MOVEMENT AND FATE OF ETHYLENE DIBROMIDE (EDB) IN GROUND WATER IN SEMINOLE COUNTY, GEORGIA

By James B. McConnell

U.S. GEOLOGICAL SURVEY

Water Resources Investigations Report 87-4030

Prepared in cooperation with the

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF PESTICIDES AND TOXIC SUBSTANCES

OFFICE OF PESTICIDE PROGRAMS

HAZARD EVALUATION DIVISION

EXPOSURE ASSESSMENT BRANCH

Doraville, Georgia

1987

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief, WRD
U.S. Geological Survey
Suite B
6481 Peachtree Industrial Boulevard
Doraville, Georgia 30360

Copies of this report can be
purchased from:

U.S. Geological Survey
Books and Open-File Reports
Federal Center, Bldg. 41
Box 25424
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

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

Multiply inch-pound units	By	To obtain SI units
	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 kilometer (km^2)
square foot (ft^2)	0.0929	square meter (m^2)
	Volume	
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
	3.785	liter (L)
	Flow	
gallon per minute (gal/min)	0.0630	liter per second (L/s)
	Mass	
pound (lb)	0.454	kilograms (kg)
ounce (oz)	28.38	gram (g)
	28.35×10^3	milligram (mg)
	28.35×10^6	microgram (g)

Transmissivity

foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Temperature

degrees Fahrenheit (°F)	°C = 5/9 x (°F - 32)	degrees Celsius (°C)

Sea Level

In this report "sea level" refers to the 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 of 1929."

MOVEMENT AND FATE OF ETHYLENE DIBROMIDE (EDB)

IN GROUND WATER IN SEMINOLE COUNTY, GEORGIA

By James B. McConnell

ABSTRACT

An investigation to assess the movement and fate of ethylene dibromide (EDB) in the Upper Floridan aquifer (formerly the principal artesian aquifer) was conducted in cooperation with the U.S. Environmental Protection Agency. An investigation conducted in August 1983, had found EDB contamination of the aquifer in about a 4-square-mile area in central Seminole County, Georgia.

Analyses of water from wells re-sampled in June 1985 indicate that EDB was present in the ground water 2 years after last being applied as a soil fumigant. The investigation revealed that ground-water recharge and irrigation pumping between August 1983 and June 1985 did not substantially change the areal extent of EDB in the Upper Floridan aquifer but concentrations of EDB seem to be declining. The highest concentrations again were found in two irrigation wells near Buck Hole, a sinkhole in a swampy depression in central Seminole County. EDB concentrations in these two wells ranged from 1.5 to 13 micrograms per liter. Samples from two of three wells in the residuum near Buck Hole also had detectable concentrations of EDB.

The presence of EDB in water samples from wells tapping the residuum and wells tapping the Upper Floridan aquifer indicates that agriculturally applied EDB has moved downward from the surface soils through the residuum and into the aquifer. Results of aquifer tests conducted in a similar geohydrologic setting suggest that local pumping from the highly transmissive aquifer may accelerate the downward movement of water and EDB.

Potentiometric surface maps of the Upper Floridan aquifer indicate that east of Fishpond Drain, where the highest concentrations of EDB were detected, the direction of ground-water flow and the direction of potential EDB transport generally is south-southeasterly. However, the movement of an EDB plume from the area of relatively high concentrations near Buck Hole along inferred ground-water flow lines was not detected.

INTRODUCTION

In August 1983, the extent of ethylene dibromide (EDB) contamination of ground water in the Upper Floridan aquifer (then termed the principal artesian aquifer) of Seminole County, Ga., was investigated by the U.S. Geological Survey in cooperation with the U.S. Environmental Protection Agency. Seminole County is a highly productive agricultural area of southwest Georgia where EDB was regularly applied as a soil fumigant to control nematodes prior to suspension of its use on September 28, 1983. Analyses of well water determined that detectable concentrations of EDB were limited to a 4 mi^2 area of the aquifer in the vicinity of Buck Hole, a sinkhole in a swampy depression in central Seminole County about 7 mi south of Donalsonville (fig. 1). The investigators reported that the ground-water contamination probably was due to soil fumigation with EDB, but because high concentrations of the pesticide occurred in a localized area, they concluded that the contamination could have resulted from a spill (McConnell and others, 1984, p. 20).

The present study was conducted by the U.S. Geological Survey in cooperation with the U.S. Environmental Protection Agency to assess the movement and fate of EDB in the aquifer. EDB is a water-soluble, low molecular weight compound that is very mobile in soils and could persist for more than 6 years in ground water at ambient ground-water temperatures and pH (Cohen and others, 1984). Wells that were sampled during the previous study were re-sampled in September 1983, October 1984, and June 1985, to monitor changes in EDB concentrations with time. Water levels were measured once during a nonirrigation, nonpumping period (Dec. 10-11, 1984) and once during a irrigation-pumping period (June 27, 1985) to determine the local ground-water gradients and the direction of ground-water flow. The investigation was confined to a 75-mi^2 area in central Seminole County, which includes the 4-mi^2 area where EDB was detected in ground water during the previous study (fig. 1).

GEOHYDROLOGY

The source of most water used for irrigation, domestic, municipal, and industrial supplies in Seminole County is the Upper Floridan aquifer. The Upper Floridan is part of a large carbonate aquifer system that underlies the Coastal Plain of Georgia, adjacent parts of South Carolina and Alabama, and all of Florida. In Seminole County the aquifer consists mainly of limestone and ranges in thickness from 125 ft in the northern part of the county to 300 ft in the southern part (McConnell and others, 1984, p. 4). In most of the area, the aquifer is highly fractured, and solutioning has created a labyrinth of subterranean channels which result in transmissivities that range from 75,000 to 300,000 ft^2/d (Hayes and others, 1983, p. 45).

The Upper Floridan aquifer is overlain by residuum that ranges in thickness from about 50 to 100 ft (McConnell and others, 1984, p. 7). Soils of the residuum generally consist of sand, sandy clay, and clay and contain little organic matter. The characteristics of the major soil types in Seminole County are shown in table 1. Permeable sand lenses commonly occur in the upper half of the residuum and generally are underlain by less permeable, clayey material that confines the Upper Floridan aquifer. Although clayey material confines the aquifer, many sinkholes in the area breach the residuum

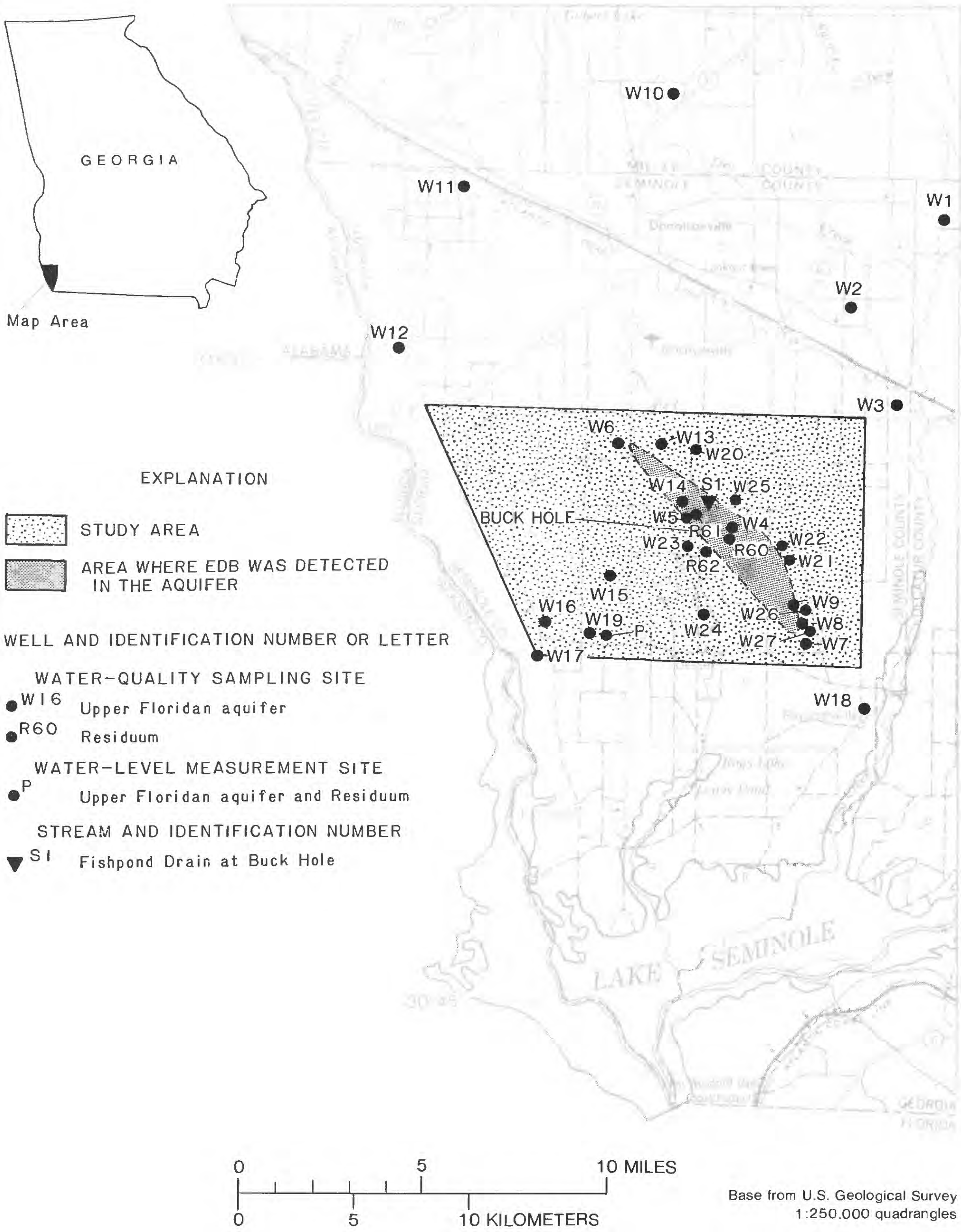


Figure 1.--Location of data-collection sites and approximate area where EDB was detected in ground water.

Table 1.--Soil survey information for Seminole County

[Data from Middleton and Smith, 1976]

Sample site	Soil association	Soil description	Soil organic content	Permea- bility (in/hr)
W2, W10, W12, W15, W16, W17, W19, W21, W22, R62	Tifton-Norfolk-Grady	Well drained clay	Low to moderate	Moderate (0.6-6.0)
W3, W4, W9, W25 W26, R60, R61	Wagram-Troup	Well drained upland loamy sand	Low	Moderate to rapid (0.6-20.0)
W1, W5, W7, W8, W14, W18, W23, W27	Lucy-Orangeburg	Well drained loamy sand	Low	Moderate to rapid (0.6-20.0)
W11	Meggett-Grady	Poorly drained loam over sandy clay	Low to moderate	Slow (0.06-2.0)
W6, W13, W20	Goldsboro-Irvington-Grady	Well drained sandy loam over sandy clay loam	Low	Moderate (0.6-6.0)
	Angie-Riverview-Congaree	Well drained sandy loam and silty clay loam	Low	Slow (0.06-2.0)

and provide a direct hydraulic connection between the surface and the aquifer. Hayes and others (1983) noted that the transmissivity of the residuum may increase greatly during the wet season as the sand lenses in the upper half of the residuum become saturated. Thus, the presence or absence of sand lenses, the saturated thickness of the residuum, and the occurrence of sinkholes could have a significant effect on the movement of contaminants through the residuum and into the Upper Floridan aquifer.

DATA COLLECTION AND PRESENTATION

Water-level data from a well tapping the Upper Floridan aquifer and a well tapping the residuum (site P, fig. 1) are used in this report to represent general water-level trends in the Upper Floridan aquifer and in the residuum, respectively. The water level in the Upper Floridan aquifer was recorded hourly by a digital recorder. The water level in the residuum was measured periodically by using the wetted-tape method.

Potentiometric-surface maps for the Upper Floridan aquifer were constructed from water-level data collected from 45 wells in the study area. The potentiometric surface represents the altitude at which the water level would have stood in tightly cased wells that penetrate the aquifer. The water-level altitudes used to construct the potentiometric maps were determined by measuring the distance from land surface to the water in each well and subtracting that distance from the land-surface altitude. Land-surface altitudes at the well sites were determined by surveying altimeters.

Water samples from the Upper Floridan aquifer were collected from irrigation wells 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 5 min prior to sample collection. Samples from domestic wells tapping the Upper Floridan aquifer also were collected at water spigots between the wells and the storage-pressure tanks after about 15 min of continuous pumping at the rate of 2 to 3 gal/min. Past experience has shown that the above pumping rates and times usually are sufficient to yield water samples of stable chemistry.

Three wells in the residuum, R60, R61, and R62, were constructed in the vicinity of Buck Hole (fig. 1). Wells R60 and R61 are located at the edge of fields on either side of a swampy area and adjacent to irrigation wells W4 and W5, respectively. Well R61 was constructed in a wooded area next to a swampy depression south of Buckhole. The wells in the residuum were about 35 ft deep, constructed of 2-in. diameter stainless-steel casing, and fitted at the bottom with 12-in. lengths of stainless-steel screen. After construction, the wells were developed by bailing. Water samples from the residuum were collected by using a PTFE (polytetrafluoroethlyene) bailer after several well volumes of water were bailed from each well and specific conductance measurements indicated that the water chemistry was stable.

The water samples were collected in 40-mL glass vials and sealed with PTFE-lined siliccn septa and plastic screwcaps. Water was delivered to the vials through 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 fill completely before capping. Care was taken to ensure that the water samples were free of air bubbles. The samples were stored in ice until analyzed.

The determination of EDB in the water samples was performed by dual-capillary-column electron-capture gas chromatography after preconcentration by liquid-liquid extraction into hexane. Details of the analytical procedures used are presented in the earlier investigation of EDB in Seminole County (McConnell and others, 1984, p. 12-13).

Water-level data collected at monitoring site P from March 1979 to September 1985 show that the water level in the Upper Floridan aquifer may fluctuate as much as 28 ft annually (fig. 2). The water level is influenced primarily by natural recharge from rainfall and by pumping for irrigation. Relatively high water levels in the winter-spring recharge periods declined rapidly during the spring-summer irrigation periods. The high water levels observed in the spring of 1980 and 1984 indicate that the aquifer received greater recharge from rainfall in these years than in the other years of record.

At the monitoring site P the water level in the residuum was higher than that in the Upper Floridan aquifer during most of the time of concurrent measurements (fig. 2). The greatest difference between water levels in the residuum and in the aquifer occurred during 1985, which had less-than-normal precipitation.

Potentiometric-surface maps constructed from the water-level data collected in December 1984 and June 1985, and generalized directions of ground-water flow in the Upper Floridan aquifer are shown in figures 3 and 4. Because ground-water flow is in the direction of the steepest hydraulic gradient, flow lines are drawn perpendicular to the potentiometic-surface contours. The flow lines were drawn with the assumption that the hydraulic conductivity (the capacity of subsurface material to transmit water) is essentially the same in all directions. Therefore, the flow lines represent the idealized paths of water as it moves through the aquifer.

Generally, the potentiometric surface during the nonirrigation, nonpumping period in December 1984 was 1 to 4 ft higher than during the irrigation-pumping period in June 1985. Although the measurements are separated by a 6-month period and represent ground-water levels during nonpumping and pumping conditions, the configuration of the potentiometric surface and the flow patterns are similar. A cone of depression is shown at site P on both maps. The cone of depression in the December potentiometric surface (fig. 3) probably is a residual of local spring-summer irrigation pumping coupled with a depressed water level resulting from less-that-normal rainfall. The cone of depression in the June potentiometric surface (fig. 4) likely is due to active pumping.

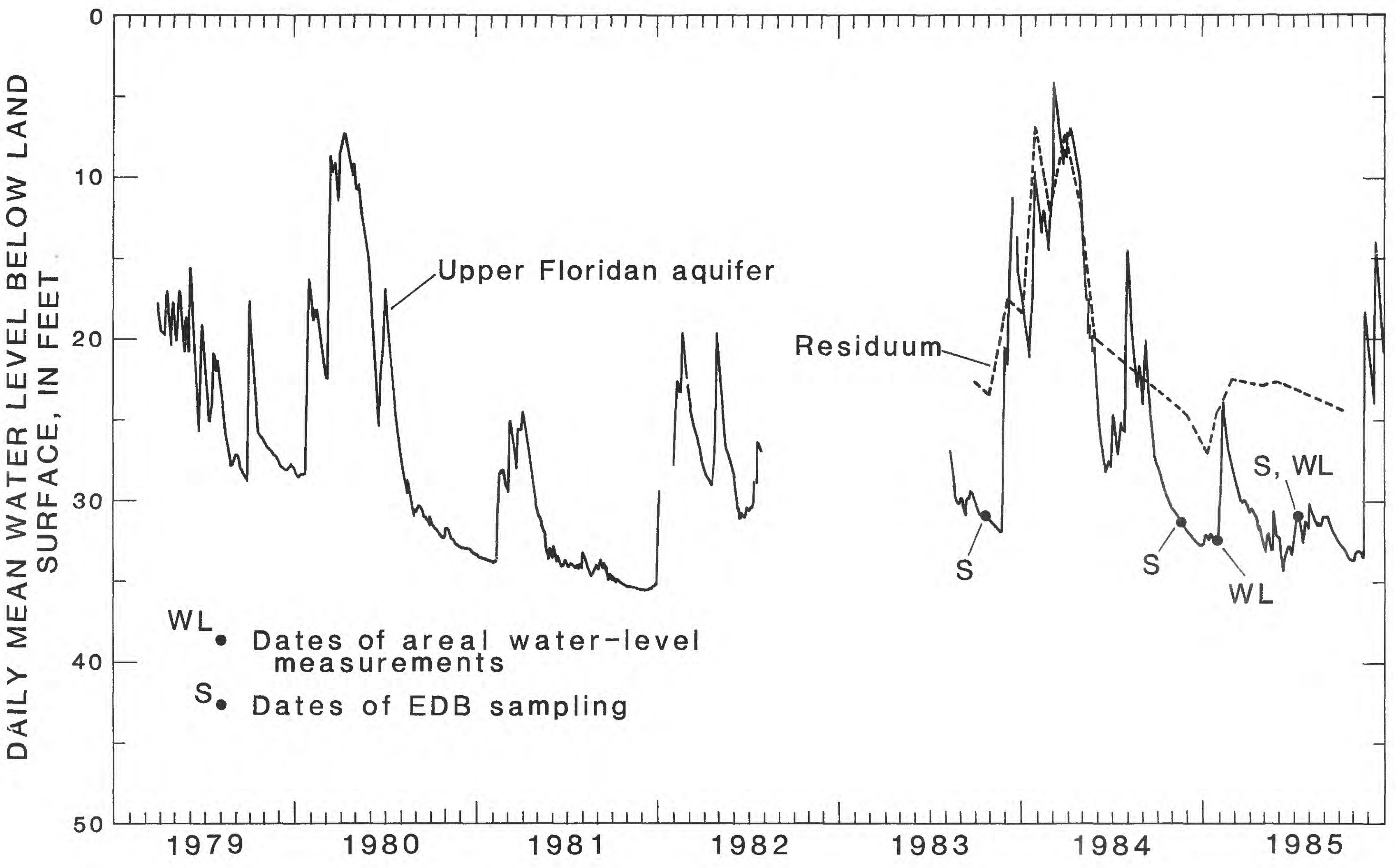
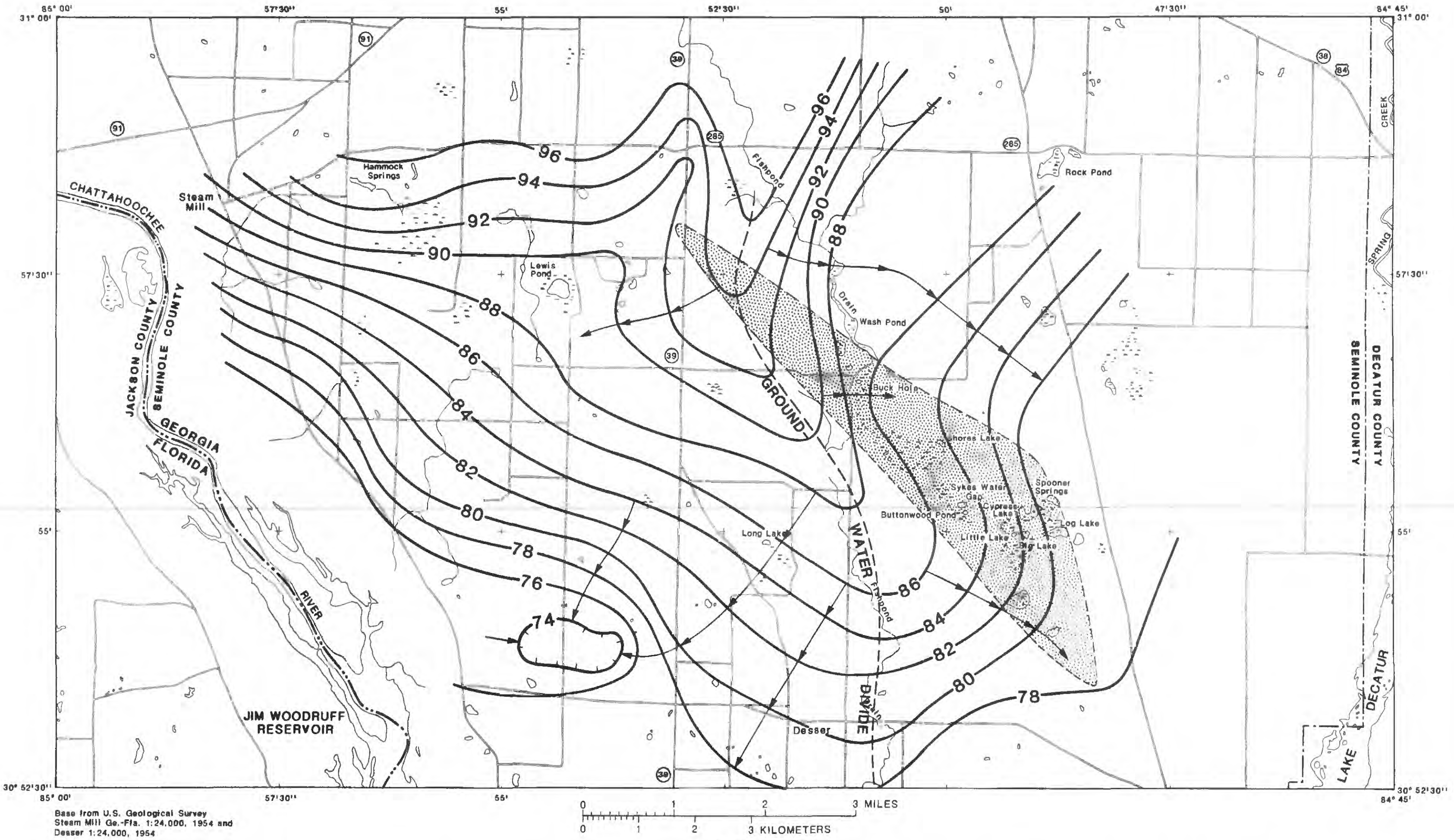


Figure 2.--Daily mean water level in the Upper Floridan aquifer and periodic EDB sampling and water level in the residuum at site P.



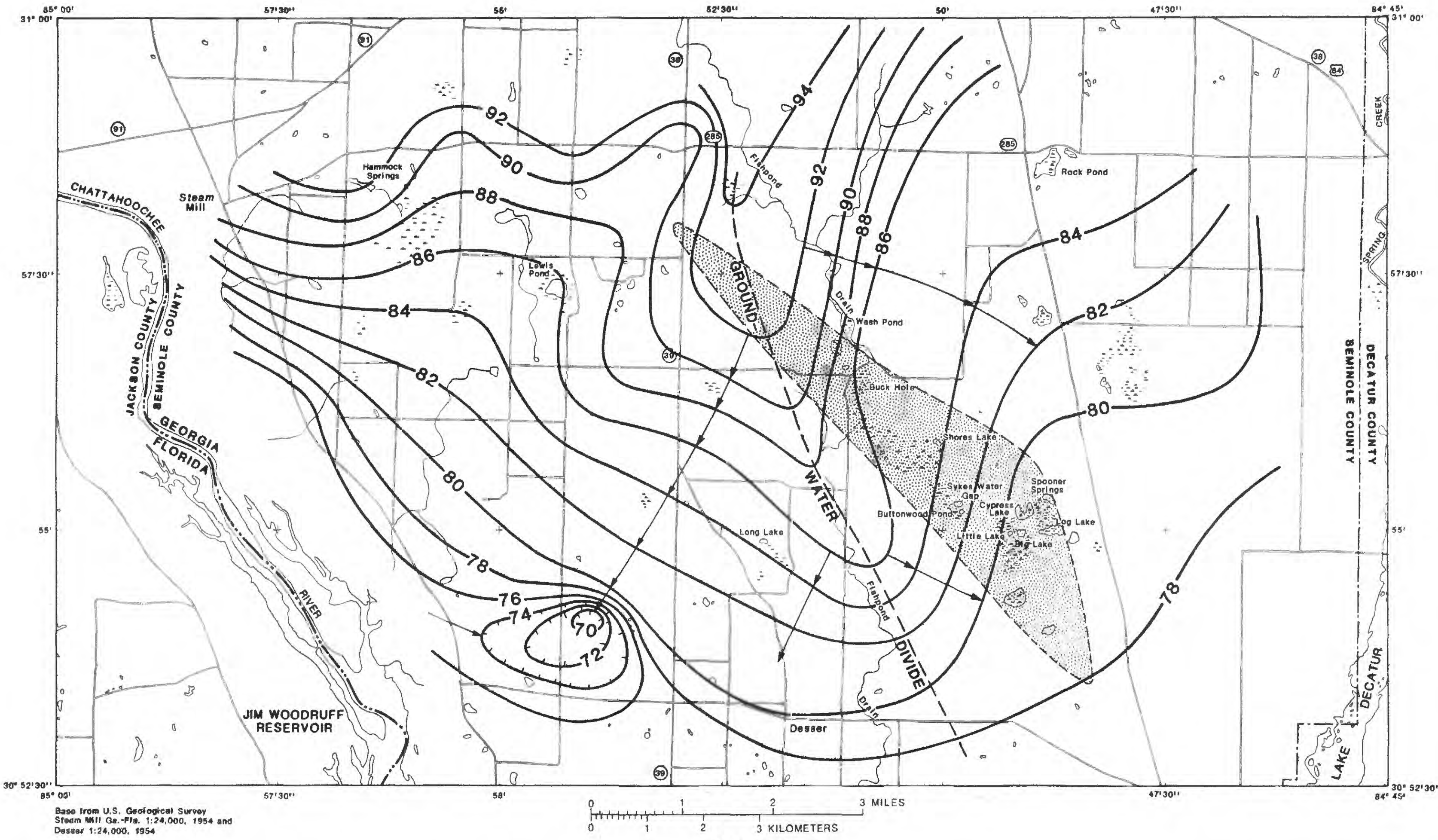
EXPLANATION

AREA WHERE EDB WAS DETECTED IN THE AQUIFER

—76— POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells tapping the Upper Floridan aquifer. Contour interval 2 feet. Datum is NGVD of 1929

→ DIRECTION OF GROUND-WATER MOVEMENT

Figure 3.--Potentiometric surface and direction of ground-water movement in the Upper Floridan aquifer, December 1984.



EXPLANATION

AREA WHERE EDB WAS DETECTED IN THE AQUIFER

—76— POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells tapping the Upper Floridan aquifer. Contour interval 2 feet. Datum is NGVD of 1929

——→ DIRECTION OF GROUND-WATER MOVEMENT

Figure 4.--Potentiometric surface and direction of ground-water movement in the Upper Floridan aquifer, June 1985.

Both potentiometric maps indicate the presence of a ground-water divide near Fishpond Drain (figs. 3 and 4). East of Fishpond Drain ground-water flow generally is southeasterly and west of Fishpond Drain ground-water flow generally is southwesterly. The potentiometric surfaces along the southwestern boundary of the study area are lower than the altitude of water surface in Jim Woodruff Reservoir, indicating a potential for flow from the reservoir into the aquifer.

Samples for the analysis of EDB were collected from wells three times during the present study and once during the previous study (Aug. 1983) (table 2). Some wells sampled in the previous study were not re-sampled because the irrigation pumps could not be operated. In September 1983 and October 1984, samples were collected from three wells in the residuum; however, these wells were not sampled in June 1985 because they were dry. Only wells W4 and W5 tapping the Upper Floridan aquifer were sampled in June 1985.

EDB was detected in the same wells as in the previous study except for W9, which was not re-sampled. The highest concentrations were found in wells W4 and W5, where concentrations ranged from 1.5 to 3.9 μg/L and 1.2 to 13 μg/L, respectively. EDB was detected in wells W21 and W22 in concentrations of 0.02 and 0.68 μg/L, respectively. EDB also was detected in wells R60 and R61 in September 1983 and October 1984. EDB was not detected in well R62.

The effect of pumping time on EDB concentration was examined at well W5 in October 1984. Samples were collected after 1, 5, and 10 min of pumping. EDB concentrations increased from 1.2 to 3.0 μg/L during the 9-min pumping interval.

DISCUSSION

Concentration data from re-sampled wells in Seminole County indicate that in June 1985, EDB was present in the ground water 2 years after it was last applied as a soil fumigant. Concentrations of EDB are about the same or are lower than the concentrations measured in the previous study, and the area of detection in the aquifer is similar.

Potentiometic-surface maps of the Upper Floridan aquifer indicate that ground-water-flow patterns are not significantly different under nonirrigation, nonpumping conditions (Dec. 1984; fig. 3) and irrigation-pumping conditions (June 1985; fig. 4). However, the nonirrigation, nonpumping condition is superposed on a period of depressed water level that resulted from less-than-normal rainfall.

Table 2.--Concentration of EDB in water samples

[Sample site designation--code used to identify and locate wells in figure 1: W-sample from well in Upper Floridan aquifer; R-sample from residuum (water-table); S-sample from surface water. Letter (a) following sample site designation indicates domestic well. Numbers (1), (2), and (3) after W4 and W5 indicate successive samples collected at 5, 15, and 25 minutes and at 1, 5, and 10 minutes, respectively. ND indicates EDB not detected: minimum dectection limit was less than 0.02 micrograms per liter. -- indicates a sample was not collected]

Sample site designation	EDB concentration (micrograms per liter)			
	Aug. 17-19, 1983	Sept. 28-29, 1983	Oct. 30-31, 1984	June 27,1985
W1	ND	--	--	--
W2(a)	ND	--	--	--
W3	ND	--	--	--
W4(1)	7.1	3.9	1.9	1.5
W5(1)	11.8	13	1.2	8.8
W5(2)	--	--	1.8	--
W5(3)	--	--	3.0	--
W6	.06	--	.10	--
W7	.03	.07	--	--
W8	ND	--	--	--
W9	.03	--	--	--
W10	ND	--	--	--
W11	ND	--	--	--
W12	ND	--	--	--
W13(a)	ND	--	ND	--
W14(a)	.03	--	.02	--
W15	ND	--	--	--
W16(a)	ND	--	--	--
W17	ND	--	--	--
W18	ND	--	--	--
W19	ND	--	--	--
W20	--	ND	ND	--
W21(a)	--	--	.02	--
W22	--	.68	--	--
W23(a)	--	ND	--	--
W24	--	ND	--	--
W25(a)	--	--	ND	--
W26	--	--	ND	--
W27	--	--	ND	--
R60	--	8.7	.57	--
R61	--	.20	.19	--
R62	--	ND	ND	--
S-1	ND	--	--	--

Since the previous study, concentrations of EDB remain highest in the Buck Hole area and are still detectable in the aquifer upgradient and downgradient from Buck Hole. Data from wells W4 and W5 indicate that a general decline in the EDB concentration has occurred in the aquifer since August 1983. An increase in the EDB concentrations of samples from well W5 between August and September 1983 and between October 1984 and June 1985, and an increase in concentrations with pumping time for samples collected on October 1984, suggest that EDB is being transported to this site from an area of higher concentration. The potential exists for EDB movement from the area of highest concentration in the vicinity of Buck Hole, southeasterly along inferred ground-water flow lines; however the formation of an EDB plume along flow lines downgradient from the Buck Hole area is not evident from the concentration data.

The presence of EDB in wells R60 and R61 indicates that part of the EDB has moved downward into the residuum. The downward transport of EDB into the residuum is supported by results of the previous study, which showed that EDB was present in soil cores at depths of 24 to 40 ft below land surface and in water samples from the Upper Floridan aquifer (McConnell and others, 1984, p. 17).

The Upper Floridan aquifer in the study area seems to be particularly susceptible to contamination from surface sources because of the local geohydrology. The configuration of the potentiometric surfaces in figures 3 and 4 indicates that surface water in the vicinity of Buck Hole and Fishpond Drain recharges the aquifer. Sinkholes are prevalent throughout the area and can act as vertical conduits that connect the Upper Floridan aquifer, the residuum, and the surface-water drainage system. Because the altitude of the water table in the residuum is higher than the potentiometric surface of the Upper Floridan aquifer nearly all the time, water and water soluble chemicals that are transported from the residuum have the potential to move downward into the aquifer. The downward movement of water and contaminants from the overlying residuum into the aquifer may be accelerated by irrigation pumping which temporarily lowers the water level in the aquifer. The likelihood that pumping from the aquifer accelerates the downward movement of water through the residuum is supported by aquifer tests recently conducted near Albany, Ga., where the geohydrologic setting is similar to that in Seminole County. The tests revealed that pumping from the aquifer caused dewatering of the overlying residuum soon after pumping began.

CONCLUSIONS

In June 1985, EDB was present in ground water in a 4-mi^2 area of Seminole County 2 years after it was last applied as a soil fumigant. However, in the vicinity of Buck Hole, EDB concentrations seem to be declining.

The direction of ground-water flow and the direction of potential EDB transport in the area of known EDB contamination generally is south-southeasterly. However, the movement of EDB from the area of relatively high concentrations near Buck Hole along inferred flow lines is not apparent. Recharge and irrigation pumping between August 1983 and June 1985 have not changed the ground-water flow system in the Upper Floridan aquifer in central Seminole County enough to alter the areal extent of EDB in the aquifer. Even though irrigation pumping did not substantially disrupt lateral ground-water flow lines, aquifer-test data from a similar geohydrologic setting near Albany, Ga., indicate that pumping from the aquifer in Seminole County could have locally accelerated the downward movement of water and the very mobile EDB from the residuum into the aquifer.

A thorough understanding of the hydraulic characteristics of the residuum and the Upper Floridan aquifer, the hydraulic relation of the two, and their relation to the surface-water drainage system are needed to accurately evaluate the vulnerability of the Upper Floridan aquifer to contamination from surface-applied chemicals. Because the hydraulic characteristics are highly variable both laterally and vertically, a large amount of time and effort would be required to collect the data needed to describe the pathways and rates of movement of contaminants into the Upper Floridan aquifer and their fate in the ground-water system.

REFERENCES

Cohen, S. Z., Creeger, S. M., Carsel, R. F., and Enfield, C. G., 1984, Potential for pesticide contamination of ground water resulting from agricultural uses: American Chemical Society Symposium Series 259, p. 297-325.

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.

McConnell, J. B., Hicks, D. W., Lowe, L. E., Cohen, S. Z., and Jovanovich, A. P., 1984, Investigation of ethylene dibromide (EDB) in ground water in Seminole County, Georgia: U.S. Geological Survey Circular 933, 20 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 Agricultural, Agriculture Experiment Station, 44 p.