Investigation of Ethylene Dibromide (EDB) in Ground Water in Seminole County, Georgia

U.S. GEOLOGICAL SURVEY CIRCULAR 933

Prepared in cooperation with
Exposure Assessment Branch
Hazard Evaluation Division
Office of Pesticide Programs
Office of Pesticides and Toxic Substances
U.S. Environmental Protection Agency

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

Investigation of Ethylene Dibromide (EDB) in Ground Water in Seminole County, Georgia

By James B. McConnell and others

U.S. GEOLOGICAL SURVEY CIRCULAR 933

Prepared in cooperation with
Exposure Assessment Branch
Hazard Evaluation Division
Office of Pesticide Programs
Office of Pesticides and Toxic Substances
U.S. Environmental Protection Agency

1984

Department of the Interior

WILLIAM P. CLARK, *Secretary*

U.S. Geological Survey

Dallas L. Peck, *Director*

Library of Congress Cataloging in Publication Data

Main entry under title:
Investigation of etylene dibromide (EDB) in ground water in Seminole County, Georgia.
(Geological Survey circular ; 933)
"Prepared in cooperation with Exposure Assessment Branch, Hazard Evaluation Division, Office of Pesticide Programs, Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency."
Bibliography: p.
Supt. of Docs. no.: I. 19.4/2:933
1. Water, Underground—Pollution—Georgia—Seminole County. 2. Ethylene dibromide. I. McConnell, James B.
II. United States. Environmental Protection Agency. Office of Pesticide Programs. Exposure Assessment Branch. III. Title: Investigation of ethylene dibromide (E.D.B.) IV. Series.
QE75.C5 no. 933 557,3s [363.7'394] 84-600172 [TD225.s456]

Free on application to Distribution Branch, Text Products Section, U. S. Geological Survey, 604 South Pickett Street, Alexandria, VA 22304

CONTENTS

ILLUSTRATIONS

TABLES

METRIC CONVERSION TABLE

For those readers who may prefer to use metric units or the International System of Units (SI) rather than inch-pound units, conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometers (km^2)
	Volume	
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
	3.785	liter (L)
	Mass	
pound (lb)	0.454	kilograms (kg)
ounce (oz)	28.38	gram (g)
	28.35×10^3	milligram (mg)
	28.35×10^6	microgram (ug)
pound (lb)	28.35×10^{12}	picogram (pg)
	Flow	
gallon per minute (gal/min)	6.309×10^{-3}	cubic meter per second (m^3/s)
	0.06309	liter per second (L/s)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Temperature	

degrees Fahrenheit (°F) = 1.8 X degrees Celsius (°C) + 32

National Geodetic Vertical Datum of 1929 (NGVD of 1929).--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada formerly called mean sea level. NGVD of 1929 is referred to as sea level in the text of this report.

Investigation of Ethylene Dibromide (EDB) in Ground Water in Seminole County, Georgia

By James B. McConnell, David W. Hicks, Luis E. Lowe, Stewart Z. Cohen[1], and Andrew P. Jovanovich[1]

ABSTRACT

An investigation of ground water in Seminole County, Georgia, for ethylene dibromide (EDB) was conducted in August 1983 by the U.S. Geological Survey in cooperation with the Exposure Assessment Branch of the U.S. Environmental Protection Agency. The purpose of the investigation was to determine whether EDB, which was previously detected in ground-water samples from four neighboring wells, was localized in the vicinity of the wells or was more widespread in the ground-water system.

EDB was detected in 6 of 19 wells sampled. Concentrations ranged from 0.03 to 11.8 micrograms per liter. Five of the six samples that contained EDB were collected from irrigation wells, and one was collected from a domestic well. Concentrations of 4.5 and 11.8 micrograms per liter were found in two irrigation wells located near Buck Hole, a sinkhole in a swampy depression in central Seminole County. EDB was not detected in samples from the remaining 10 irrigation and 3 domestic wells and the surface-water site (detection level less than 0.01 microgram per liter).

Nine core samples were collected from a borehole near one of the irrigation wells that had high EDB concentrations. EDB was found in a core sample near the surface and in samples from depths of 24 to 25, 34 to 35, and 39 to 40 feet in the residuum. EDB concentrations in the core samples ranged from 0.06 to 2.4 micrograms per kilogram.

EDB in the aquifer was found in a 4-square-mile area of the county in the vicinity of Buck Hole. EDB application information and the local hydrogeology indicate that EDB contamination in ground water in Seminole County probably is due to soil fumigation with EDB. Apparently, EDB moves downward through the residuum and, through undetermined pathways, enters the aquifer. However, because the high concentration of EDB in the aquifer seems to be localized in the Buck Hole area, the possibility of contamination from an EDB fumigant spill cannot be disregarded at this time.

INTRODUCTION

In August 1983, the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency (EPA), Exposure Assessment Branch, conducted an investigation of ground water in Seminole County, Ga., for ethylene dibromide or 1,2-dibromoethane (EDB) contamination. EDB is a chemical widely used in the United States as a fumigant and a gasoline additive. In the highly productive agricultural area of southwest Georgia, which includes Seminole County, EDB is used as a soil fumigant to control nematodes. The purpose of the investigation was to determine whether EDB, which was previously detected in ground-water samples from four neighboring wells, was localized in the vicinity of the wells or was more widespread in the ground-water system. Also, information about the distribution and concentration of EDB in ground water would help to determine the probable source of EDB contamination. The study was reconnaissance in nature because preliminary data were needed as rapidly as possible. In less than a month from the initial contact between agencies, the investigation was planned and conducted, methods of analysis and quality assurance were developed, and a draft report of the findings was prepared by the Exposure Assessment Branch of EPA. Completion of the task in a short time was made possible by a high degree of cooperation between EPA, the U.S. Geological Survey, the Seminole County agricultural extension agent, and the landowners in Seminole County.

BACKGROUND

Seminole County is within a highly productive, 4,400-square-mile agricultural area of southwest Georgia called the Dougherty Plain (fig. 1). The Dougherty Plain can be characterized as having both a favorable climate for agriculture and an abundant supply of ground water for irrigation. In the past decade, increased agricultural growth and productivity in the Dougherty Plain have resulted in the use of large-scale irrigation

[1]U.S. Environmental Protection Agency.

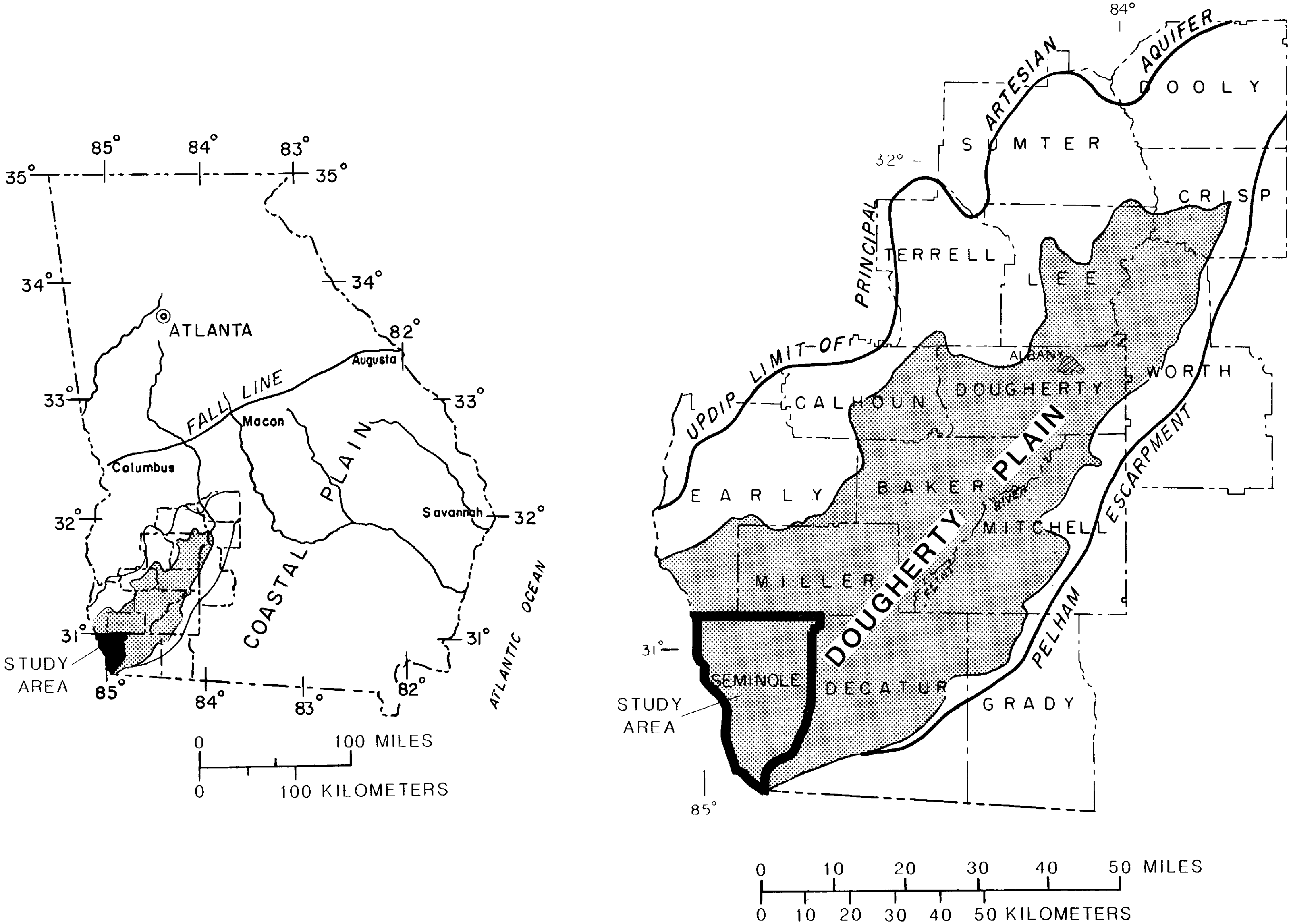


FIGURE 1.—Location of the study area.

systems, multicropping, and increased applications of EDB and other pesticides.

In Seminole County, the principal crops are vegetables, peanuts, soybeans, and pecans during the summer months and grains during the winter months. EDB (trade names Soilbrom[2] and Dowfume) is used extensively on vegetable and peanut crops and to a lesser extent on soybean crops to control nematodes. EDB is applied several inches below the soil surface as a liquid at the rate of 1 to 2 gal (15 to 30 lbs of active ingredients) per acre.

Prior to this investigation, a researcher from Florida State University, Tallahassee, had detected EDB in water samples collected from three irrigation wells and one domestic well south of Donalsonville near Buck Hole in Seminole County (fig. 8). Buck Hole is one of many sinkholes in a swampy depression that is connected to Fishpond drain, a major drainage that flows from north to south through the center of the county. The researcher initially found EDB in water samples from these wells during a method development study for synthetic organic compounds. In subsequent sampling, the researcher confirmed the presence of EDB in these wells. The findings are listed in the following table:

Well designation*	Date sampled	EDB concentration (ug/L)
BH1(W5)	October 1981	27.0
BH2(W4)	do.	110.0
BG1	do.	.5
BH1(W5)	May 1982	36.0
BH2(W4)	do.	90.0
BG1	do.	.3
BH1(W5)	June 1982	27.0
BH2(W4)	do.	11.0
Domestic well	do.	.2

* BH and BG are well designations used by Florida State University. BH stands for Buck Hole, a sinkhole in a swampy depression in the vicinity of the wells sampled. BG is a well owners initials. W is the well designation used by U.S. Geological Survey.

Two analytical approaches were used by the Florida State University researcher to determine EDB concentrations in the water samples: extraction of the sample followed by gas chromatographic analysis of the extract, and a purge-and-trap technique using a Tenax trap. Detection limits were about 0.2 μg/L.

The University informed the EDB manufacturers of the findings in May 1982. The manufacturers resampled the wells, confirmed the presence of EDB in ground water from BH1 and BH2, and notified the EPA Office of Pesticide Programs of the contamination. The manufacturers submitted data to the Office of Pesticide Programs in September 1982 that showed EDB had been used annually for several years as a soil fumigant for control of nematodes in the fields where the BH1 and BH2 irrigation wells are located. The history of EDB use in the field where BG1 is located is uncertain. The domestic well is located in the vicinity of fields where EDB has been applied.

After the contamination was reported, the EPA informally requested that the manufacturers design and conduct a ground-water-quality monitoring study in southwest Georgia, but no study has been initiated to date. Recent reports of EDB contamination of ground water in Florida, Georgia, California, and Hawaii prompted the EPA to conduct its own study in Seminole County, Ga., as quickly as possible to better define the nature of the contamination problem. In August 1983 the U.S. Geological Survey, in cooperation with the Exposure Assessment Branch of EPA, began an investigation of EDB in ground water in Seminole County.

HYDROGEOLOGY

PRINCIPAL ARTESIAN AQUIFER

The source of most domestic, municipal, industrial, and irrigation water in southwest Georgia is the principal artesian aquifer. This carbonate aquifer system extends from South Carolina through Florida. In the Dougherty Plain (fig. 1), the upper surface of the aquifer dips generally southeastward and ranges from about 300 ft above sea level in the northern part of the area to about sea level in the southern part (fig. 2). However, the surface of the aquifer is highly irregular because of differential weathering and solution-cavity collapse. The aquifer ranges in thickness from 25 ft on the northwestern edge of the Dougherty Plain to more than 350 ft on the southern edge (fig. 3). In many areas, the limestone is largely fractured, and solutioning has created a labyrinth of subterranean channels which result in high transmissivities for wells that penetrate the channels. Regionally, estimates of transmissivity values range from 3,000

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

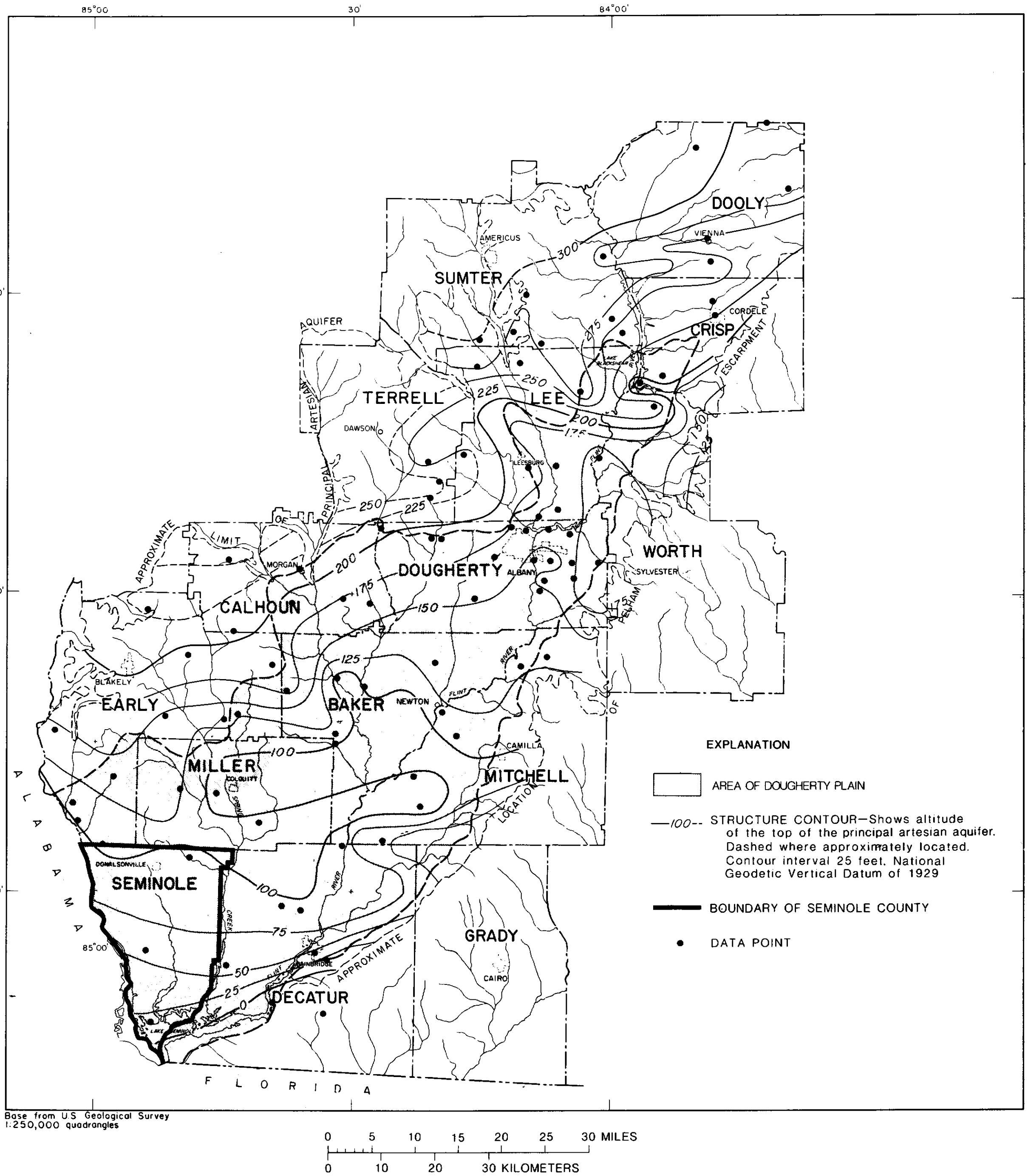


FIGURE 2.—Altitude of the top of the principal artesian aquifer.

to 300,000 ft²/d (Hayes and others, 1983). (See fig. 4.)

In Seminole County, the top of the aquifer ranges from about 100 ft above sea level to sea level (fig. 2), and the aquifer ranges in thickness from about 125 to 300 ft (fig. 3). Transmissivities exceed 75,000 ft²/d for almost the entire county and may reach 300,000 ft²/d in southern Seminole County (fig. 4). Natural rates of water movement have not been measured in the study area, but they probably are highly variable. For example, Hayes and others (1983) reported computed

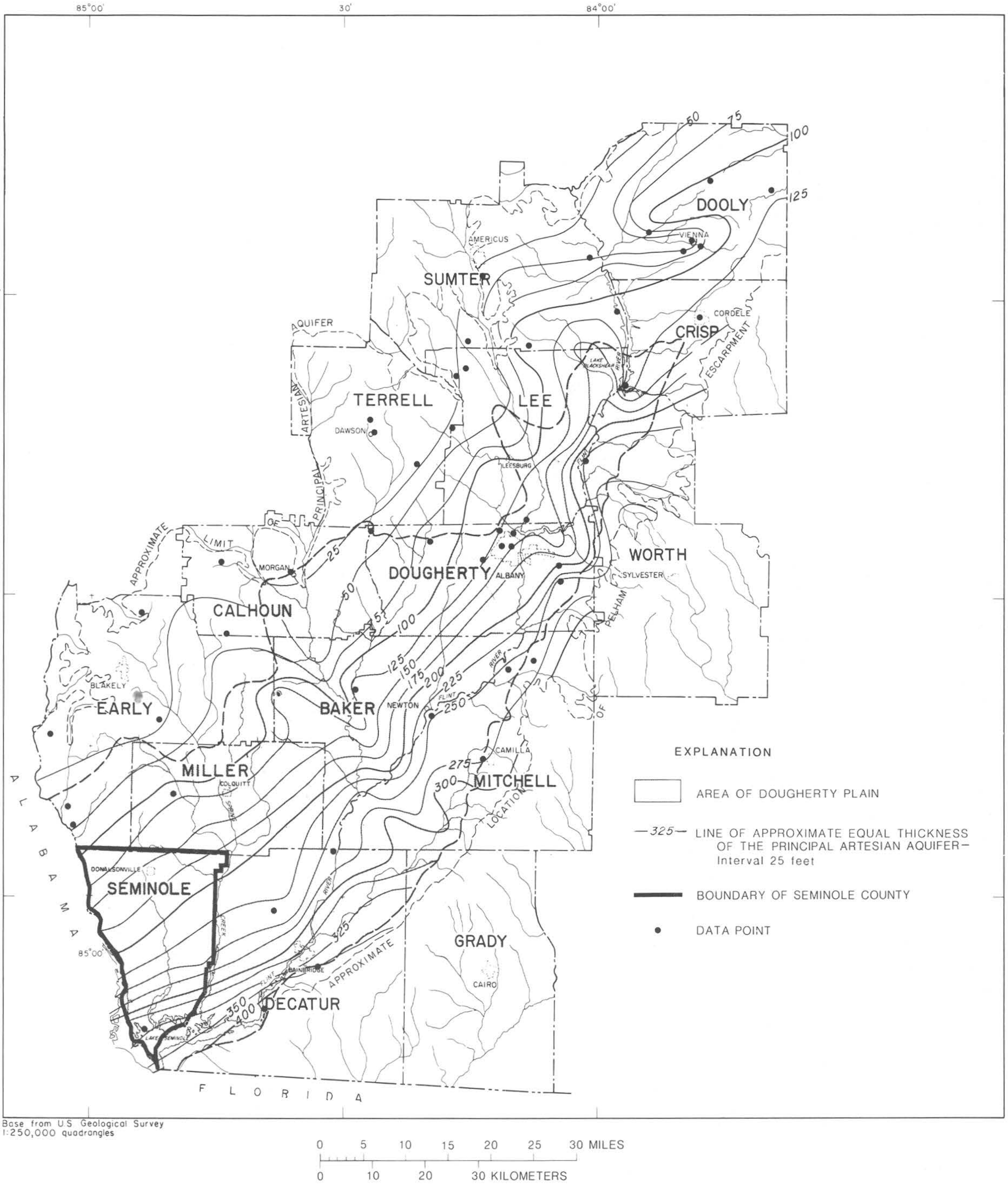


FIGURE 3.—Approximate thickness of the principal artesian aquifer.

average velocities of 3 ft/d near the Flint River upstream from Bainbridge and 0.2 ft/d in the northern part of the Dougherty Plain, away from streams. Average velocities of ground-water flow vary greatly in the principal artesian aquifer because the limestone acts as both a free-flow (channel flow) and a diffuse-flow system. Actual ground-water velocity may be more or less than the average values, depending on the flow path followed and local geohydrologic conditions (Hayes and others, 1983). The maximum potential rate of lateral water movement in the vicinity

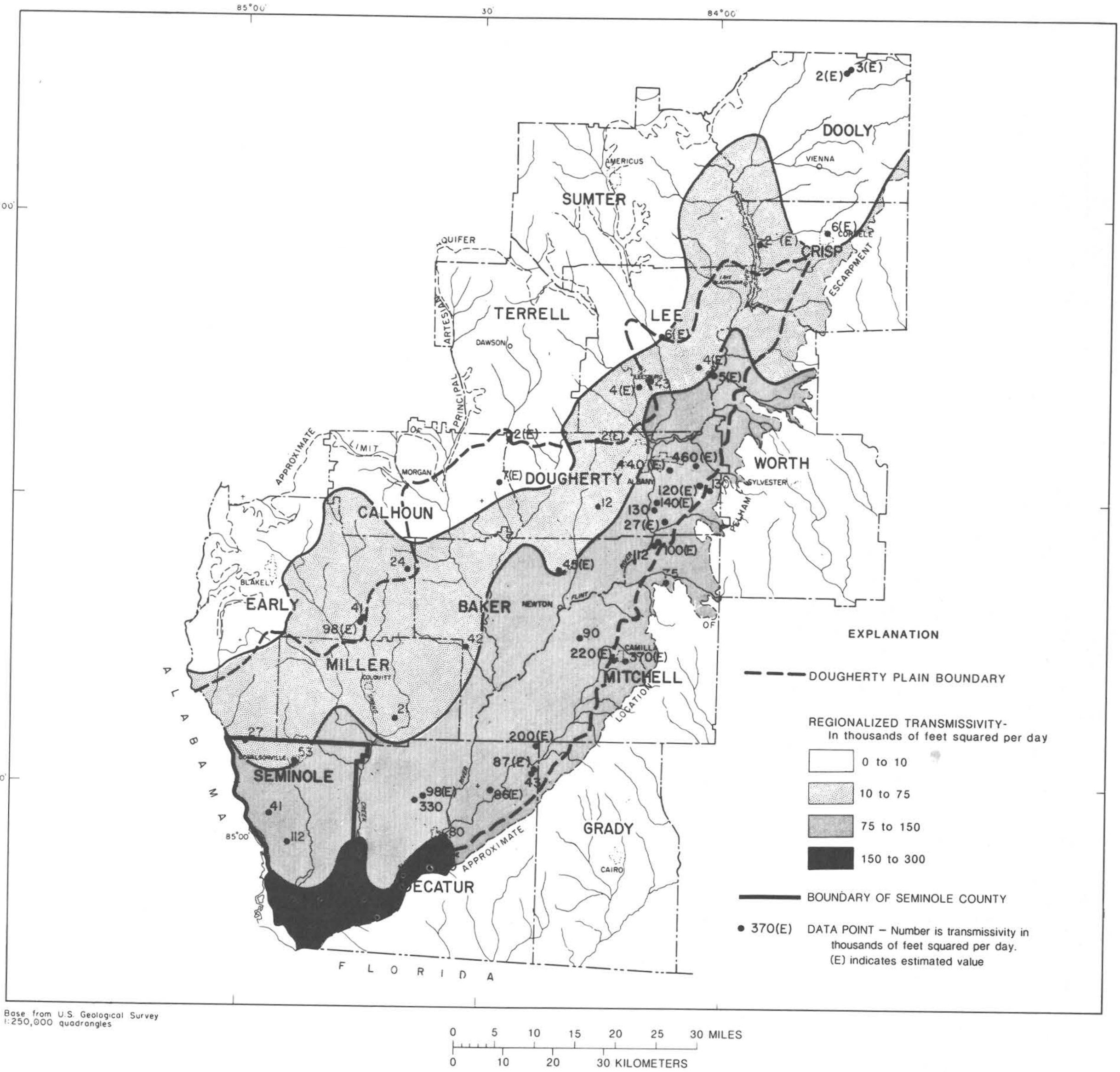


FIGURE 4.—Approximate transmissivities of the principal artesian aquifer.

of an operating well would be several times greater than the average velocities.

The direction of regional ground-water flow within the principal artesian aquifer in the study area is generally from north to south toward Lake Seminole. Flow direction is indicated by the potentiometric surface contours shown in figures 5 and 6: flow direction is generally downgradient, perpendicular to the countour lines. Water levels shown are typical of the water levels that follow low recharge and the irrigation season (fig. 5) and that follow winter and early spring recharge prior to the irrigation season (fig. 6). The water-level fluctuation for any particular year at a site is controlled by the amount of decline during the summer from pumping, evapotranspiration, and stream discharge and by the amount of recharge from rainfall during the spring.

The shape of the potentiometric contours suggests that major streams, including Fishpond Drain in central Seminole County, are areas of ground-water discharge (streams gain water). However, additional water-level data are needed to adequately define the potentiometric contours in the vicinity of the stream reaches.

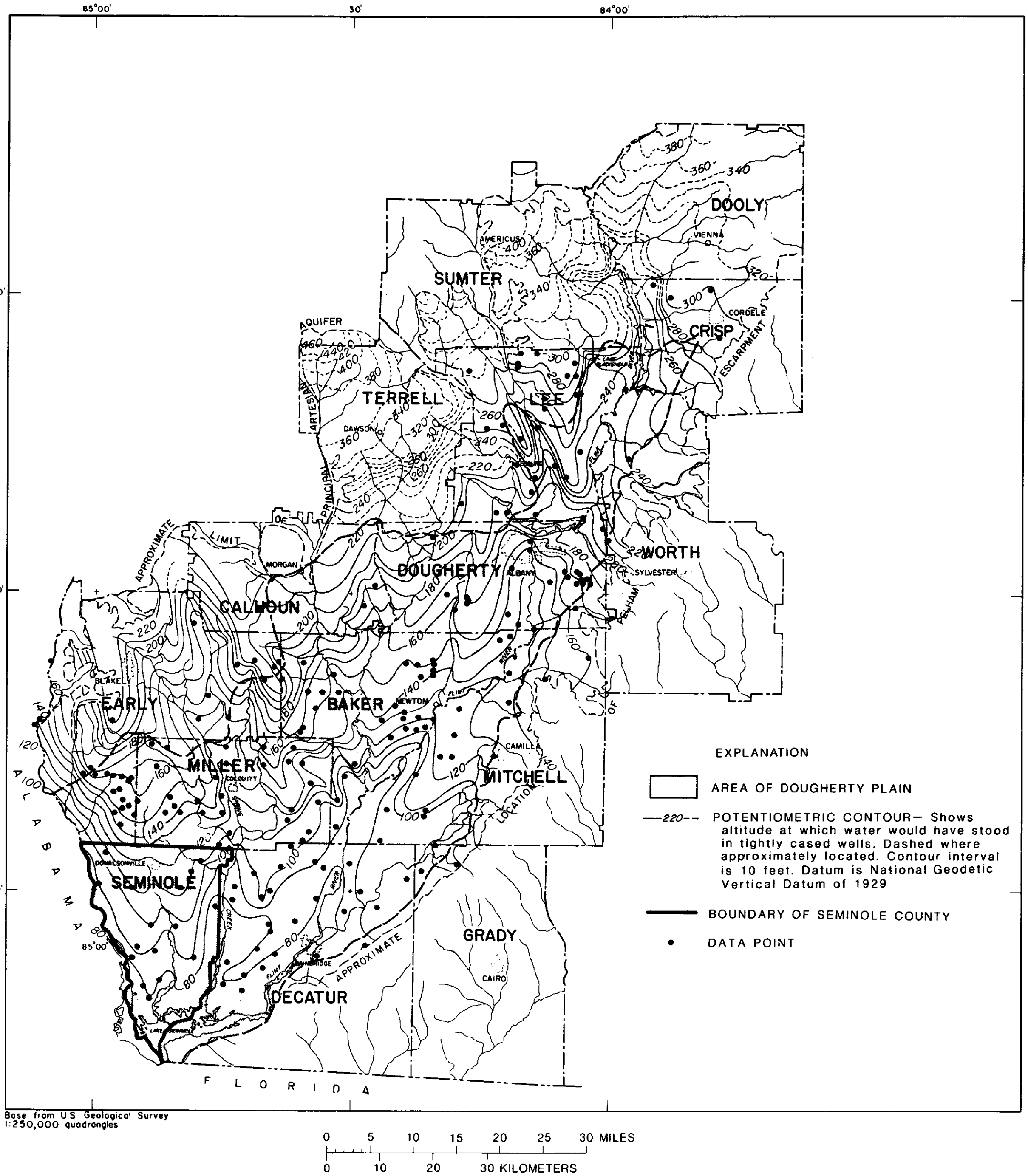


FIGURE 5.—Potentiometric surface of the principal artesian aquifer, November 1979.

RESIDUUM

A sandy-clay residuum overlies the principal artesian aquifer, and in Seminole County it ranges in thickness from about 50 to 100 ft (fig.7). Water levels in the residuum respond to rainfall and are highest in March and April and lowest in November and December. According to Hayes and others (1983), where the residuum is relatively thick and impermeable, the water table is believed to be a subdued replica of the topography; where the residuum is relatively thin and

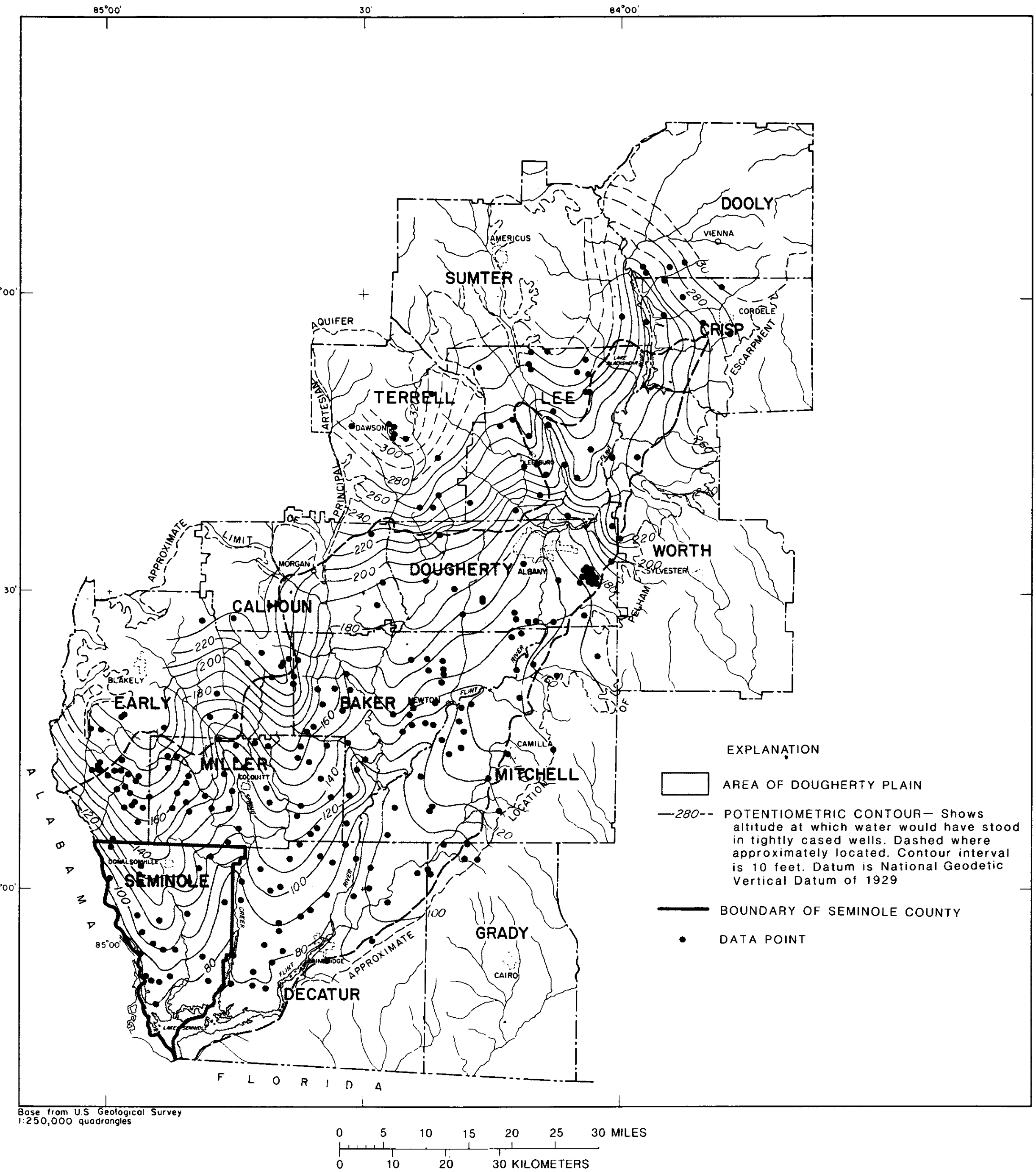


FIGURE 6.—Potentiometric surface of the principal artesian aquifer, May 1980.

permeable, the water table is believed to be a subdued but higher replica of the potentiometric surface of the principal artesian aquifer. Transmissivities of the residuum, estimated to range from 0.002 to 1,000 ft²/d, depend largely on the presence or absence of permeable sand lenses, which seem to occur more commonly in the upper half of the residuum than in the lower half. Generally, the lower half of the residuum acts as a confining bed. Transmissivities of the residuum may increase greatly during periods of high water levels as the sand lenses in the upper half of the

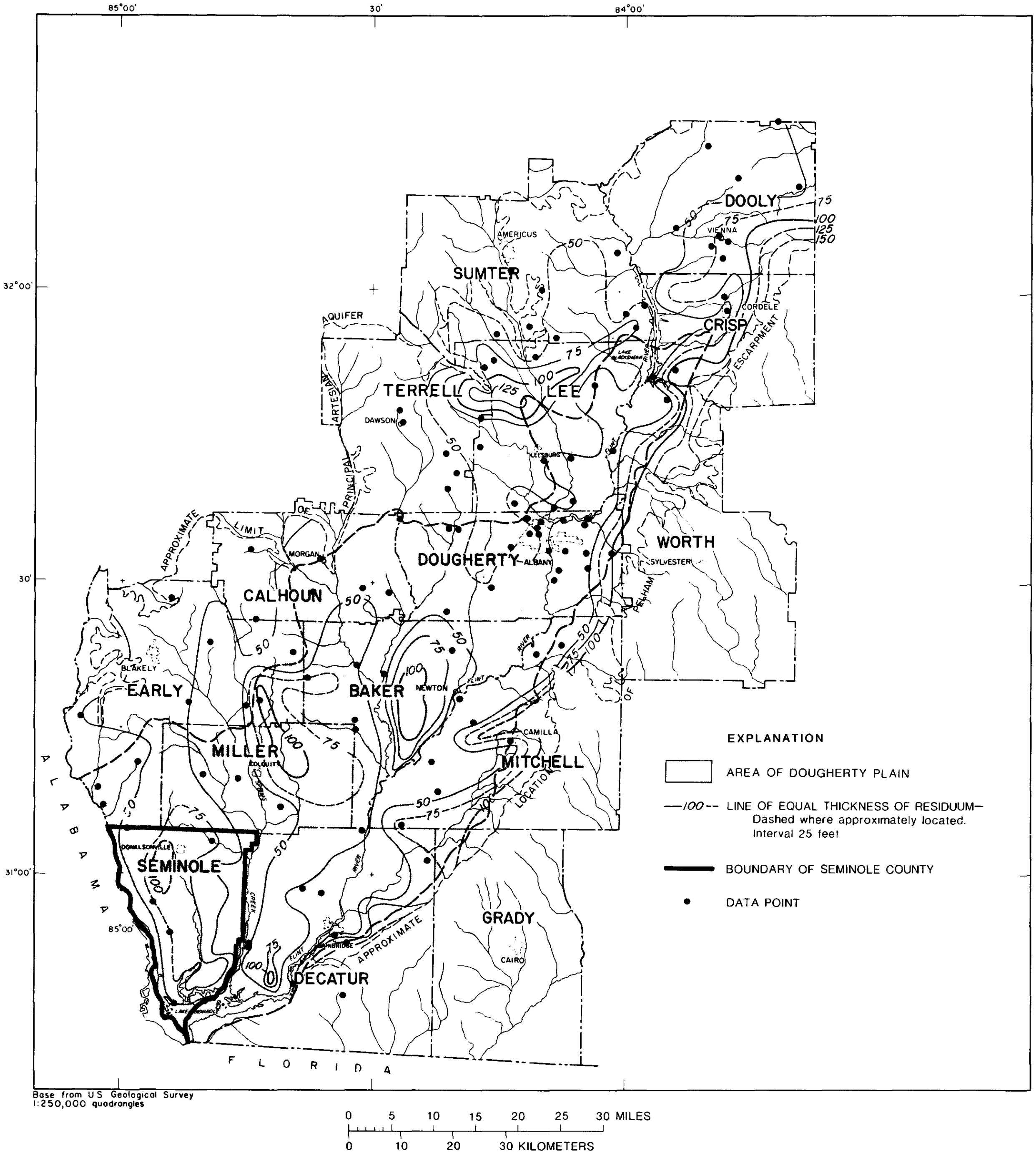


FIGURE 7.—Approximate thickness of the residuum.

residuum become saturated. Thus the presence or absence of sand lenses in the residuum and the height of water levels could have a significant effect on the movement of contaminants through the residuum and into the limestone aquifer.

DATA COLLECTION AND ANALYSIS

On August 17-19, 1983, the U.S. Geological Survey collected ground-water samples for EDB analysis from 15 irrigation wells and 4 domestic wells that tap the principal artesian aquifer. One sample of ponded surface water was collected from Fishpond Drain near Buck Hole. The locations of the sampling sites are shown in figure 8. In addition, nine core samples for EDB and particle-size analysis were collected from a 42-foot test hole at 4-foot intervals beginning a foot below land surface.

SITE SELECTION

Selection of sampling sites for EDB was based on available information for EDB in ground water, hydrogeologic data and soil surveys, EDB application information obtained from the county agent and landowners, land-use data, and landowners cooperation. Land use was determined from 1982 high-altitude photographs by the Environmental Photographic Interpretation Center of the EPA Office of Research and Development. Wells W4(BH2) and W5(BH1), in the vicinity of Buck Hole where the highest concentrations of EDB in ground water had been reported by Florida State University, were selected for resampling in this study. Other sites were selected upgradient and downgradient from Buck Hole in fields with different soil types, some of which had not received EDB applications. All the sites, except one well in southernmost Miller County, were in Seminole County. The site selected for the collection of core samples was about 150 ft south of well W4 (fig. 8).

METHODS OF SAMPLE COLLECTION

Ground-water samples from irrigation wells were collected at water spigots on the delivery lines between the pumps and the sprinkler systems. Irrigation systems that were not operating were started and allowed to pump at a rate of several hundred gallons per minute for at least 15 min. prior to sample collection. Samples from domestic wells were also collected at a water spigot after about 15 min. of continuous pumping. Domestic wells sampled tapped the same aquifer as the irrigation wells, and the water was untreated.

Water samples were collected in 40-mL glass vials and sealed with Teflon-lined silicone septa and plastic screwcaps. Water was delivered to the vials through a piece of small-diameter silicon tubing attached to the spigots. The tubing was inserted into the vials and the vials were flushed with several volumes of sample water. The tubing was then slowly removed while the water was flowing to allow the vials to completely fill before capping. Care was taken to ensure that the water samples were free of air bubbles. To reduce the possibility of cross contamination, new tubing was used each time a sample was collected. The surface-water sample was collected with a brass "grab type" sampler and transferred to a 40-mL vial through silicon tubing to minimize aeration of the sample. The samples were stored in ice until analyzed.

Core samples were collected with a split-spoon coring device 18 in. long by 2 in. in diameter. A truck-mounted flight auger was used to bore to the desired sampling depth. After the loose cuttings were removed from the hole with the auger, the split-spoon was attached to a solid steel rod, lowered to the bottom of the hole, and driven into the formation. The coring device was then lifted to land surface and split apart, and a central section of the core (4 to 6 in. long) was removed for EDB and particle-size analysis. Core samples for EDB analysis were sealed in clean glass jars and stored in ice until analyzed. Core samples for grain-size analysis were stored in plastic containers. Before each core sample was collected, the core barrel was rinsed with acetone and then with chemically pure water.

During the boring, the cuttings that were removed from the hole were used to describe the lilthology of the residuum. After the core samples were collected, a continuous natural gamma radiation log was made of the hole with a borehole geophysical logger according to procedures described by Keys and MacCary (1971). Natural gamma radiation was detected by a sodium iodide crystal that was lowered into the bore hole on a wire line. The wire line also served as an electrical connector between the crystal and a strip-chart recorder at the land surface. The natural gamma radiation log supplemented the core data by providing additional data to identify sand, clay, and limestone in the borehole.

Guidelines used for the collection of EDB samples in ground water were provided by U.S. Geological Survey, Water Quality Branch Memorandum 83.12, "Guidelines for the Collection of Ground-Water Samples for the Analysis of Organic Compounds." Recommended sampling

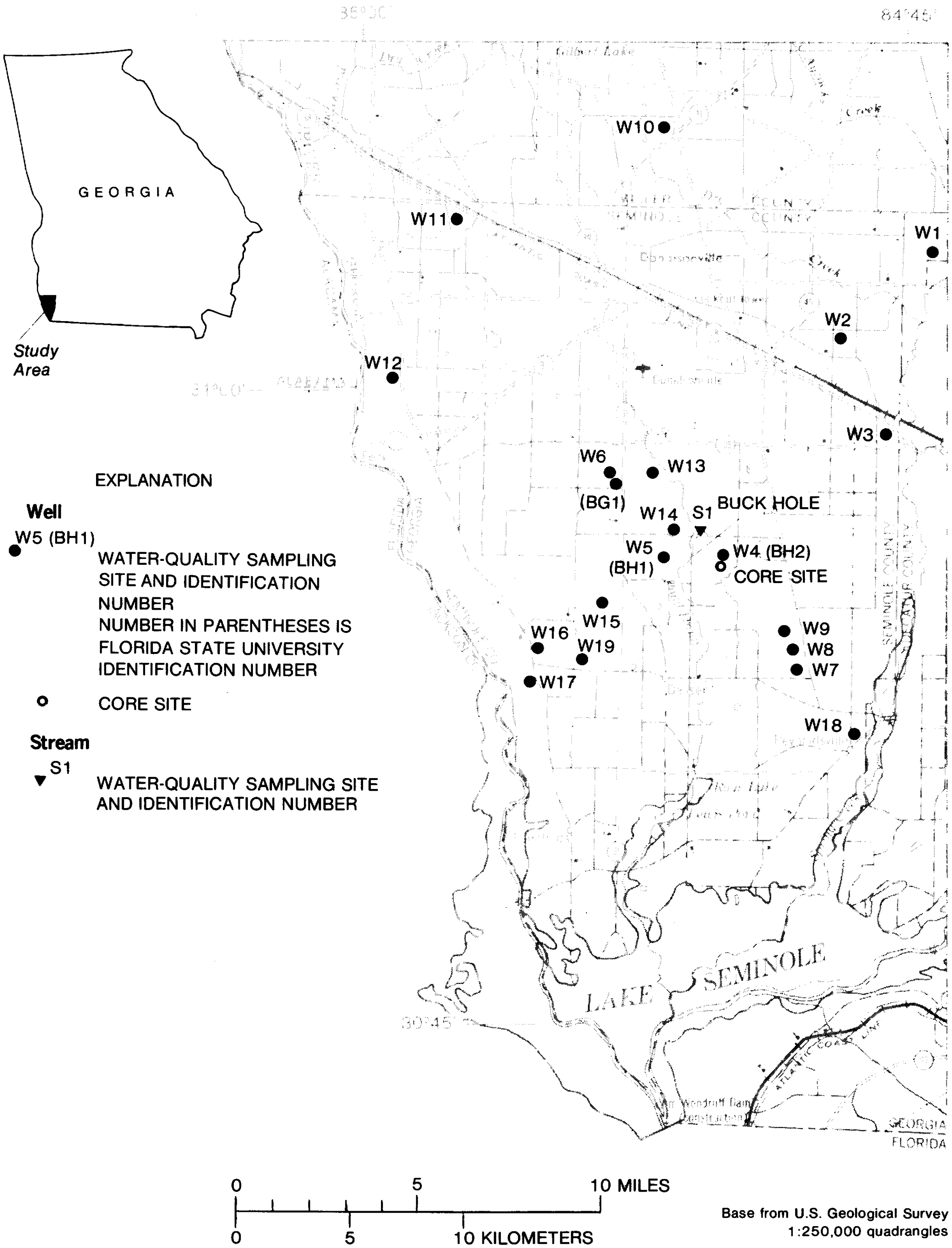


FIGURE 8.—Location of water-quality sampling sites and residuum-core site.

devices could not be used because the samples had to be collected from existing irrigation and domestic wells. However, the absence of air bubbles in the pumped water indicated that the potential loss of EDB due to cavitation or aeration by the irrigation or domestic well pumps was minimal.

ANALYTICAL METHODOLOGY FOR EDB DETERMINATIONS

The determination of EDB in both water and soil samples was performed by dual-capillary-column electron-capture gas chromatography after preconcentration by liquid-liquid extraction into hexane. The presence of EDB was confirmed by gas chromatography followed by computer-assisted mass spectrometry (GC/MS), using the purge-and-trap method of separation and preconcentration as described in EPA method 624 (U.S. Environmental Protection Agency, 1982). The analytical methodology for EDB determinations was developed specifically for this project because standard methods were not available. The time constraints of the project did not permit a complete interlaboratory method validation, but spike-recovery data indicated that the methods provide accurate and precise EDB data.

Details of these procedures are described below:

SAMPLE PREPARATION

For water samples, 2 mL of hexane (pesticide-analysis quality) was added to 37 mL of water sample in the original field-sample vial and shaken for 1 min. to extract EDB. A 1-μL subsample of the hexane extract was removed for analysis using a Hamilton #701N 10-μL glass syringe.

For soil samples, approximately 30 g of soil was weighed to +0.01 g in a tared 43-mL vial, and sufficient 2-percent (v/v) aqueous solution of methanol (pesticide-analysis quality) was added to raise the liquid level to the shoulder of the vial. The vial was then covered with a Teflon-lined silicone septum, capped with a screwcap, and agitated for 5 min. to disperse the soil particles. Some samples required sonication (Mettler model ME4.6) for several minutes for complete dispersion. All samples were allowed to stand overnight for phase separation.

Two milliliters of hexane was added to the vial, and the vial was capped and gently agitated for 3 min. to extract the EDB from the sample into the hexane layer. The layers were separated by centrifugation for 6 min. at 900 rpm, and a 1-μL subsample of the hexane layer was removed for analysis using a 10-μL glass syringe.

ANALYSIS

Both water and soil extracts were analyzed by isothermal gas chromatography, using a Hewlett-Packard model 5880 gas chromatograph fitted with two capillary columns of differing polarities and dual electron-capture detectors. A 1.0-μL sample of the hexane extract described above was injected onto each of the two capillary columns using a 1 to 5 ratio split injection. Column A was a 15-m × 0.20-mm i.d. fused silica capillary column coated with Se–54 silicone. Column B was identical to column A but was coated with OV–1701 silicone. Column conditions were as follows:

Inlet temperature	210°C
Oven temperature	40°C
Column flow	1 mL/min
Carrier gas	Nitrogen

Quantification on both columns, accomplished with a Hewlett-Packard model 3354 data system, was based on a single-point calibration. The lower of the two EDB concentrations was reported on the assumption that the higher concentration may result from interference caused by incomplete chromatographic separation. The detection limit for this analysis was determined to be about 0.02 μg/L.

CONFIRMATION

The gas-chromatographic analysis was confirmed in samples found to contain the highest concentrations of EDB by use of a Hewlett-Packard model 5992A gas chromatograph/mass spectrometer (GC/MS). A purge-and-trap sampling system (EPA method 624) (U.S. Environmental Protection Agency, 1982) was used to isolate EDB from the water samples or from the 2-percent methanol-water leachates of the soil samples. Intermediate concentrations (0.05 to 1.0 μg/L) were confirmed and quantified by the selected-ion-monitoring (SIM) mode using the mass-107 ion. Higher concentrations (greater than 1.0 μg/L) were confirmed in the full-scan mode. Fluorobenzene was added to all samples as a surrogate.[3]

Analytical conditions were as follows:

Column: 1.8-m × 2-mm i.d., 1-percent SP-1000 on 80/100 mesh Carbopak B

Sparging time	11 min
Injection port temperature	180°C
Initial oven temperature	80°C
Initial hold time	2.5 min
Temperature ramp rate	16°C/min
Final oven temperature	220°C
Run time	12 min

QUALITY ASSURANCE

For water samples, the gas chromatograph was calibrated daily using a standard solution containing 43.4 pg/μL of EDB in hexane. Calibration was checked with the same standard solution at least twice daily.

Spiked reagent water samples, prepared in the laboratory by pipetting microliter quantities of a solution of EDB in methanol into 37 mL of water contained in sample vials, were analyzed and confirmed by the same methods used to analyze the samples. Recovery data for extraction and purge-and-trap methodologies are reported in the following table:

Recovery data for laboratory prepared spikes

Extraction methodology EDB concentrations (ug/L) Added	Found	Purge-and-trap methodology EDB concentrations (ug/L) Added	Found
2.2	2.0	0.17	0.15
2.2	2.0	.17	.17
10.8	9.1	.17	.16
10.8	9.6	.17	.14
21.8	18.4	.34	.29
21.8	17.4	.34	.39
13	11.8	.68	.67
.21	.22	.51	.48
.085	.06	.51	.48
.013	.026	.51	.65
.21	.16	.51	.49
.036	.044		
.036	.044		
.036	.043		
.036	.044		
.036	.038		
.036	.034		

Laboratory and field blanks were analyzed with the samples, and EDB was not detected in either set of blanks. Fluorobenzene was added to all samples as a surrogate prior to GC/MS confirmation. Recoveries fell within the acceptable limits (70–110 percent) described in EPA method 624 (U.S. Environmental Protection Agency, 1982).

Duplicate water samples were collected from five wells in the field and analyzed as blind samples by the laboratory. Results of blind duplicate analyses were as follows:

Blind duplicate analyses

[ND; not detected; concentrations were less than 0.01 ug/L detection limit.]

Well number	EDB (ug/L) Electron capture detector	Single ion monitoring mass spectrometry
W4	4.5 4.4	-
W6	.06 .12	0.07 .06
W10	ND ND	-
W17	ND ND	-
W18	ND ND	-

Standard solutions for soil samples were prepared and used as described for water samples. Spikes were not used for soil samples.

DATA PRESENTATION

Sampling locations, land-surface altitudes, available well construction data, and pumping information are listed in table 1. EDB application information and soil charateristics are shown in tables 2 and 3, respectively. The results of the water-sample analyses for EDB are listed in table 4.

A synopsis of data gathered during this study is presented in figure 9. Included in figure 9 are map locations of sample sites, EDB concentrations in water samples, and information on land use, soil permeability, crop type, and EDB applications. Potential nonagricultural sources of ground-water contamination such as gasoline storage tanks and the Seminole County landfill are also shown.

WELL DEPTHS AND YIELDS

Irrigation and domestic wells in the study area commonly are 150 to 200 ft deep (see table 1).

[3]A surrogate is a compound which is similar in physical and chemical properties to the analytes of interest. Surrogates may be added to every sample to provide quality control by monitoring for matrix effects and for gross sample-processing errors.

TABLE 1.—*Location and information for wells sampled*

[Sample site: numbers used to identify wells in report and to locate wells on map in fig. 8. Use: I, irrigation; D, domestic]

Sample site	Latitude (N.)	Longitude (W.)	County	Quadrangle (7.5 min)	Land surface altitude (ft above NGVD of 1929)	Well			
						Depth (ft)	Casing depth (ft)	Yield (gal/min)	Use
W1	31°03'30"	084°44'17"	Seminole	Boykin	-			-	I
W2	31°01'12"	084°46'56"	do.	Donalsonville East	-	-	-	-	D
W3	30°59'00"	084°45'36"	do.	Desser	122	200	60	1,200	I
W4(1)*	30°56'17"	084°50'02"	do.	do.	115	160	60	1,200	I
W4(2)	30°56'17"	084°50'02"	do.	do.	115	160	60	1,200	I
W4(3)	30°56'17"	084°50'02"	do.	do.	115	160	60	1,200	I
W5	30°56'17"	084°51'22"	do.	do.	112	140	-	1,200	I
W6	30°57'58"	084°53'10"	do.	Steam Mill	122	200	130	1,200	I
W7	30°53'30"	084°48'20"	do.	Desser	108	235	105	1,200	I
W8	30°54'06"	084°48'10"	do.	do.	115	-	-	-	I
W9	30°54'39"	084°48'42"	do.	do.	111	200	140	1,200	I
W10	31°06'19"	084°51'27"	Miller	Donalsonville East	164	-	-	-	I
W11	31°04'06"	084°57'24"	Seminole	Donalsonville West	161	175	-	550	I
W12	31°00'29"	084°59'18"	do.	do.	134	195	90	1,300	I
W13	30°57'55"	084°52'01"	do.	Desser	112	-	-	-	D
W14	30°56'33"	084°51'27"	do.	do.	122	-	-	-	D
W15	30°55'10"	084°53'41"	do.	Stream Mill	118	85	-	650	I
W16	30°54'01"	084°55'31"	do.	do.	138	-	-	-	D
W17	30°53'10"	084°55'24"	do.	do.	157	250	124	1,400	I
W18	30°51'40"	084°46'31"	do.	Reynoldsville	110	-	-	-	I
W19	30°53'35"	084°54'05"	do.	Stream Mill	111	-	-	-	I

* Numbers (1), (2), (3) indicate samples were collected after 5, 15, and 25 minutes of pumping, respectively.

TABLE 2.—*EDB application near wells sampled*

Sample site	EDB application
W1	First applied in 1983.
W2	Applied on nearby fields.
W3	Applied in 1979 and 1983.
W4	Applied annually.
W5	Applied annually.
W6	Applied twice yearly since 1979.
W7	Applied annually since 1979.
W8	Land recently cleared; first applied in 1983.
W9	Land recently cleared; never applied.
W10	Applied annually to nearby field.
W11	Applied annually except for 1983.
W12	Applied annually.
W13	Applied to nearby fields.
W14	Applied annually to nearby field.
W15	First applied in 1983.
W16	Applied annually.
W17	Applied annually.
W18	Applied annually.
W19	Never applied.

Wells generally are cased to the top of the limestone and are open-hole from the top of the limestone to the bottom of the well. Yields of 1,200 gal/min from the irrigation wells are common.

USE OF EDB

EDB has been applied for several years to many fields throughout Seminole County (table 2). Water samples were collected at wells W9, and W19, which are located in fields where EDB has never been applied, and at wells W1, W8, and W15, which are located on recently cleared land where EDB was applied only in 1983. The history of EDB use was obtained from the county agent and farmers, based on their recollections.

SOIL CHARACTERISTICS

Soils in Seminole County and throughout a large part of the Dougherty Plain consist of sand, sandy-clay, and clay and are low in organic matter. The characteristics of major soil types in Seminole County are shown in table 3. These data were developed by the U.S. Department of Agriculture Soil Conservation Service (Middleton

TABLE 3.—*Soil survey information for Seminole County*

[Data from Middleton and Smith, 1976]

Sample site	Soil number	Soil association	Soil description	Soil organic content	Permeability (in./hr)
W2, W10, W12 W15, W16, W17 W19	1	Tifton-Norfolk-Grady	Well drained clay loam	Low to moderate	Moderate (0.6-6.0)
W3, W4, W9	2	Wagram-Troup	Well drained upland loamy sand	Low	Moderate to rapid (0.6-20.0)
W1, W5, W7 W8, W14, W18	3	Lucy-Orangeburg	Well drained loamy sand	Low	Moderate to rapid (0.6-20.0)
W11	4	Meggett-Grady	Poorly drained loam over sandy clay	Low to moderate	Slow (0.06-2.0)
W6, W13	5	Goldsboro-Irvington-Grady	Well drained sandy loam over sandy clay loam	Low	Moderate (0.6-6.0)
	6	Angie-Riverview-Congaree	Well drained sandy loam and silty clay loam	Low	Slow (.06-2.0)

TABLE 4.—*Concentration of EDB (ethylene dibromide) in samples from study area*

[Sample site number: number used to identify well or surface-water sample site in report and to locate site on map in fig. 8. Superscript a indicates domestic well. ND, not detected (concentrations were less than 0.01 μg/L)]

Sample site number	Latitude (N.)	Longitude (W.)	Sample collection date	EDB concentration (ug/L)
W1	31°03'30"	084°44'17"	Aug. 17, 1983	ND
W2[a]	31°01'12"	084°46'56"	do	ND
W3	30°59'00"	084°45'36"	do	ND
W4(1)*	30°56'17"	084°50'02"	do	7.1
W4(2)	30°56'17"	084°50'02"	do	5.4
W4(3)	30°56'17"	084°50'02"	do	4.5
W5	30°56'17"	084°51'22"	do	11.8
W6	30°57'58"	084°53'10"	do	.06
W7	30°53'30"	084°48'20"	do	.03
W8	30°54'06"	084°48'10"	do	ND
W9	30°54'39"	084°48'42"	do	.03
W10	31°06'19"	084°51'27"	Aug. 18, 1983	ND
W11	31°04'06"	084°57'24"	do	ND
W12	31°00'29"	084°59'18"	do	ND
W13[a]	30°57'55"	084°52'01"	do	ND
W14[a]	30°56'33"	084°51'27"	do	.03
W15	30°55'10"	084°53'41"	do	ND
W16[a]	30°54'01"	084°55'31"	do	ND
W17	30°53'10"	084°55'24"	do	ND
W18	30°51'40"	084°46'31"	do	ND
W19	30°53'35"	084°54'05"	Aug. 19, 1983	ND
S1	30°56'37"	084°50'48"	Aug. 17, 1983	ND

* Numbers (1), (2), (3) indicate samples were collected after 5, 15, and 25 minutes of pumping, respectively.

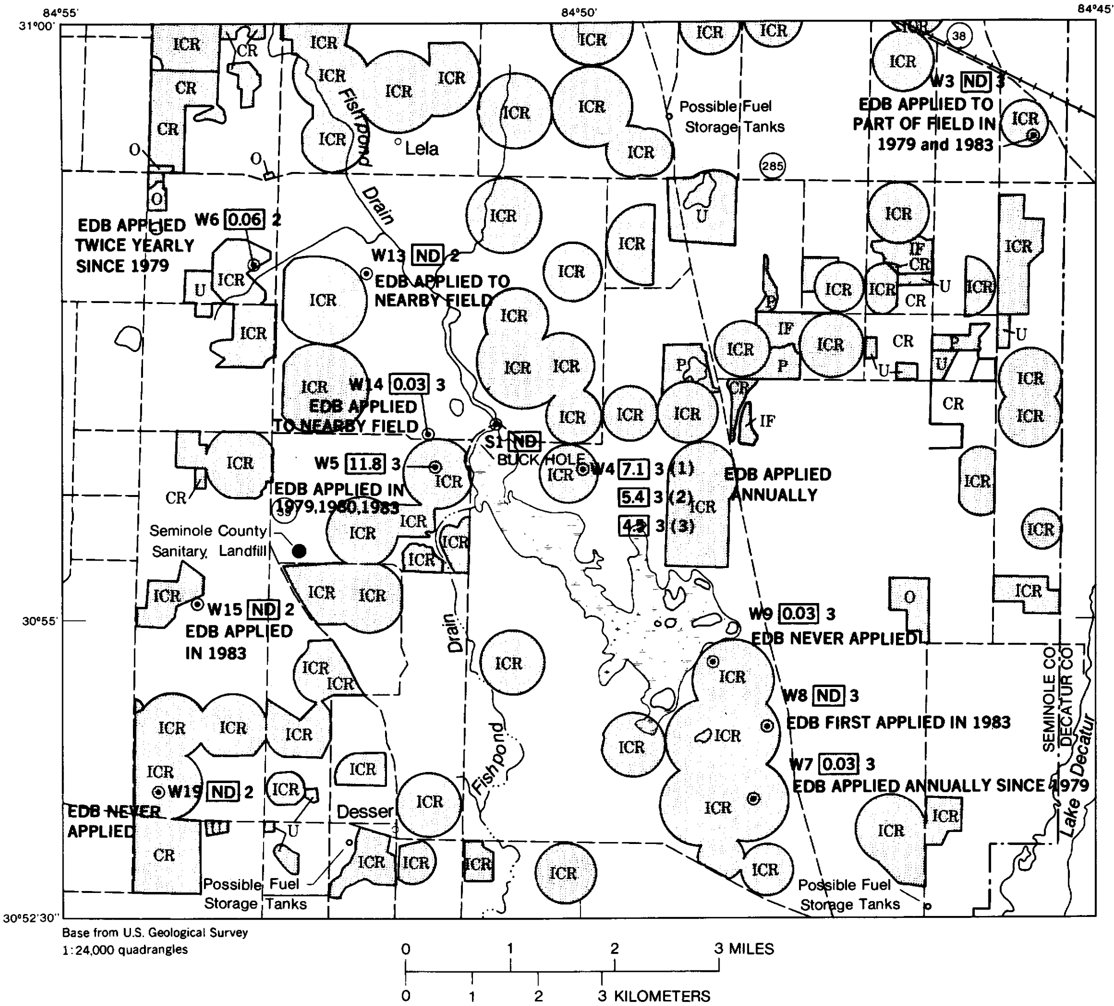
and Smith, 1976) and consider only the upper 60 to 80 in. of soil.

ANALYSIS OF WATER SAMPLES

EDB was found in 6 of 19 wells (table 4). The highest concentrations of EDB in ground water in Seminole County were found in the Buck Hole area of Fishpond Drain. Concentrations at wells W4 (BH2) and W5 (BH1), east and west of Buck Hole, were 7.1 and 11.8 μg/L, respectively, much higher than at the other wells sampled. However, concentrations at these two sites have decreased substantially since May 1982. (See table in "Background" section.)

At well W4, three samples were collected in succession after 5, 15, and 25 min. of continuous pumping. During this period, concentrations of EDB decreased from 7.1 to 4.5 μg/L. A decrease in concentrations with increased pumping time would be expected where high levels of contaminant are localized.

North of Buck Hole (upgradient in the aquifer), EDB concentrations in ground water were much less than at wells W4 and W5 and in most samples were below the level of detection (less than 0.01 μg/L). The concentration at well W14, a domestic well about one-half mile north of well W5, was roughly 400 times lower than at well W5. The concentration in well W13, a domestic well about 3 mi north-northwest of well W5, was below the level of detection. At well W6, about 4 mi northwest of well W5, the concentration was about 200 times less than at well W5. EDB was not detected in the remaining six wells to the north. A sample of ponded surface water collected from Fishpond Drain near Buck Hole did not contain detectable levels of EDB. South of Buck



EXPLANATION

AREA OF FIELD

FARM LAND USE—
Interpreted from 1982 high-altitude photographs

CR — Cover and row crops
ICR — Irrigated cover and row crops
IF — Idle farm land
O — Orchards
P — Pasture
U — Undefined

SOIL PERMEABILITY CODE

1 — Slow, 0.06 to 2.0 inches per hour
2 — Moderate, 0.6 to 6.0 inches per hour
3 — Moderate to rapid, 0.6 to 20 inches per hour

W4 7.1 **3 (1)**

WATER-QUALITY SAMPLING SITE—Number at left is site identification number; number in box is EDB concentration, in micrograms per liter (ND indicates concentration is below the level of detection); number at right of box is soil permeability code; number in parentheses indicates order sample was collected at the site

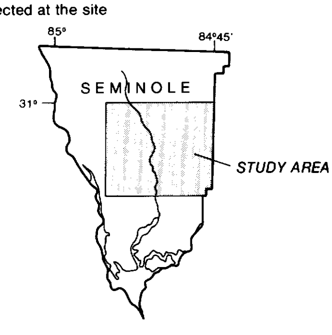


FIGURE 9.—Concentration of EDB in ground water and EDB use, soil characteristics, and crop types in the central part of the study area.

Hole (downgradient in the aquifer) concentrations in ground water at most wells were below the detection level. Exceptions were at wells W7 and W9. Concentrations of EDB at these two wells were 0.03 µg/L. Interestingly, the concentration at well W8, which is between wells W7 and W9, was below the detection level even though EDB was applied to the field surrounding well W8 in 1983.

RESIDUUM CORE ANALYSIS

The results of the EDB and particle-size analyses of core samples collected about 150 ft south of well W4 are shown in table 5. A lithologic description of material extracted from the borehole and a natural gamma radiation log of the hole are presented in figures 10 and 11, respectively.

EDB was detected in core samples collected at a depth of 1.5 ft and at interals between 24 and 25, 34 and 35, and 39 and 40 ft. The highest concentration was 2.4 µg/kg in the 1.5-foot sample, and the second highest (1.1 µg/kg) was just above the limestone at 39–40 ft. Core composition data, the lithologic description of the residuum material, and the natural gamma log indicate the presence of clay layers at this site. The percentage of clay is relatively high at depths of 6 to 8 ft and 29 to 35 ft. At a depth of about 32 ft, a large quantity of water entered the hole and the water level rose to within about 12 ft of land surface. The samples from the intervals above 32 ft were collected before the water level rose in the hole and therefore were not contaminated by water from deeper in the residuum. Core samples collected at the intervals of 34 to 35 ft and 39 to 40 ft were saturated with water.

DISCUSSION

Data indicate that EDB contamination of the principal artesian aquifer in the Seminole County study area most likely is from nonpoint sources related to agricultural use. Analysis of core samples from the borehole near well W4 indicates the presence of EDB at various depths in the residuum. Apparently, EDB applied to soil moves downward through the residuum and, through undetermined pathways, enters the aquifer.

TABLE 5.—*Concentration of EDB (ethylene dibromide) in core samples and composition of core samples from the residuum côre hole near Buck Hole*

[Sample depth is depth below land surface. Particle size classification, in millimeters: sand, 2.000–0.062; silt, 0.062–0.004; clay, <0.004. ND, not detected (concentrations were less than 0.05 µg/kg)]

Sample depth (ft)	EDB concentration (ug/kg)	Percent sand	Percent silt	Percent clay
1.5	2.4	87	7	6
5–6	ND	40	2	58
9–10	ND	63	4	33
14–15	ND	50	3	47
19–20	ND	54	4	42
24–25	.12	50	10	40
29–30	ND	34	6	60
34–35	.06	39	4	57
39–40	1.1	42	26	32

Leachate from the county landfill and spills from gasoline storage tanks and from barrels of EDB fumigant are other possible sources of EDB contamination. Contamination of the aquifer from the county-managed landfill is not likely because the distribution of EDB in the aquifer is not consistent with regional ground-water flow patterns at the landfill location and because pesticides are not permitted in the landfill. Contamination from gasoline spills is not evident, according to data collected by a Florida State University researcher. Ground-water samples collected from wells near Buck Hole in 1981 and analyzed by Florida State University for organic compounds did not contain gasoline. No significant spills of EDB fumigant in the area has been reported. However, contamination of the ground water from a spill cannot be entirely ruled out at this time.

EDB contamination of the ground water in Seminole County seems to be most prevalent in the vicinity of the swampy area of Fishpond drain near Buck Hole. The high concentrations of EDB found in ground-water samples adjacent to Buck Hole (wells W4 and W5) suggest that the aquifer in this area is particularly sensitive to EDB use. Concentrations of EDB in ground-water samples collected from wells W6, W7, and W18, which are in areas having similar EDB usage and soil permeability, were many times lower than at wells W4 and W5 (tables 2 and 3, fig. 9).

The local hydrogeology adds to the contamination potential of the aquifer in the swampy area of fishpond drain. Potentiometric-surface contours

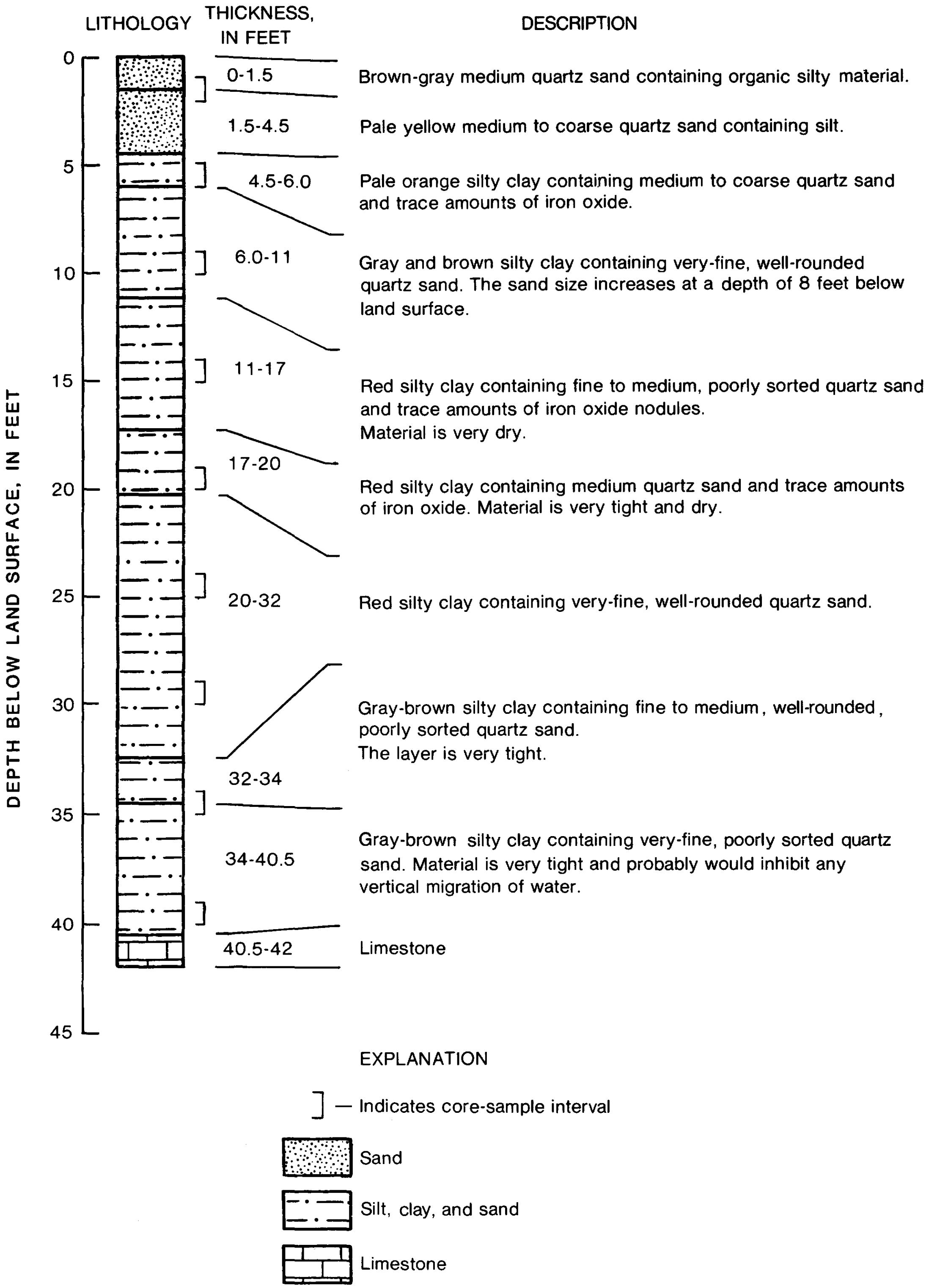


FIGURE 10.—Lithologic description of the residuum at the coring site near Buck Hole.

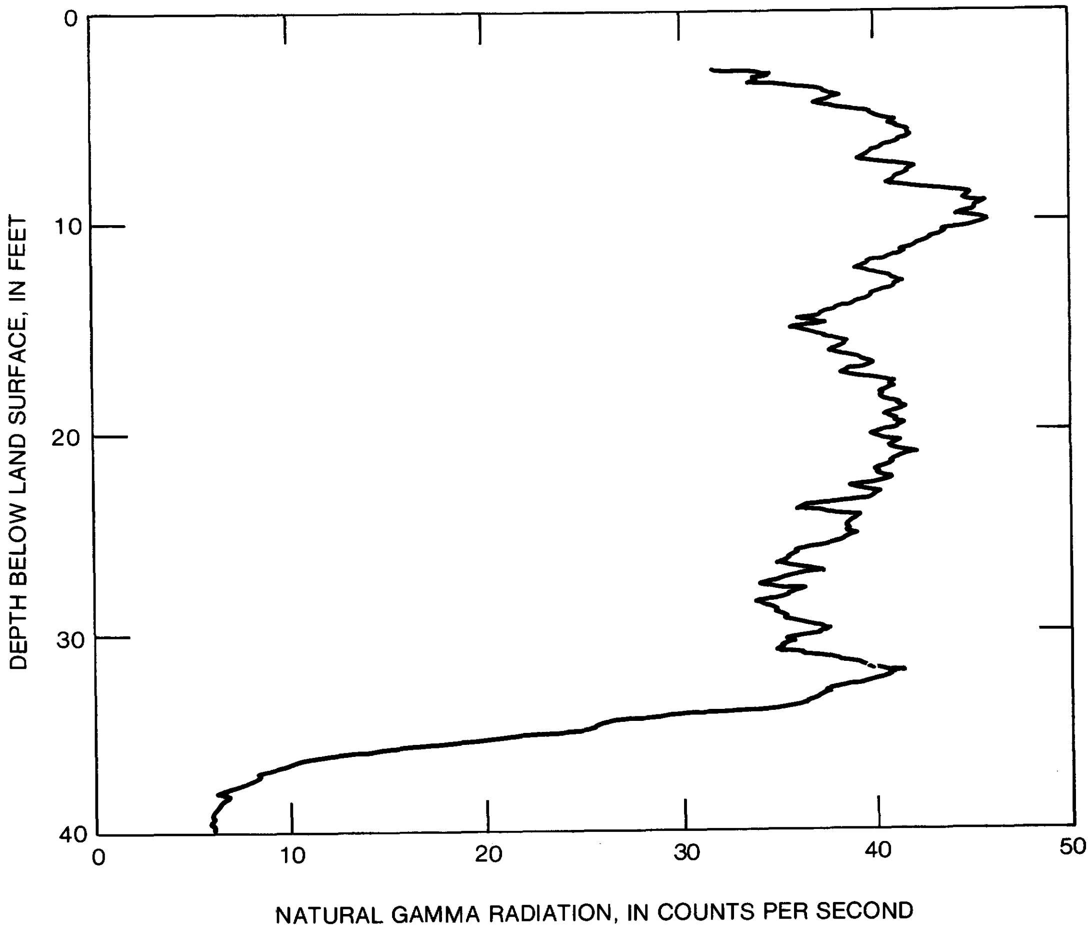


FIGURE 11.—Natural gamma log of the residuum core hole near Buck Hole.

(figs. 5 and 6) suggest that the aquifer discharges into Fishpond Drain. Sinkholes, which are prevalent throughout this area, act as vertical conduits connecting the principal artesian aquifer, the water-table aquifer, and the surface-water drainage system. During the summer and fall, pumping temporarily lowers the water level locally in the aquifer, and ground-water discharge to Fishpond Drain decreases or ceases. A lowering of the water level may accelerate the downward movement of water and contaminants from the overlying residuum into the aquifer.

Lithologic data obtained at the coring site near well W4 indicate the presence of clay layers in the residuum. A layer of dense clay exists just above the top of the aquifer between depths of about 29 and 35 ft below land surface. The clay layers would probably retard the downward movement of contaminated water into the aquifer. Perhaps EDB that was applied to fields reached the aquifer by moving laterally downgradient through permeable zones in the residuum toward Fishpond Drain and Buck Hole or other sinkholes where the absence of clay permitted it to flow directly into the aquifer.

Possibly, EDB in the residuum moved down the annular spaces between the well casings and the surrounding soil and residuum at wells where the annular spaces were not sealed with grout during construction. The contamination of ground water by EDB at wells W6, W7, and W9 may have resulted from leakage of locally applied EDB downward through the residuum, or from movement of EDB downward through the annular spaces between the well casings and the residuum into the aquifer. Contamination at wells W7 and W9 also may have been from the movement of a plume of EDB in the ground water from the Buck Hole area to those wells. Ground-water-level data are not available to define hydraulic gradients during periods of heavy pumping. These data are needed to assess the direction of movement of a potential contaminant plume. Movement of a contaminant plume southward from the Buck Hole area is plausible because that is the natural direction of ground-water flow. The presence of a plume to the south of Buck Hole is suggested by the low concentration of EDB detected at well W9, which is in a new field where EDB has never been applied. However, no EDB was found in the ground water at well W8 three-fourths of a mile southeast. Farther south, EDB was detected at well W7, where applications of EDB have been made one or two times annually since 1979. Locally applied EDB, rather than a plume, may have been the source of contamination at well W7.

NEED FOR ADDITIONAL STUDY

Data are needed that will describe the pathways and rates of movement of contaminants into the aquifer and their fate in the ground-water system. These data will provide information that can be used to assess potential contamination problems from pesticide use in Seminole County and other areas having similar hydrogeology.

Data that will provide information on the pathways, rates of movement, and fate of contaminants in the study area could be obtained by: (1) sampling a network of residuum and aquifer wells and surface-water sites for EDB, (2) measuring ground-water levels in the residuum and the aquifer to define the local seasonal hydraulic gradients during pumping, and (3) collecting residuum core data to describe local lithology and to determine EDB concentrations in the residuum.

CONCLUSIONS

Contamination of the aquifer with EDB seems to be limited to about a 4-square-mile area in central Seminole County in the vicinity of Buck Hole. Five of the six wells contaminated with EDB are within high EDB-use areas where the soil permeability ranges from moderate to rapid. The sixth well, W9, is in an area having moderate to rapid soil permeability and is downgradient from high-use areas. Considering the contamination pattern, the soil-core data, local hydrogeology, the location of the county landfill with regard to the area of contamination, and the lack of evidence of gasoline spills, the ground-water contamination in Seminole County probably is due to soil fumigation with EDB. However, because the high concentrations of EDB in the aquifer seems to be localized in the Buck Hole area, the possibility of contamination from an EDB fumigant spill cannot be disregarded at this time.

The levels of EDB found in this study are representative of a single point in time. It is likely that repetitive sampling would show significant temporal variability, particularly on a seasonal basis, owing to the high transmissivities, seasonal fluctuations in water levels and recharge rates, and seasonal variations in irrigation withdrawals.

REFERENCES CITED

Hayes, L. R., Maslia, M. L., and Meeks, W. C., 1983, Hydrology and model evaluation of the principal artesian aquifer, Dougherty Plain, southwest Georgia: Georgia Geologic Survey Bulletin 97, 91 p.

Keys, S.W., and MacCary, L. M., 1971, Application of borehole geophysics to water-resources investigations: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 2, Chapter El, 126 p.

Middleton, R. G., and Smith, E. H., 1976, Soil survey of Miller and Seminole Counties, Georgia: U.S. Department of Agriculture, Soil Conservation Service, in cooperation with University of Georgia, College of Agriculture, Agriculture Experiment Stations, 44 p.

Mitchell, G. D., 1981, Hydrogeologic data of the Dougherty Plain and adjacent areas, southwest Georgia: Georgia Geologic Survey Information Circular 58, 124 p.

U.S. Environmental Protection Agency, July 1982, Test Method, Purgeables—Method 624: Environment Monitoring and Support Laboratory, Cincinnati, Ohio, p.624-7—624-12.

Watson, T. W., 1981, Geohydrology of the Dougherty Plain and adjacent area, southwest Georgia: Georgia Geologic Survey Hydrologic Atlas 5.