, discharging at a series of large springs. Generally, ground-water flow is from east to west, towards the Flint River; however, the potentiometric surface is locally affected by irrigation pumping.

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APPENDIXES

A. Records of wells in the study area

B. Record of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Ga.

C. Lithologic logs of selected wells drilled in the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base near Albany, Ga.

Appendix A. Records of wells in the study area

[—, data unavailable; Do., ditto; M, multiple; AT, acoustic televiewer; AV, acoustic velocity; B, brine tracer; C, caliper, E, electrical; FR, fluid resistivity; G, natural gamma; G-G, gamma-gamma; N, neutron; T, temperature]

Well number	Well name	Latitude	Longitude	Land-surface altitude (feet)	Aquifer[1]	Total depth (feet below land surface)	Casing		Opening		Logs available	
							Diameter (inches)	Depth (feet below land surface	Bottom (feet below land surface)	Type	Geophysical	Drillers
12K166	Merck MW-21	31°30'03"	84°07'44"	192.67	Upper Floridan	57.2	2	40.8	M 57.2	screen	—	Law Environmental
12K167	Merck MW 22	31°29'46"	84°07'40"	189.58	do.	93	2	77	93	do.	—	Do.
12K168	Merck MW 23	31°29'38"	84°07'43"	189.23	do.	57.2	2	39.8	57.2	do.	—	Do.
12L001	Albany 06	31°34'39"	84°08'05"	206	multi-aquifer	955	18 to 8	M	M	screen	E	Layne-Atlantic
12L004	Albany 09	31°34'48"	84°08'32"	195	do.	795	30 to 10	M	M	screen and open hole	—	Do.
13K092	Sunnyland Farms #1	31°29'57"	84°04'25"	220	Upper Floridan	144	3	—	144	open hole	—	—
13L002	Albany-Turner City	31°35'51"	84°06'24"	212.84	Clayton	760	12	713	760	do.	G,G-G,N	Layne-Atlantic
13L003	Albany-Dougherty County	31°33'13"	84°00'21"	225	Upper Floridan	259	6	206	259	do.	G	Do.
13L007	Albany 25	31°34'28"	84°04'49"	194	multi-aquifer	960	34 to 12	M	M	screen and open hole	B,C,FR,T	Do.
13L009	Albany 30	31°34'45"	84°06'40"	215	multi-aquifer	1,146	26 to 12	M	M	screen	AV,G,G-G	Layne-Atlantic
13L010	USGS TW 01	31°31'05"	84°06'41"	195	Cretaceous	1,515	10 to 6	1,075	1,515	open hole	E,G,G-G,C,N	Georgia Geologic Survey
13L012	USGS TW 03	31°31'05"	84°06'43"	195	Upper Floridan	218	4	54	2	do.	AT,B,C,FR,G	—
13L014	Miller Brewery OCALA 2	31°35'49"	84°04'38"	206	do.	99	4	84	99	do.	C,G	—
13L015	Firewell SAC APRON	31°36'21"	84°04'09"	200	Claiborne	351	4	240	351	do.	B,C,E	Layne-Atlantic
13L018	U.S. Marine Corps 03	31°33'00"	84°05'12"	200	multi-aquifer	900	26 to 10	M	M	screen and open hole	—	Georgia Geologic Survey/U.S. Geological Survey
13L019	U.S. Marine Corps 02	31°32'52"	84°02'22"	258	do.	997	26 to 10	M	M	do.	—	Georgia Geologic Survey/U.S. Geological Survey
13L025	U.S. Marine Corps 01	31°33'05"	84°03'26"	220	do.	940	26 to 10	M	M	do.	E	Georgia Geologic Survey/U.S. Geological Survey
13L026	Miller Brewery PW-1	31°35'28"	84°04'47"	205	do.	1,116	32 to 12	M	M	do.	E,G	Layne-Atlantic
13L027	Miller Brewery OW-1	31°35'28"	84°04'52"	201	do.	1,116	16 to 4	M	M	do.	G	—

Appendix A. Records of wells in the study area—Continued

[—, data unavailable; Do., ditto; M, multiple; AT, acoustic televiewer; AV, acoustic velocity; B, brine tracer; C, caliper, E, electrical; FR, fluid resistivity; G, natural gamma; G-G, gamma-gamma; N, neutron; T, temperature]

Well number	Well name	Latitude	Longitude	Land-surface altitude (feet)	Aquifer	Total depth (feet below land surface)	Casing		Opening		Logs available	
							Diameter (inches)	Depth (feet below land surface	Bottom (feet below land surface)	Type	Geophysical	Drillers
13L028	Fleming Farm 14	31°30'42"	84°02'09"	220	Upper Floridan	300	24 to 16	110	300	open hole	C,E,G	P.E. LaMoreaux and Associates
13L029	Fleming Farm12	31°30'43"	84°02'46"	220	do.	310	16	75	310	do.	C,E,G	Do.
13L030	Fleming Farm 11	31°31'15"	84°02'43"	218	do.	280	24 to 16	100	280	do.	C,E,G,G-G	Do.
13L031	Fleming Farm 10	31°31'39"	84°02'41"	221	do.	290	24 to 16	70	290	do.	C,E,G	Do.
13L032	Fleming Farm 09	31°32'09"	84°02'50"	220	do.	285	16	95	285	do.	C,E,G	Do.
13L033	Fleming Farm 08	31°30'50"	84°03'14"	243	do.	310	16	70	310	do.	C,E,G	Do.
13L034	Fleming Farm 07	31°31'11"	84°03'21"	215	do.	290	24 to 16	90	290	do.	C,E,G	Do.
13L035	Fleming Farm 06	31°31'48"	84°03'22"	227	do.	295	24 to 12	140	295	do.	C,E,G	Do.
13L036	Fleming Farm 05	31°32'26"	84°03'24"	220	do.	260	24 to 16	70	260	do.	C,E,G	Do.
13L037	Fleming Farm 03	31°31'26"	84°03'52"	212	do.	280	24 to 16	118	280	do.	C,E,G	Do.
13L038	Fleming Farm 02B	31°32'15"	84°03'44"	219	do.	300	16	70	300	do.	C,E,G	Do.
13L039	Fleming Farm Valley	31°31'21"	84°02'07"	231	do.	271	12	147	271	do.	C,G,E	P.E. LaMoreaux and Associates
13L040	AG TIMBER MNGT FCP	31°32'21"	84°04'06"	222	Cretaceous	950	12 to 16	940	950	do.	C,E	Do.
13L041	Fleming Farm F00-10B	31°31'19"	84°02'05"	234	Upper Floridan	273	10	250	273	do.	C,E,G	Do.
13L042	Fleming Farm F00-10A	31°31'20"	84°02'06"	233	do.	275	6	M	M	screen and open hole	C,E,G	Do.
13L043	Procter and Gamble	31°33'11"	84°06'29"	192.98	do.	215	18	106	235	do.	—	Layne-Atlantic
13L044	Procter and Gamble	31°33'11"	84°06'30"	182	do.	210	16	99	210	do.	—	Do.
13L045	Firestone P1	31°34'03"	84°03'12"	220	do.	265	20 to 16	165	265	open hole	—	Do.
13L046	Firestone P2	31°33'43"	84°03'12"	200	do.	284	20 to 16	150	284	do.	—	Do.
13L048	USGS TW 17	31°30'31"	84°00'59"	245	do.	345	6	71	345	do.	C,E,G	Eubanks
13L049	Miller Ammo Supply	31°35'21"	84°05'10"	204	do.	170	6	103	170	do.	C,G	Layne-Atlantic
13L051	Fleming FCO & FOO	31°32'23"	84°04'06"	219	Claiborne	410	16 to 6	300	410	do.	C,E,G	P.E. LaMoreaux and Associates

Appendix A. Records of wells in the study area—Continued

[—, data unavailable; Do., ditto; M, multiple; AT, acoustic televiewer; AV, acoustic velocity; B, brine tracer; C, caliper, E, electrical; FR, fluid resistivity; G, natural gamma; G-G, gamma-gamma; N, neutron; T, temperature]

Well number	Well name	Latitude	Longitude	Land-surface altitude (feet)	Aquifer	Total depth (feet below land surface)	Casing		Opening		Logs available	
							Diameter (inches)	Depth (feet below land surface	Bottom (feet below land surface)	Type	Geophysical	Drillers
13L052	Miller Ocala 3	31°36'09"	84°04'35"	205	Upper Floridan	105	4	60	105	open hole	C,G	—
13L056	J. Championed Abandoned	31°35'07"	84°01'12"	233	do.	199	3	45	199	do.	G	—
13L057	Frank Boucher	31°33'47"	84°02'11"	227	do.	150	3	—	—	do.	—	—
13L176	Miller Brewery (Ocala 2) RW	31°35'49"	84°04'38"	206	do.	45	3	32.5	45	screen	—	—
13L179	MCLB CH #2U	31°32'46"	84°03'22"	220.7	do.	120	2	70	120	do.	—	USGS/ABB-ES
13L180	MCLB CH #3L	31°32'47"	84°00'50"	230.1	do.	310	4	220	310	open hole	C,E,G,T	Do.
13L181	MCLB CH #1L	31°33'39"	84°05'37"	194.2	do.	2	4	140	225	do.	C,E,G,T	Do.
13L182	MCLB CH #2L	31°32'47"	84°03'19"	219.1	do.	27	6	185	270	do.	C,E,G,T	Do.
13L183	ABB ALB03-19C	31°33'26"	84°02'23"	231.05	do.	205	2	190	205	screen	G	ABB-ES
13L184	ABB ALB01-15C	31°33'18"	84°01'52"	231.92	do.	194.8	2	179.8	194.8	do.	G	ABB-ES
13L185	ABB ALB02-9C	31°33'17"	84°02'18"	243.84	do.	176.6	2	161.6	176.6	do.	G	ABB-ES
13L186	ABB ALB01-23C	31°33'17"	84°01'55"	[2]232	do.	192	2	177	192.	do.	G	—
13L187	ABB ALB03-23C	31°33'30"	84°02'26"	233.93	do.	190	2	175	190	do	.G	ABB-ES
13L188	ABB ALB03-21C	31°33'28"	84°02'29"	230.74	do	194	2	179	194	do.	G	Do.
13L189	ABB ALB06-6D	31°33'07"	84°04'08"	203.41	do.	125	2	110	125	do.	G	Do.
13L190	ABB ALB06-11C	31°33'03"	84°04'08"	208.62	do.	100	2	85	100	do.	G	Do.
13L19	ABB ALB10-2D	31°32'48"	84°04'14"	212.62	do.	130	2	115	130	do.	G	Do.
13L192	ABB ALB12-1D	31°33'03"	84°03'53"	221.23	do.	125	2	110	125	do.	G	Do.
13L193	Sunnyland Farms #2	31°30'36"	84°04'05"	223	do.	51.7	3	—	51.7	open hole	—	—
13L194	Charles S. Jones	31°34'26"	84°04'50"	205	do.	81.5	3	—	81.5	do.	C,G	—
13L195	Lt. George Frantz	31°35'33"	84°03'50"	217	do.	140	3	—	140	do	—	—
13L196	Gillionville Farms #2	31°30'05"	84°05'52"	202	do.	115	3	—	115	do.	—	—
13L198	Gillionville Farms #1	31°30'49"	84°05'42"	197	do.	102	3	—	102	do.	—	—
13L199	James L. Mathis	31°35'29"	84°01'01"	242	do.	250	3	130	250	do.	C,G,T	—
13L200	Dougherty County LF. GWC-12	31°32'32"	84°01'28"	277.85	do.	104	2	88.4	104	screen	—	Geosciences

Appendix A. Records of wells in the study area—Continued

[—, data unavailable; Do., ditto; M, multiple; AT, acoustic televiewer; AV, acoustic velocity; B, brine tracer; C, caliper, E, electrical; FR, fluid resistivity; G, natural gamma; G-G, gamma-gamma; N, neutron; T, temperature]

Well number	Well name	Latitude	Longitude	Land-surface altitude (feet)	Aquifer	Total depth (feet below land surface)	Casing		Opening		Logs available	
							Diameter (inches)	Depth (feet below land surface	Bottom (feet below land surface)	Type	Geophysical	Drillers
13L201	Dougherty County LF. GWC-7	31°32'19"	84°01'46"	276.25	do.	105	2	89.4	105	do.	—	Do.
13L202	Dougherty County LF. GWC-5	31°32'10"	84°01'46"	270.58	do.	98	2	82.4	98	do.	—	Do.
13L203	Dougherty County LF. GWC-4	31°32'05"	84°01'46"	255.87	do.	88	2	72.4	88	do.	—	Do.
13L204	MCLB/RUST MW-11	31°33'04"	84°04'03"	213.70	do.	78.4	2	68.4	78.4	do.	G	—
13L205	MCLB/RUST MW-13	31°33'03"	84°04'01"	218.27	do.	69.7	2	59.7	69.7	do.	G	—
13L206	MCLB/RUST MW-15	31°33'05"	84°03'54"	216.42	do.	79	2	69	79	do.	—	—
13L207	MCLB/RUST MW-16	31°33'06"	84°03'59"	214.91	do.	110.1	2	100.1	110.1	do.	—	—
13L209	MCLB/RUST MW-17	31°33'05"	84°04'00"	212.69	do.	108.5	2	98.5	108.5	do.	—	—
13L208	MCLB/RUST MW-18	31°33'02"	84°04'01"	217.99	do.	110	2	100	110	do.	G	—
13L210	ALBBW-8B	31°33'30"	84°03'48"	207.50	do.	50.7	2	35	50.7	do.	—	ABB-ES
13L211	ALBBW-9B	31°33'15"	84°03'14"	209.10	do.	55.	2	40	55	do.	—	ABB-ES
13L212	ALBBW-10B	31°33'30"	84°03'21"	214.70	do.	57.1	2	42	57.1	do.	—	Do.
13L213	ALBBW-11L/MCLB A-L	31°32'38"	84°05'35"	190.8	do.	252	4	186	252	open hole	C,G	ABB-ES/USGS
13L214	ALBBW-11U	31°32'38"	84°05'35"	190.3	do.	114.1	4	43.5	114.1	screen	—	Do.
13L215	ALBBW-12L/MCLB B-L	31°33'16"	84°04'57"	193.4	do.	257	4	165	257	open hole	C,G,T	Do.
13L216	ALBBW-12U	31°33'16"	84°04'57"	193.3	do.	124.3	4	44.3	124.3	screen	—	Do.
13L217	ALBBW-13L/MCLB F-L	31°33'24"	84°02'05"	224.5	do.	302	4	195	302	open hole	—	Do.
13L218	ALBBW-13U	31°33'24"	84°02'05"	224.8	do.	145	4	65	145	screen	—	Do.
13L219	ALBBW-14L/MCLB D-L	31°33'04"	84°03'15"	211.2	do.	296	4	187	296	open hole	C,G,T	Do.
13L220	ALBBW-14U	31°33'04"	84°03'15"	210.9	do.	150	4	60	150	screen	—	Do.
13L22	ALBBW-15L/MCLB E-L	31°32'38"	84°02'35"	248.8	do.	332	4	235	332	open hole	C,G,T	Do.
13L222	ALBBW-15U	31°32'38"	84°02'34"	249.1	do	171	4	140	171	screen	—	Do.
13L22	ALBBW-16L/MCLB H-L	31°33'18"	84°00'51"	223.3	do.	297	4	195	297	open hole	—	Do.
13L224	ALBBW-16U	31°33'18"	84°00'50"	223.3	do.	155	4	66	155	screen	—	Do.

Appendix A. Records of wells in the study area—Continued

[—, data unavailable; Do., ditto; M, multiple; AT, acoustic televiewer; AV, acoustic velocity; B, brine tracer; C, caliper, E, electrical; FR, fluid resistivity; G, natural gamma; G-G, gamma-gamma; N, neutron; T, temperature]

Well number	Well name	Latitude	Longitude	Land-surface altitude (feet)	Aquifer	Total depth (feet below land surface)	Casing		Opening		Logs available	
							Diameter (inches)	Depth (feet below land surface	Bottom (feet below land surface)	Type	Geophysical	Drillers
13L225	ALBBW-17LMCLB G-L	31°32'51"	84°01'57"	255.3	do.	318	4	195	318	open hole	C,G,T	Do.
13L226	ALBBW-17U	31°32'52"	84°01'57"	255.1	do.	163	4	83	163	screen	—	Do.
13L227	ALBBW-18L/MCLB C-L	31°33'30"	84°03'21"	214.7	do.	272	4	196	272	open hole	C,G,T	Do.
13L228	ALBBW-18U	31°33'30"	84°03'22"	214.8	do.	137	4	55	137	screen	—	Do.
13L229	MCLB CH #1U	31°33'39"	84°05'36"	194.7	do.	100	2	50	100	do.	—	Do.
13L230	MCLB CH #3U	31°32'48"	84°00'50"	230.3	do.	150	2	80	150	do.	—	Do.
14L001	ALBANY 29	31°35'19"	83°59'49"	250	multi-aquifer	950	32 to 12	M	M	do.	AV,C,G,G-G, E, N,T	Layne-Atlantic
14L048	Llyde W. Haustead	31°33'28"	83°59'48"	239	Upper Floridan	135	3	—	135	open hole	—	—

[1]For a complete description of aquifers other than the Upper Floridan aquifer, please see McFadden and Periello (1983).

[2]Estimated.

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
2210-MW-1	562724.74	530511.50	213.10	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	50.0	35.0	2	PVC	screened	170.6
2210-MW-2	562646.34	530566.60	213.00	do.	55	40	2	do.	do.	165.5
2210-MW-3	562633.70	530536.63	212.80	do.	55	40	2	do.	do.	165.3
2218-MW-1	562257.58	530287.37	214.32	do.	50	35	2	do.	do.	171.6
2218-MW-2	562272.64	530345.81	214.28	do.	55	40	2	do.	do.	166.2
2218-MW-3	562053.48	530372.54	213.35	do.	45	30	2	do.	do.	175.2
2218-MW-4	561974.28	530263.55	241.50	do.	55	40	2	do.	do	166.8
2218-MW-5	562186.95	530089.53	212.50	do.	55	40	2	do.	do.	164.7
2218-MW-6	562344.07	530145.63	212.51	do.	55	40	2	do.	do.	164.8
2218-MW-7	562401.84	530379.06	212.89	do.	55	40	2	do.	do.	166.2
2228-MW-1	562551.70	530716.72	213.40	do.	55	40	2	do.	do.	165.9
2228-MW-2	562530.68	530740.15	214.10	do.	55	40	2	do.	do.	166.6
2228-MW-3	562482.80	530704.21	214.10	do.	55	40	2	do.	do.	166.6
2228-MW-4	562521.72	530658.92	214.00	do.	55	40	2	do.	do.	166.5
712-MW-1	562529.74	530169.97	213.94	do	54	39	2	do.	do.	167.2
712-MW-2	562445.72	530197.40	213.70	do.	55	40	2	do.	do.	166
712-MW-3	562506.16	530221.76	213.36	do.	54	39	2	do.	do.	166.6
ALB01-01B	565798.39	542422.48	226.19	upper water-bearing zone of the Upper Floridan aquifer	61.1	51.1	2	do.	do.	170.1
ALB01-02	565647.25	542268.58	229.59	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	55.3	45.3	2	do.	do.	179.3
ALB01-02B	565637.07	542285.05	230.34	upper water-bearing zone of the Upper Floridan aquifer	88	78	2	do.	do.	147.3
ALB01-03	565781.38	542171.58	229.70	undifferentiated overburden	37.3	27.3	2	do.	do.	197.4

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB01-03B	565762.90	542171.97	229.81	upper water-bearing zone of the Upper Floridan aquifer	61.8	51.8	2	do.	do.	173.0
ALB01-04B	565323.39	542262.62	233.13	do.	74	64	2	do.	do.	164.1
ALB01-05B	565463.50	542250.77	231.73	do.	84.5	69.5	2	do.	do.	154.7
ALB01-06B	565453.33	542226.07	232.15	do.	122.4	107.4	2	do.	do.	117.3
ALB01-07B	565504.14	542504.97	224.70	do.	84.7	69.7	2	do.	do.	147.5
ALB01-08B	565481.96	542147.68	232.87	do.	83.2	68.2	2	do.	do.	157.2
ALB01-09B	565619.45	542186.56	231.72	do.	88.1	73.1	2	do.	do.	151.1
ALB01-10B	565218.14	542288.77	234.38	do.	84.5	69.5	2	do.	do.	157.4
ALB01-11C	565504.97	542217.71	231.78	do.	157.5	142.5	2	do.	do.	81.8
ALB01-12B	565716.67	542049.97	229.13	do.	88.5	73.5	2	do.	do.	148.1
ALB01-13B	565636.46	542593.32	220.28	do.	94	79	2	do.	do.	133.8
ALB01-14B	565421.55	542568.31	220.25	do.	84.5	69.5	2	do.	do.	143.3
ALB01-15C	565529.45	542206.26	231.92	lower water-bearing zone of the Upper Floridan aquifer	194.8	179.8	2	do.	do.	44.6
ALB01-16B	565536.49	542076.09	231.90	upper water-bearing zone of the Upper Floridan aquifer	102.6	87.6	2	do.	do.	136.8
ALB01-17B	565481.87	541802.42	234.42	do.	114.6	99.6	2	do.	do.	127.3
ALB01-18B	565711.68	541834.23	233.23	do.	116.6	101.6	2	do.	do.	124.1
ALB01-19B	565306.78	541928.19	235.53	do.	115.8	100.8	2	do.	do.	127.2
ALB01-20C	565521.53	541928.22	231.91	do.	155.1	140.1	2	do.	do.	84.3
ALB01-21B	565225.24	541778.29	241.84	do.	124.6	109.6	2	do.	do.	124.7
ALB01-23C	565428.93	541945.28	[2]232	upper and lower water-bearing zones of the Upper Floridan aquifer	192	177	2	do.	do.	47.5
ALB02-01B	565658.27	541036.24	240.86	upper water-bearing zone of the Upper Floridan aquifer	92.2	82.2	2	do.	do.	153.7

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB02-03	564973.60	540567.14	256.69	undifferentiated overburden	34.7	24.7	2	do.	do.	227
ALB02-03B	564979.64	540556.61	256.60	upper water-bearing zone of the Upper Floridan aquifer	97.4	87.4	2	do.	do.	164.2
ALB02-04B	564877.35	540338.56	260.86	do.	108.5	98.5	2	do.	do.	157.4
ALB02-05	565040.93	539903.40	250.33	undifferentiated overburden	34.8	24.8	2	do.	do.	220.5
ALB02-05B	564998.57	539909.48	250.67	upper water-bearing zone of the Upper Floridan aquifer	108.3	98.3	2	do.	do.	147.4
ALB02-06B	565738.52	540271.94	241.06	do.	124.2	109.2	2	do.	do.	124.4
ALB02-07B	565241.10	540814.57	246.20	do.	102.9	87.9	2	do.	do.	150.8
ALB02-08B	565321.40	540997.93	244.47	do.	123.6	108.6	2	do.	do.	128.4
ALB02-09C	565481.52	539973.82	243.84	lower water-bearing zone of the Upper Floridan aquifer	176.6	161.6	2	do.	do.	74.7
ALB02-10B	565268.86	541138.19	247.41	upper water-bearing zone of the Upper Floridan aquifer	126.2	111.2	2	do.	do.	128.7
ALB02-11B	565421.50	541530.10	246.47	do.	123.2	108.2	2	do.	do.	130.8
ALB02-12B	565037.20	541022.92	249.81	do.	123.9	108.9	2	do.	do.	133.4
ALB02-13B	566147.90	541256.08	222.90	do.	87	81	2	do.	do.	138.9
ALB02-13C	566152.74	541214.08	223.80	lower water-bearing zone of the Upper Floridan aquifer	190	175	2	do.	do.	41.3
ALB03-01B	566208.67	539712.84	234.97	upper water-bearing zone of the Upper Floridan aquifer	92.1	82.1	2	do.	do.	147.9
ALB03-02	564526.26	538792.33	248.81	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	47.5	37.5	2	do.	do.	206.3
ALB03-03	565567.35	538384.99	251.10	undifferentiated overburden	30.6	20.6	2	do.	do.	225.5
ALB03-03B	565552.74	538382.59	251.46	upper water-bearing zone of the Upper Floridan aquifer	109.9	99.9	2	do.	do.	146.6
ALB03-07	564545.84	539518.52	249.74	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	40.1	30.1	2	do.	do.	214.6

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB03-07B	564552.67	539514.63	249.35	upper water-bearing zone of the Upper Floridan aquifer	96.4	86.4	2	do.	do.	158
ALB03-08	566191.45	538266.27	239.82	undifferentiated overburden	29.9	19.9	2	do.	do.	214.9
ALB03-09A	564427.96	538909.67	248.05	do.	29.8	19.8	2	do.	do.	223.3
ALB03-09B	564421.47	538909.50	248.15	upper water-bearing zone of the Upper Floridan aquifer	100.9	90.9	2	do.	do.	152.3
ALB03-10A	564860.94	538653.38	249.72	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	46.2	36.23	2	do.	do.	208.5
ALB03-10B	564872.31	538645.91	250.15	upper water-bearing zone of the Upper Floridan aquifer	109.3	99.3	2	do.	do.	145.9
ALB03-11B	565201.12	539486.91	249.64	do.	124.4	109.4	2	do.	do.	132.7
ALB03-12B	566082.67	539447.17	234.57	do.	85	70	2	do.	do.	157.1
ALB03-13B	566241.30	539082.57	230.35	do.	106.3	91.3	2	do.	do.	131.6
ALB03-14B	566269.73	538257.57	238.8000	do.	125	110	2	do.	do.	121.3
ALB03-15B	565871.87	538035.51	245.59	do.	124.3	109.3	2	do.	do.	128.8
ALB03-16B	566323.77	539376.76	231.29	do.	103.5	88.5	2	do.	do.	135.3
ALB03-16C	566332.71	539298.00	229.80	do.	144.3	129.3	2	do.	do.	93
ALB03-17B	565996.78	537886.39	241.45	do.	124.3	109.3	2	do.	do.	124.7
ALB03-18B	566474.19	539543.81	232.30	do.	139	124	2	do.	do.	100.8
ALB03-19C	566308.70	539550.70	231.05	lower water-bearing zone of the Upper Floridan aquifer	205	190	2	do.	do.	33.6
ALB03-20B	566549.35	539196.99	232.68	upper water-bearing zone of the Upper Floridan aquifer	110	95	2	do.	do.	130.2
ALB03-21B	566566.48	538994.87	228.76	do.	150.5	135.5	2	do.	do.	85.8
ALB03-21C	566595.35	539169.73	230.70	lower water-bearing zone of the Upper Floridan aquifer	194	179	2	do.	do.	44.2
ALB03-22B	565755.92	537946.94	248.14	upper water-bearing zone of the Upper Floridan aquifer	123.3	108.3	2	do.	do.	132.3

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB03-23C	566777.08	539300.59	233.93	lower water-bearing zone of the Upper Floridan aquifer	190	175	2	do.	do.	51.4
ALB03-24C	567196.29	538923.48	220.46	lower water-bearing zone of the Upper Floridan aquifer	190	175	2	do.	do.	38
ALB03-25C	566859.01	538705.96	227.30	do.	190	175	2	do.	do.	44.8
ALB03-29B	566384.74	538723.23	228.26	upper water-bearing zone of the Upper Floridan aquifer	115	100	2	do.	do.	120.8
ALB06-05A	565240.86	531117.18	209.13	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	40	25	2	do.	do.	179.1
ALB06-05B	565240.86	531117.18	208.89	upper water-bearing zone of the Upper Floridan aquifer	62	47	2	do.	do.	156.9
ALB06-05C	565240.86	531117.18	209.77	do.	114	99	2	do.	do.	104.8
ALB06-06A	564436.31	530473.68	202.80	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	39	24	2	do.	do.	173.8
ALB06-06B	564436.31	530473.68	202.23	upper water-bearing zone of the Upper Floridan aquifer	62	47	2	do.	do.	151
ALB06-06C	564436.31	530473.68	203.59	do.	103	88	2	do.	do.	110.6
ALB06-06D3	564433.31	530477.44	203.41	do.	125	110	2	do.	do.	85.9
ALB06-07A	564053.91	529910.24	203.48	undifferentiated overburden	40	25	2	do.	do.	173.5
ALB06-07B	564053.91	529910.24	203.54	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	62	47	2	do.	do.	151.5
ALB06-07C	564053.91	529910.24	203.51	upper water-bearing zone of the Upper Floridan aquifer	114	99	2	do.	do.	99.8
ALB06-08B	563674.84	524003.15	193.30	do.	55	40	2	do.	do.	145.8
ALB06-09B	564253.09	530688.46	209.40	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	55	40	2	do.	do.	161.9
ALB06-09C	564245.72	530696.12	209.60	upper water-bearing zone of the Upper Floridan aquifer	90	75	2	do.	do.	127.1
ALB06-10B	564460.80	529896.40	201.90	do.	58	43	2	do.	do.	151.4

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB06-10C	564470.58	529897.61	201.90	do.	91	76	2	do.	do.	118.4
ALB06-11B	563960.89	530432.50	209.26	do.	70	55	2	do.	do.	146.8
ALB06-11C	563978.83	530414.67	208.62	do.	100	85.	2	do.	do.	116.1
ALB06-12B	563236.95	529698.78	208.65	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	85	70	2	do.	do.	131.1
ALB06-12C	563256.73	529663.04	207.65	upper water-bearing zone of the Upper Floridan aquifer	115	100	2	do.	do.	100.2
ALB06-13B	562555.90	529307.48	209.31	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	50	35	2	do.	do.	166.8
ALB06-14B	564878.34	529937.01	197.90	upper water-bearing zone of the Upper Floridan aquifer	50	35	2	do.	do.	155.4
ALB06-14C	564848.13	529937.37	[2]197.50	do.	78	63	2	do.	do.	127
ALB06-15B	562607.48	529046.42	210.24	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	55	40	2	do.	do.	162.7
ALB06-16B	562744.38	528824.30	209.17	upper water-bearing zone of the Upper Floridan aquifer	60	45	2	do.	do.	156.7
ALB10-01B	562385.64	530241.94	212.73	do.	68	58	2	do.	do.	149.7
ALB10-02B	562461.39	529868.52	212.07	do.	70	60	2	do.	do.	147.1
ALB10-02C	562464.78	529872.85	212.20	do.	110	100	2	do.	do.	107.2
ALB10-02D	562482.03	529928.23	212.62	do.	130	115	2	do.	do.	90.1
ALB10-03B	562881.97	529771.95	212.48	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	55	45	2	do.	do.	165
ALB10-03C	562902.93	529815.30	212.56	upper water-bearing zone of the Upper Floridan aquifer	106	96	2	do.	do.	114.1
ALB10-04B	562772.55	530477.24	213.41	do.	64	55	2	do.	do.	153.9
ALB10-05B	562538.85	529869.10	211.90	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	89.5	74.5	2	do.	do.	129.9
ALB10-06B	562612.23	530350.12	213.50	do.	55	40	2	do.	do.	166

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB10-07B	561976.20	529301.19	213.55	do.	55	40	2	do.	do.	166.1
ALB10-07C	561972.86	529284.83	214.52	upper water-bearing zone of the Upper Floridan aquifer	92	77	2	do.	do.	130
ALB10-08B	561830.63	529844.35	207.09	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	45	30	2	do.	do.	169.6
ALB10-09B	561851.87	530399.43	213.57	do.	60	45	2	do.	do.	161.1
ALB10-09C	561811.53	530400.10	213.64	upper water-bearing zone of the Upper Floridan aquifer	90	75	2	do.	do.	131.1
ALB10-11B	563417.30	531165.95	216.51	do.	70	55	2	do.	do.	154
ALB10-12B	562851.01	530752.47	212.70	do.	70	55	2	do.	do.	150.2
ALB10-13B	562153.07	530679.43	213.55	do.	65	50	2	do.	do.	156.1
ALB10-14B	562708.94	530890.75	212.43	do.	65	50	2	do.	do.	154.9
ALB10-15B	563647.15	531898.03	223.27	do.	65	50	2	do.	do.	165.8
ALB10-15C	563664.35	531897.41	223.20	do.	90	75	2	do.	do.	140.7
ALB11-01B	564273.10	544686.02	228.38	do.	70.7	60.7	2	do.	do.	162.7
ALB11-03	563956.17	544566.11	226.18	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	43	33	2	do.	do.	188.2
ALB11-03B	563963.16	544561.18	226.18	upper water-bearing zone of the Upper Floridan aquifer	92.2	82.2	2	do.	do.	139
ALB11-04	563879.18	544645.84	224.40	undifferentiated overburden	27.1	17.1	2	do.	do.	202.3
ALB11-05	564045.29	544728.39	225.10	do.	21.3	11.3	2	do.	do.	208.8
ALB11-05B	564038.34	544723.61	225.05	upper water-bearing zone of the Upper Floridan aquifer	63.7	53.7	2	do.	do.	166.4
ALB12-01B	564162.55	531848.25	217.00	do.	70	55	2	do.	do.	154.5
ALB12-01C	564175.16	531855.69	216.90	do.	97	82	2	do.	do.	127.4
ALB12-01D	563996.75	531769.49	221.23	do.	125	110	2	do.	do.	103.7

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB12-02B	564267.58	531838.89	212.00	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	70	55	2	do.	do.	149.5
ALB12-03B	564364.17	531637.05	215.10	upper water-bearing zone of the Upper Floridan aquifer	65	50	2	do.	do.	157.6
ALB12-04B	563718.19	531628.93	220.14	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	70	55	2	do.	do.	157.6
ALB12-05B	564469.15	530933.16	205.31	do.	45	30	2	do.	do.	167.8
ALB12-05C	564483.13	530960.63	205.45	upper water-bearing zone of the Upper Floridan aquifer	80	65	2	do.	do.	133
ALB12-06B	564807.07	531736.05	205.80	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	50	35	2	do.	do.	163.3
ALB12-06C	564815.18	531758.00	205.64	upper water-bearing zone of the Upper Floridan aquifer	80	65	2	do.	do.	133.1
ALB12-07B	564243.63	532170.79	214.55	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	50	35	2	do.	do.	172
ALB12-08B	563604.86	531776.86	219.18	do.	80	65	2	do.	do	146.7
ALB12-08C	563636.28	531809.28	219.92	upper water-bearing zone of the Upper Floridan aquifer	115	100	2	do.	do.	112.4
ALB12-10	564292.18	531050.59	207.10	do.	68.3	58.3	2	do.	do.	145.3
ALB12-11	564069.69	530832.12	213.50	do.	78.4	68.4	2	do.	do.	141.6
ALB12-12	563776.96	530537.86	214.30	do.	69.5	59.5	2	do.	do.	152.1
ALB12-13	563815.81	531112.64	218.10	do.	69.7	59.7	2	do.	do.	156.6
ALB12-15	564197.72	531694.23	216.90	do.	79	69	2	do.	do.	145.5
ALB12-18	563902.54	531025.22	217.90	do.	110	100	2	do.	do.	115.6
ALB12-19	564001.84	530763.2	213.80	do.	110	100	2	do.	do.	111.2
ALB13-01B	562890.79	529918.82	213.20	undifferentiated overburden/upper water-bearing zone of the Upper Floridan aquifer	53	38	2	do.	do.	167.7
ALB13-02B	562946.86	529910.62	212.70	do.	50	35	2	do.	do.	170.2

Appendix B. Records of wells drilled by ABB Environmental Services, Inc., on the Marine Corps Logistics Base, Albany, Georgia—Continued

[PVC, polyvinyl chloride; do., ditto]

Well number	Coordinate system[1]		Land-surface altitude (feet)	Water-bearing zone	Total depth (feet below land surface)	Casing			Opening	
	Northing	Easting				Depth (feet below land surface)	Diameter (inches)	Material	Type	Centroid (feet above sea level)
ALB13-03B	563202.75	530165.65	212.70	do.	70	55	2	do.	do.	150.2
ALB13-04B	563319.00	530282.31	212.40	do.	55	40	2	do.	do.	164.9
ALB13-05B	563503.03	530578.41	213.90	do.	60	45	2	do.	do.	161.4
ALB13-06B	563781.31	530797.00	215.80	do.	70	55	2	do.	do.	153.3
ALB13-07B	563669.95	531149.95	219.30	do.	60	45	2	do.	do.	166.8
ALB13-08B	563368.26	530869.00	214.40	upper water-bearing zone of the Upper Floridan aquifer	60	45	2	do.	do.	161.9
ALB13-09B	563392.68	530682.66	214.70	do.	60	45	2	do.	do.	162.2
ALB13-10B	563327.24	530688.62	214.20	do.	85	70	2	do.	do.	136.7
ALB13-11B	562828.61	530563.53	213.50	do.	60	45	2	do.	do.	161
ALB22-01B	562061.61	530023.85	211.40	do.	57	42	2	do.	do.	161.9
ALB22-02B	562239.98	529877.8	212.30	do.	58	43	2	do.	do.	161.8
ALB22-03B	562471.13	530426.74	213.20	do.	55	40	2	do.	do.	165.7
ALB22-04B	562065.00	530181.28	214.10	do.	75	60	2	do.	do.	146.6
ALB22-05C	562128.96	530064.13	213.50	do.	98	83	2	do.	do.	123
ALB26-1B	565823.52	536949.94	222.53	do.	65	50	2	do.	do.	165
ALB26-2B	565462.59	537597.00	242.35	do.	83.5	68.5	2	do.	do.	166.4
ALB26-3B	566188.62	537651.76	237.57	do.	70.1	55.1	2	do.	do.	175
ALB26-4B	566480.54	537687.81	233.50	do.	109	94	2	do.	do.	132
ALB26-4C	566481.95	537662.61	233.50	do.	149	134	2	do.	do.	92
ALB26-5B	565069.57	537616.54	257.90	do.	135	120	2	do.	do.	130.4
ALB26-6B	564984.72	536554.44	224.50	do.	100	85	2	do.	do.	132

[1]10,000-foot grid based on Georgia State Plane coordinate system, west zone.
[2]Estimated.

Appendix C. Lithologic logs for selected wells drilled in the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base near Albany, Georgia

Well number	Well name	Water-bearing unit	Thickness (feet)	Depth below land surface (feet)	Description of Lithology
13L180	MCLB Corehole 3 Lower	Ocala Limestone	134	134	no samples.
			40	174	LIMESTONE: pale gray to white, aphanitic, recrystallization common; fossiliferous, soft with hard lenses
			6	180	LIMESTONE: calcareous clay, light gray, highly weathered
			19	199	LIMESTONE: white with green, aphanitic with glauconite
			50	249	LIMESTONE: white to cream, aphanitic with some fine to medium quartz sand and silt; fossiliferous decreasing with depth; firm to weak calcareous cement
			55	304	LIMESTONE: very light gray, oolitic and aphanitic with some very fine to fine quartz sand; fossiliferous, firm calcareous cement
			10	314	Sandy LIMESTONE: light gray to yellow gray, oolitic with very fine to fine quartz sand, well sorted; weak calcareous cement
			6	320	Sand: light yellow and gray coarse quartz, calcareous, sub-rounded to sub-angular, poorly sorted
		Lisbon Formation	9	329	Sandy CLAY: pale yellow brown, calcareous; fine to very coarse grained quartz; marl common, glauconite abundant
13L181	MCLB Corehole 1 Lower	Ocala Limestone	125	125	no samples
			20	145	LIMESTONE: yellow gray, aphanitic, fossiliferous, some fine to medium sand, sub-rounded to sub-angular, calcareous cement; iron oxide staining present 140-145 feet
			15	160	LIMESTONE: similar to above, but silt and fine sand sized particles; small zone of silicification at approximately 146 feet
			40	200	LIMESTONE: pale gray, fossiliferous, fossils decrease in size and quantity with depth; recrystallization increases with depth, while primary porosity decreases
			15	215	SAND: gray calcareous to clayey, poorly sorted pebbles to clay-sized particles
			5	220	SAND: light yellow to gray coarse quartz, some glauconite silt; angular to sub-angular poorly sorted
		Lisbon Formation	5	225	Sandy CLAY: pale yellow to green, contains considerable glauconite and phosphate; sand fine to very fine, calcareous
13L182	MCLB Corehole 2 Lower	Ocala Limestone	78	78	no samples
			50	128	LIMESTONE: white, aphanitic with recrystallization common, fossiliferous with weak to firm calcareous cement; light and porous; silt to fine sand sized particles
			60	188	LIMESTONE: white to tan, aphanitic with weak to firm calcareous cement, fossils decreasing with depth; clay to silt sized particles; slight iron precipitation
			30	218	LIMESTONE: white to pale yellow, aphanitic and fossiliferous, firm calcareous cement
			30	248	LIMESTONE: pale yellow, aphanitic with some fine to medium quartz sand; rare fossils, firm calcareous cement
			15	263	LIMESTONE: white to pale yellow, aphanitic with some fine to medium quartz sand; some shells, firm calcareous cement
			18	281	LIMESTONE: pale yellow, aphanitic with fine to coarse quartz sand; no fossils, firm calcareous cement
			7	288	Sandy LIMESTONE: tan to pale yellow, poorly sorted fine to coarse sand and pebbles

Appendix C. Lithologic logs for selected wells drilled in the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base near Albany, Georgia—Continued

Well number	Well name	Water-bearing unit	Thickness (feet)	Depth below land surface (feet)	Description of Lithology
13L213	ALBBW-11L	Overburden	2	2	Silty SAND: gray brown, dry; very fine to fine; poorly sorted, unconsolidated
			4	6	Sandy CLAY: dark yellow orange, low to moderate plasticity; some fine sand
			22	28	CLAY: mottled gray, red, yellow orange, and brown, moderate to low plasticity, dry to damp; trace fine to medium sand
		Ocala Limestone	18	46	LIMESTONE: yellow gray to pink gray, highly weathered, wet; fine to coarse gravel mixed with clay and fine to medium sand
			40	86	LIMESTONE: pale gray, highly weathered, wet; fine gravel mixed with very fine sand and clay; trace small cobbles; some competent layers
			100	186	LIMESTONE: pale gray to gray orange to yellow brown, highly weathered, wet; small cobbles and coarse to fine gravel mixed with fine to very fine sand and clay; some invertebrate fossils in cobbles, increasing with depth
			54	240	LIMESTONE: yellow brown to yellow orange, well lithified, fossiliferous; fine to coarse sand and trace glauconite
		Lisbon Formation	12	252	Sandy CLAY: pale green, coarse sand, trace glauconite
13L215	LBBW-12L	Overburden	11	11	Silty CLAY: red brown to mottled orange and tan, medium to high plasticity; trace fine sand
			9	20	CLAY: mottled orange, tan, and white, high plasticity; some silt and fine quartz sand; abundance of white kaolinitc clay and black carbon
			5	25	Silty CLAY: mottled orange and tan, medium plasticity; small zones of limestone
		Ocala Limestone	30	55	LIMESTONE: light tan to cream, highly weathered, wet; coarse gravel mixed with silt and fine to coarse sand; some oxidation
			60	115	LIMESTONE: light tan to cream, highly weathered, wet, some iron staining; coarse gravel and limestone cobbles with shell molds mixed with silt and clay
			50	165	LIMESTONE: light tan, highly weathered, wet; cobbles and coarse gravel in fine sand and silt matrix; shells and molds abundant throughout
			77	242	LIMESTONE: yellow orange to pale yellow, well lithified, fossiliferous, some iron oxide and glauconite
		Lisbon Formation	5	247	Sandy CLAY: pale green to yellow green, glauconite, fine sand
13L217	ALBBW-13L	Overburden	9	9	Sandy CLAY: mottled red brown and light brown, non-plastic, dry; very fine to coarse angular sand
			13	22	CLAY: mottled red brown and pale gray, non-plastic, dry; some fine to coarse sub-rounded sand and cobbles, poorly sorted
			1	23	SAND: gray orange and light brown, dry, very fine to fine, moderately well sorted
			21.5	44.5	CLAY: yellow orange to yellow brown to red purple, plastic, damp to wet; some fine to coarse sand and fine gravel
		Ocala Limestone	51.5	96	LIMESTONE: yellow gray to pale gray, highly weatherd, wet; fine sand to cobbles mixed with clay and silt, poorly lithified
			54	150	LIMESTONE: yellow gray to green gray, highly weathered, wet; fine sand to gravel mixed with silt and clay, fossiliferous, more competent limestone layers increase with depth

Appendix C. Lithologic logs for selected wells drilled in the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base near Albany, Georgia—Continued

Well number	Well name	Water-bearing unit	Thickness (feet)	Depth below land surface (feet)	Description of Lithology
			46	196	LIMESTONE: yellow gray to green gray, highly weathered, wet; fine to medium sand mixed with silt and clay, fossiliferous, frequent 2-3 inch lithified limestone layers
			54	250	LIMESTONE: pale yellow to yellow brown to gray orange, well lithified, sparry; fossiliferous, shell fragments and molds
			47	297	LIMESTONE: yellow orange to milky yellow, very well lithified; fossiliferous, some coarse sand and glauconite
		Lisbon Formation	5	302	Sandy CLAY: pale green to yellow green, glauconite, fine sand
13L219	ALBBW-14L	Overburden	4	4	Clayey SAND: yellow orange, dense, dry; very fine to medium sand, poorly sorted
			36	40	Sandy CLAY: mottled yellow orange, red, and gray to dark red brown, non-plastic, dry to damp; some very fine to coarse sand
			3	43	CLAY: gray brown, plastic, damp to wet; some sand and limestone cobbles
		Ocala Limestone	74	117	LIMESTONE: pale orange to pale gray, highly weathered, wet; fine sand to coarse gravel with some cobbles mixed with silt, fossiliferous
			20	137	LIMESTONE: white to pale orange with iron staining, highly weathered, wet; fine to coarse sand with some gravel
			20	157	no recovery
			30	187	LIMESTONE: white to pale orange, highly weathered, wet; fine to coarse sand with some gravel, some iron staining
			105	292	LIMESTONE: tan to orange brown to white, well lithified; some silt and sand, fossiliferous
		Lisbon Formation	4	296	CLAY: pale green to gray, glauconite pellets numerous
13L221	ALBBW-15L	Undifferentiated Overburden	17	17	Sandy CLAY: red brown to yellow orange to pale orange, non-plastic, dry; fine to coarse sand and gravel mixed with silt
			27	44	CLAY: mottled yellow, orange, yellow brown, and red, plastic, damp; fine to coarse sand and trace gravel
			1	45	Clayey SAND: red brown, damp to wet; fine to coarse, sub-rounded, poorly sorted
			35	80	CLAY: mottled yellow, orange, yellow brown, and red, plastic, damp; fine to coarse sand and trace gravel
			2	82	Clayey SAND: gray red, damp to wet; fine to coarse, sub-rounded, very poorly sorted
			25	107	CLAY: yellow orange to yellow brown to red, plastic, wet; fine to coarse sand and trace gravel mixed with silt
			9	116	Clayey SAND: gray to gray brown to red, wet, heavily weathered; fine sand to gravel mixed with silt and clay
		Ocala Limestone	100	216	LIMESTONE: pale gray to yellow orange, highly weathered, wet; fine to coarse sand with gravel and cobbles in silt and clay, fossiliferous; more competent with depth
			111	327	LIMESTONE: white to off-white, well lithified, fossiliferous; recrystallized, shell fragments and molds
		Lisbon Formation	5	332	Sandy CLAY: pale gray to green gray, glauconite
13L223	ALBBW-16L	Undifferentiated Overburden	3	3	SAND: orange brown, fine to medium; some silt and gravel
			8	11	CLAY: orange with gray, low to moderate plasticity; some silt
			3	14	Clayey SAND: orange with gray, fine to medium; some silt
			21	35	CLAY: orange to gray to white to brown to red mottled, plastic, damp; trace silt

Appendix C. Lithologic logs for selected wells drilled in the Upper Floridan aquifer in the vicinity of the Marine Corps Logistics Base near Albany, Georgia—Continued

Well number	Well name	Water-bearing unit	Thickness (feet)	Depth below land surface (feet)	Description of Lithology
			10	45	CLAY: red to brown mottled with gray, purple, and brown, plastic, damp to wet; silt and fine to coarse sand, increasing with depth
		Ocala Limestone	50	95	LIMESTONE: white to light gray, highly weathered, wet; silt and clay with some fine sand
			95	190	LIMESTONE: tan to yellow green, highly weathered, wet; silt and fine to coarse sand with fine gravel
			45	235	LIMESTONE: tan to tan yellow, highly weathered, wet; medium to coarse sand and gravel with some silt, fossiliferous
			57	292	LIMESTONE: tan to white, well lithified, fossiliferous; trace glauconite
		Lisbon Formation	5	297	Sandy CLAY: yellow green, fine sand, some glauconite
13L225	ALBBW-17L	Undifferentiated Overburden	23	23	Clayey SAND: brown to orange with white, dry; fine to medium, some silt
			10	33	CLAY: orange with white, plastic, dry to damp
			2	35	Clayey SAND: brown, wet; fine to medium
			8	43	CLAY: orange to white to yellow, plastic, damp
			4	47	Clayey SAND: orange brown, moist; fine to medium, some silt
			8	88	CLAY: red brown to tan with white, plastic, damp
			2	57	Clayey SAND: orange brown, damp; fine to medium, some silt
			18	75	CLAY: orange to brown, plastic, damp
		Ocala Limestone	60	135	LIMESTONE: white to light tan, highly weathered, wet; silt and fine to coarse sand mixed with gravel
			20	155	No recovery
			72	227	LIMESTONE: white to light tan, highly weathered, wet; silt and fine to coarse sand mixed with gravel, fossiliferous
			80	307	LIMESTONE: white to tan, well lithified, fossiliferous; fine sand and trace glauconite
		Lisbon Formation	11	318	CLAY: green with glauconite
13L227	ALBBW-18L	Undifferentiated Overburden	10	10	Clayey SILT: orange brown, dry, some organic material
			10	20	Clayey SAND: mottled tan, white, brown, and red, dry; fine sand
			10	30	Sandy CLAY: white and purple, dry; fine to medium sand
			12	42	Silty CLAY: brown with black carbon, damp to wet, plastic; some limestone and chert gravel
		Ocala Limestone	73	115	LIMESTONE: tan to off-white, highly weathered, damp to wet; some gravel and cobbles
			80	195	LIMESTONE: tan, highly weathered, wet; gravel and cobbles mixed with fine to coarse sand and silt; some competent layers
			71	266	LIMESTONE: tan to white, well lithified, fossiliferous
		Lisbon Formation	6	272	Sandy CLAY: green, fine sand, glacuconite