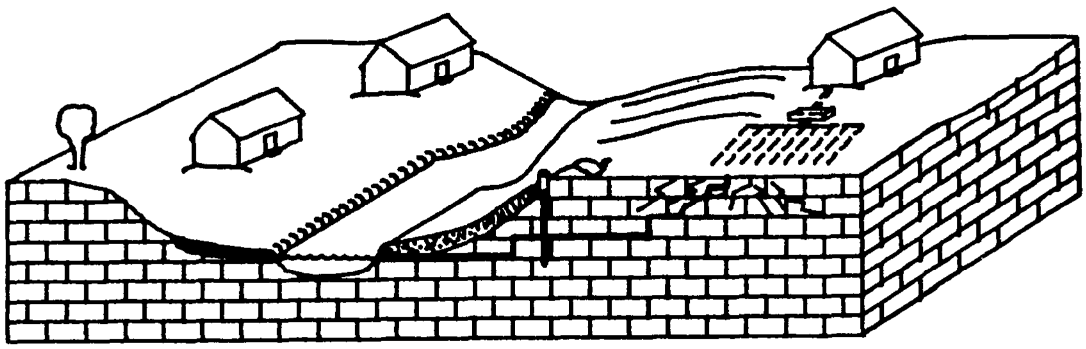
science for a changing world

Water-Resources Investigations Report 91-4011

EFFECTS OF SEPTIC-TANK EFFLUENT ON GROUND-WATER QUALITY IN NORTHERN WILLIAMSON COUNTY AND SOUTHERN DAVIDSON COUNTY, TENNESSEE



Prepared by the
U.S. GEOLOGICAL SURVEY

in cooperation with the
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION,
DIVISION OF WATER POLLUTION CONTROL

EFFECTS OF SEPTIC-TANK EFFLUENT ON GROUND-WATER QUALITY IN NORTHERN WILLIAMSON COUNTY AND SOUTHERN DAVIDSON COUNTY, TENNESSEE

By Dorothea Withington Hanchar

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 91-4011

Prepared in cooperation with the
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION,
DIVISION OF WATER POLLUTION CONTROL

Nashville, Tennessee
1991

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
810 Broadway, Suite 500
Nashville, Tennessee 37203

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center, Building 810
Box 25425
Denver, Colorado 80225

CONTENTS

Abstract 1
Introduction 1
- Purpose and scope 2
- Acknowledgments 2

Septic-tank systems 2
Geohydrology of the study area 3
Well construction 6
Data collection and analysis 7
Effects of septic-tank effluent on ground-water quality 9
- Major inorganic constituents 9
- Nutrients 9
- Organic substances 13
- Optical brighteners 13
- Bacteria 14

Summary and conclusions 14
References cited 15

ILLUSTRATIONS

Figure 1. Map showing location of observation wells, *springs, and surface-water sampling sites in* Williamson County 4
2. Map showing location of domestic well and spring in Davidson County 5
3. Stratigraphic column of wells Wm:O-13 and Wm:O-15 8

TABLES

Table 1. Well construction, yield, and water-level data for observation and domestic wells in the study area 7

2. Water-quality analyses 10

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	0.004047	square kilometer
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
pound (lb)	0.4536	kilogram
square mile (mi^2)	2.590	square kilometer
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8 * °C + 32$$

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 Sea Level Datum of 1929.

EFFECTS OF SEPTIC-TANK EFFLUENT ON GROUND-WATER QUALITY IN NORTHERN WILLIAMSON COUNTY AND SOUTHERN DAVIDSON COUNTY, TENNESSEE

By Dorothea Withington Hanchar

ABSTRACT

An investigation of the potential contamination of ground water from septic tank systems blasted in bedrock in Williamson and Davidson Counties, Tennessee, was conducted during 1988-89. Water samples were collected from domestic and observation wells, springs, and surface-water sites in a residential subdivision in the northern part of Williamson County near Nashville. The subdivision has a high density of septic-tank field lines installed into blasted bedrock. Water samples also were collected from a well located in an area of Davidson County where field lines were installed in 5 feet of soil. Samples were analyzed for major inorganic constituents, nutrients, total organic carbon, optical brighteners, and bacteria. Although results of analyses of water samples from wells indicate no effect of septic-tank effluent on ground-water quality at these sites, water from two springs located downgradient from the subdivision had slightly larger concentrations of nitrite plus nitrate (2.2 and 2.7 milligrams per liter N), and much larger concentrations of fecal coliform and fecal streptococci bacteria (2,000 to 3,200 and 700 to 900 colonies per 100 milliliters of sample, respectively), than other wells and springs sampled during 1988. Water from one of these springs contained optical brighteners, which indicates that septic-tank effluent is affecting ground-water quality.

INTRODUCTION

Subsurface sewage disposal systems are the largest sources of wastewater to the ground, and are the most frequently reported causes of ground-water contamination (Miller, 1980, p. 186). The likelihood of ground-water contamination by these systems is greatest where septic systems are closely spaced as in subdivided tracts in suburban areas and in areas where the bedrock is covered by little or no soil. In the rocky terrain of Middle Tennessee, the field lines of as many as 20 percent of the domestic septic systems are installed in blasted bedrock with virtually no soil (Brent Ogles, Tennessee Department of Health and Environment, Division of Ground Water Protection, oral commun., 1987). Concern about the effects of these domestic septic systems on ground-water quality prompted the U.S. Geological Survey, in cooperation with the Tennessee Department of Health and Environment (TDHE)[1],

[1]Tennessee Department of Environment and Conservation (TDEC) as of 1991.

Division of Water Pollution Control, to initiate in 1988 an investigation of the occurrence of septic-tank effluent in ground water and the effects of any effluent present on ground-water quality. The study area, in northern Williamson County and southern Davidson County, was selected because most of the septic systems in this area have field lines installed in blasted bedrock.

Purpose and Scope

This report presents the results of the study of ground-water quality in areas of septic tanks in northern Williamson County and southern Davidson County. The purpose of the study was to:

1. Determine if a hydraulic connection exists between septic-tank systems and the ground-water system and, if so,

2. Determine the potential for occurrence or existence of ground-water contamination by septic-system effluent.

The study included the collection of water samples from springs, observation wells, and domestic wells in Williamson and Davidson Counties for analysis of water-quality characteristics. Observation wells were installed in an area where field lines for septic systems were installed in blasted bedrock. These wells were completed in both the shallow and deep water-bearing zones upgradient from ground-water-discharge points. Samples were collected from these wells and springs in May 1988, November 1988, and May 1989 to coincide with dry (May) and rainy (November) conditions. Water samples were analyzed for bacteria, nutrients, major inorganic constituents, specific conductance, pH, temperature, and total organic carbon, and, in May 1988, for concentrations of organic constituents. Most of the water samples were from wells in an area where field lines were installed in blasted bedrock, although, for comparison, one well was in an area where field lines were installed in soil averaging about 5 feet in thickness. Water from the four springs also was sampled in April 1989 and analyzed for optical brighteners to determine if the springs and the subsurface sewage-disposal systems are hydraulically connected.

Acknowledgments

The author thanks Mr. Larry Robinson, Environmental Specialist for Williamson County; Mr. Brent Ogles, Environmental Manager, TDHE, Division of Ground Water Protection; Mr. Tom Petty, Environmental Specialist for Wilson County; and Mr. Christopher Andel, Ms. Karen Grubbs, and Dr. Andrew Barrass of the Nonpoint Source Program, Tennessee Department of Health and Environment, Division of Water Pollution Control, for their assistance. Also, the author thanks the many homeowners who allowed access to their land.

SEPTIC-TANK SYSTEMS

A typical septic-tank system consists of two parts, the tank itself and field lines installed into an absorption field. If the tank is properly constructed, only wastewater will flow through the field lines. Field lines generally are installed in trenches dug into soils having a minimum thickness of 3 feet, where the bottom of the trench is underlain by at least 2 feet of soil above the water table or creviced bedrock. Where rock crops out at the surface, common practice in Tennessee until June 1990 was to install field lines in trenches blasted in the bedrock and back-filled with gravel. In Middle Tennessee, limestone formations commonly crop out at land surface with little or no soil cover.

Ground water in the carbonate rocks of Middle Tennessee typically flows through solution openings that have developed along bedding planes, fractures, and joints (Hollyday and Goddard, 1979). Blasting near-surface bedrock to install field lines can create fractures in the limestone that hydraulically connect to an existing solution opening. If this occurs, the fracture can provide a conduit from the field lines to the ground-water reservoir.

Domestic septic-tank effluent typically contains elevated concentrations of chloride, sulfate, nitrite plus nitrate, ammonia, organic nitrogen, total nitrogen, total phosphate, fecal coliform and fecal streptococci bacteria, and total organic carbon (TOC) (Canter and Knox, 1985). Concentrations of nitrite plus nitrate as nitrogen (N) greater than 3 mg/L (milligrams per liter) generally indicate influence of human activity (Madison and Burnett, 1985). Elevated concentrations of chloride, ammonia, and sulfate also have been interpreted to be the result of septic-tank effluent (Waller and others, 1987; Pitt and others, 1975). Effluent migration has been monitored, both vertically and laterally, using variations in concentrations of these constituents (Waller and others, 1987). All of these constituents, however, are commonly found in ground water (Aley, 1985). As a result, unless elevated concentrations are present, one cannot confidently determine whether a system has been affected by sewage (Aley, 1985).

Common components of septic-tank effluent that are not naturally present in ground water are fluorescent white dyes used as optical brighteners in laundry soap and detergents. The occurrence of optical brighteners in ground water downgradient from septic-tank field lines is an indicator of the presence of septic-tank effluent. This indicator is particularly effective in karst areas (Mull and others, 1988; Wilson and others, 1988).

GEOHYDROLOGY OF THE STUDY AREA

The study area includes two sites, one with a high density of septic-system field lines installed in blasted bedrock and another with field lines installed in soils averaging about 5 feet in thickness. The first site is in northern Williamson County (fig. 1) and includes a subdivision where septic systems have a high rate of failure both to the surface and to the ground (Larry Robinson, Williamson County, oral commun., 1987). Most runoff from the site drains to a central sinkhole, which in turn is drained by a ditch blasted in bedrock (fig. 1). The site is underlain by limestone that is capable of yielding small quantities of water to wells in the area.

Three springs lie downgradient of the septic systems, Wm:O-9 and Wm:O-11, which flow year round, and Wm:O-10, which flows only after periods of sustained rain (fig. 1). Springs Wm:O-9 and Wm:O-11, therefore, discharge water from the water-table aquifer. Discharge of all three springs generally is less than about 2 gallons per minute.

The second sampling site is located in southern Davidson County (fig. 2) about 7 miles northwest of the first site. This site is in an older neighborhood, where septic systems have been in use for as long as 75 years. Septic-system field lines at this site are installed in soil which generally is 3 to 5 feet thick. The soil is underlain by limestone which is capable of yielding small quantities of water to wells in the area.

A small spring, Dv:F-2 (fig. 2) lies about 700 feet to the southeast of residential areas using septic systems. The spring flows year round and has a discharge of less than 3 gallons per minute.

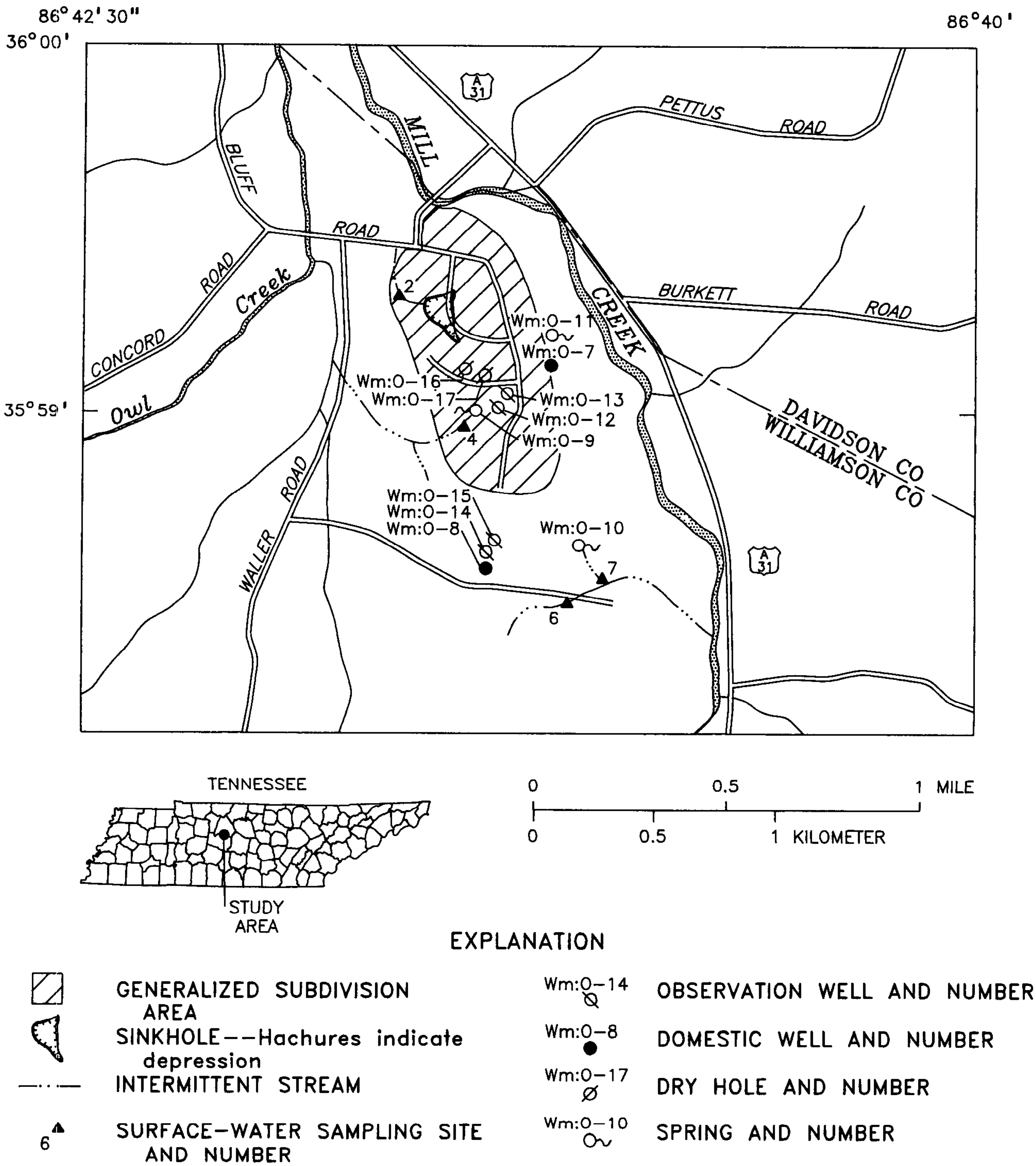
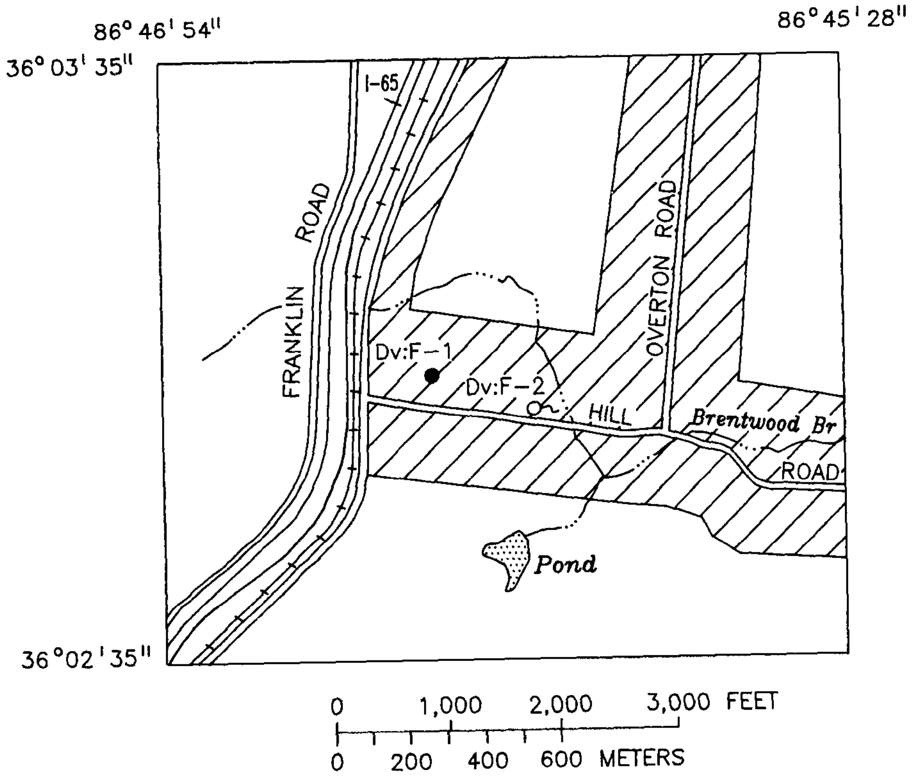


Figure 1.--Location of observation wells, springs, and surface-water sampling sites in Williamson County.



EXPLANATION

GENERALIZED SUBDIVISION AREA

INTERMITTENT STREAM

Dv:F-1 DOMESTIC WELL AND NUMBER

Dv:F-2 SPRING AND NUMBER

Figure 2.--Location of domestic well and spring in Davidson County.

The Williamson County site overlies limestone with little soil coverage. The formations underlying the site are, in descending order, the Hermitage Formation, the Carters Limestone, the Lebanon Limestone, and the Ridley Limestone, all of Ordovician age. The Hermitage Formation caps the hills. This formation is a thin-bedded, silty limestone and acts as a confining unit. Field lines completed within the Hermitage Formation are more likely to fail to the surface than to the subsurface because of the high clay content of this formation. Lower lying parts of the subdivision are underlain by Carters Limestone, which is a blocky micritic limestone and is a probable aquifer. Field lines completed within the Carters Limestone are more likely to fail to the subsurface than to the surface because of the potential occurrence of open fractures and solution openings.

The Lebanon Limestone acts as a confining unit, but the Ridley Limestone, also a blocky micritic limestone, is an aquifer. The two domestic wells in the area are completed in the Ridley Limestone. A major water-bearing zone has been identified at the contact between the Lebanon Limestone and the Ridley Limestone at a depth between 130 and 145 feet below land surface.

The Davidson County site overlies the Bigby-Cannon Limestone[2], which has weathered into a relatively thick soil. This formation is a soluble, silt-free limestone. The Bigby-Cannon Limestone overlies the Hermitage Formation. The spring (Dv:F-2) occurs at the contact between these two formations.

WELL CONSTRUCTION

Six observation wells were drilled at the Williamson County site (fig. 1) using the air-rotary method. Depths of these wells range from 65 to 185 feet below land surface (table 1). Six-inch diameter galvanized steel casing was set at least 20 feet into bedrock. The rest of the well was completed in rock, and left as open bore. A seal of bentonite pellets was installed in the well annulus at the base of the casing to a thickness of at least 1 foot, and the well annulus at the surface was sealed to a depth of 1 foot using cement grout. Of the six observation wells drilled, two were dry (Wm:O-16 and Wm:O-17), three had estimated yields of less than 1 gallon per minute (Wm:O-12, Wm:O-13, Wm:O-14), and one (Wm:O-15) had an estimated yield of 15 gallons per minute. All yields were measured by discharging water through a flume during the development of the well.

Two wells at this site were completed in the shallow water-bearing zone, and two wells were completed in the deep water-bearing zone. The shallow water-bearing zone occurs at or near the contact between the Carters Limestone and the Lebanon Limestone at a depth that ranges between 25 and 30 feet below land surface. Wells completed in this shallow zone are Wm:O-12 and Wm:O-14 (table 1). The deep water-bearing zone occurs at or near the contact between the Lebanon Limestone and the Ridley Limestone, which occurs between 125 and 145 feet below land surface. Well Wm:O-15 was completed in this deeper zone (table 1), and well Wm:O-13 was completed within the Ridley Limestone (fig. 3).

[2]Unit follows usage of Tennessee Division of Geology.

Table 1.--*Well construction, yield, and water level data for observation and domestic wells in the study area*

[O, observation well; D, domestic well; C/L = Carters Limestone/Lebanon Limestone; L/R = Lebanon Limestone/Ridley Limestone; *, none; **, well was dry at time of measurement; --, not measured; <, less than]

Well number	Type of well	Casing depth, in feet below land surface	Water-bearing zone	Well depth, in feet below land surface	Yield, in gallons per minute	Water level, May 8, 1989, in feet below land surface
Wm:O-12	O	21	C/L	70	<1.0	17.40
Wm:O-13	O	22	L/R	165	<1.0	83.49
Wm:O-14	O	25	C/L	105	<1.0	58.66
Wm:O-15	O	21	L/R	140	15	64.60
Wm:O-16	O	21	*	65	0	**
Wm:O-17	O	20	*	185	0	**
Wm:O-7	D	--	L/R	285	--	--
Wm:O-8	D	21	L/R	198	--	--
Dv:F-1	D	--	L/R	[a]200	--	--

[a]Approximate depth.

Well Wm:O-16 terminated in the Lebanon Limestone, and well Wm:O-17 terminated in the Ridley Limestone. Neither well intercepted a water-bearing zone, and as of May 1989, both were dry.

DATA COLLECTION AND ANALYSIS

Water samples were collected at the Williamson County site in May 1988 from the three springs (Wm:O-9, Wm:O-10, Wm:O-11), two domestic wells (Wm:O-7, Wm:O-8), and four surface-water sites (sites 2, 4, 6, and 7). Site 2 is on the drainage ditch blasted into the bedrock to drain the sinkhole. Site 4 is on the small creek downstream from spring Wm:O-9. Site 7 is on a stream that drains the study area to the south. Site 6 is on a stream that drains the hills to the south and is unrelated to the surface-water flow from the study area. Samples collected during this period were analyzed for fecal coliform and fecal streptococci bacteria, temperature, specific conductance, alkalinity, pH, major inorganic constituents, nutrients, methylene blue active substances (MBAS), and total organic carbon. Samples also were scanned using a gas chromatograph with a flame ionization detector (GC/FID) to determine if methylene chloride-extractable organic substances were present.

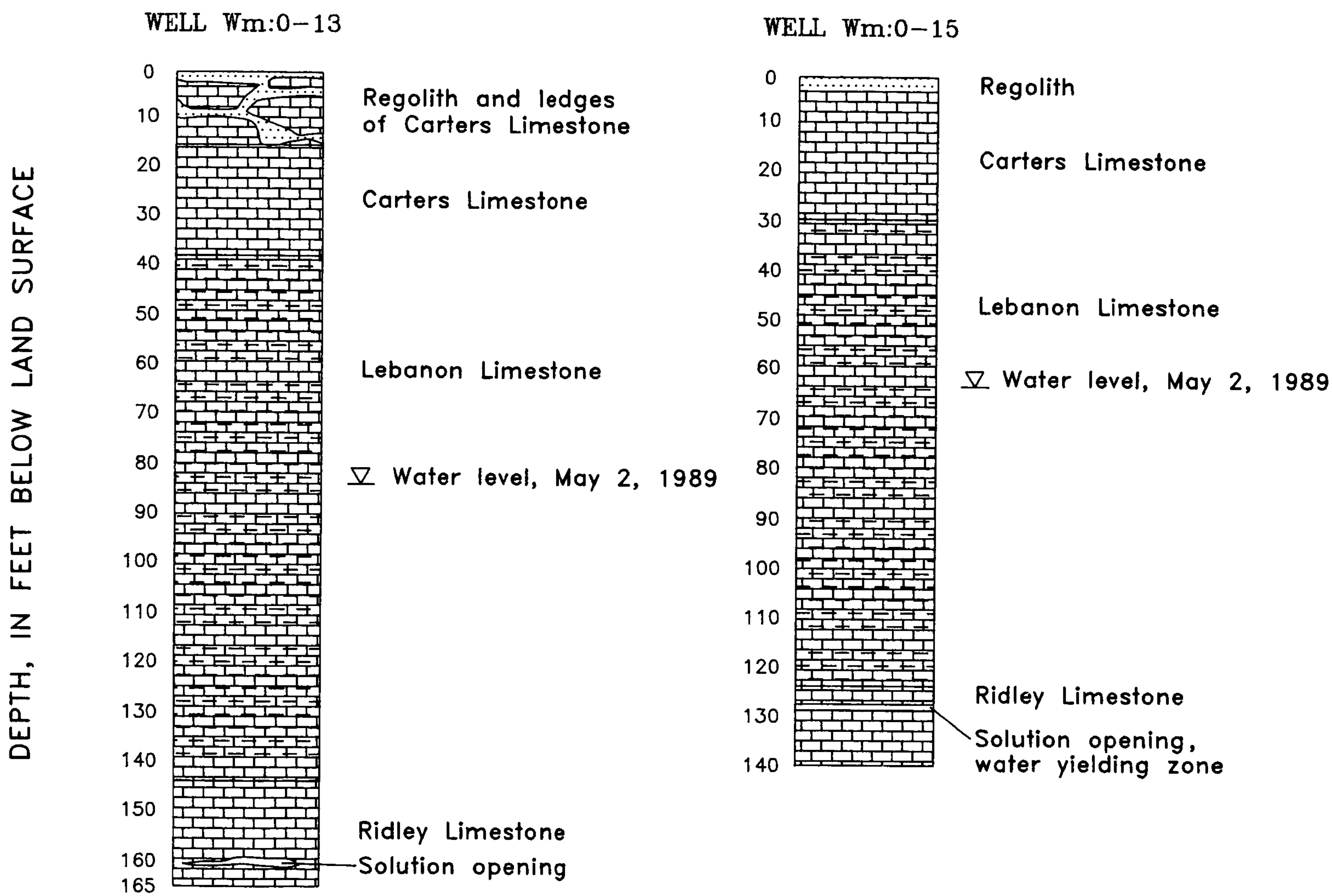


Figure 3.--Stratigraphic column of wells Wm:0-13 and Wm:0-15.

Ground-water samples were collected using two different methods -- pumping and bailing. Domestic wells were pumped and the samples were collected at faucets. The samples were collected after the specific conductance had stabilized to ensure a representative sample. The observation wells were purged of at least three casing volumes of water, using a submersible pump. Observation well Wm:O-15 was sampled by pumping. The remaining observation wells, because of their low yields, were sampled using a stainless-steel bailer. The bailer was rinsed between samples with deionized water.

Grab-samples were collected at the springs. Because of low yields, it was not possible to collect depth integrated samples.

Samples were collected a second time in November 1988. Based on the results of the first sampling period, sampling sites were limited to observation wells Wm:O-12, Wm:O-13, and Wm:O-14, and springs, Wm:O-9 and Wm:O-11. Temperature, specific conductance, and pH were measured in the field and water samples were collected and shipped to the laboratory for analysis of major inorganic constituents, nutrients, and total organic carbon. Scans for organic substances were not performed on this suite of samples because such substances were not detected in any of the samples collected in May 1988.

In April 1989, all four springs (three in Williamson County and one in Davidson County) were sampled and analyzed for optical brighteners. These analyses were performed to determine if any hydraulic connection exists between the springs and septic-tank field lines.

A final suite of samples was collected in May 1989. During this sampling effort, observation wells Wm:O-12, Wm:O-13, Wm:O-14, and Wm:O-15, and spring Wm:O-9 were sampled at the Williamson County site. A sample also was collected from domestic well Dv:F-1 at the Davidson County site. Samples were analyzed for the same constituents as in November 1988 with the addition of bacterial analyses. Results of the analyses for the three samplings are presented in table 2.

EFFECTS OF SEPTIC-TANK EFFLUENT ON GROUND-WATER QUALITY

Wells and springs were sampled on three occasions to determine if septic-tank effluent has affected ground-water quality. The sites sampled varied from one sampling event to the next, depending on the results of previous analyses.

Major Inorganic Constituents

Samples collected during the study did not exhibit concentrations of any water-quality constituents that decisively indicated effects of septic-tank effluent. Concentrations of ions such as sulfate, calcium, chloride, and sodium, which are commonly used as indicators of sewage contamination, were typical of uncontaminated ground water (table 2).

Nutrients

The principal nutrients, nitrogen and phosphorus, are potential indicators of ground-water, septic-tank contamination by effluents (Miller, 1980; p. 190 and table 23). Most of the sampling in the study was focused to determine concentrations of the principal species of nitrogen (organic, ammonia, nitrite, and nitrate) and phosphorus (organic and

Table 2.--*Water-quality analyses*

[deg C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; µg/L, micrograms per liter; SW, surface water; D, domestic well; S, spring; O, observation well; E, estimated; <, less than; --, not sampled or no analysis]

Site, well, and spring number (see figure 1)	Site type	Date	Water temperature (deg C)	Color (platinum-cobalt units)	Specific conductance field (µS/cm)	Specific conductance lab (µS/cm)	Field pH, (standard units)	Alkalinity lab (mg/L as $CaCO_3$)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrite and nitrate, dissolved (mg/L as N)
Williamson County														
2	SW	05-10-89	18.0	<5	500	544	7.95	227	0.020	0.030	<0.010	--	0.55	0.070
2		05-11-88	22.0	13	--	483	7.75	194	.050	.020	< .010	--	.30	< .100
4	SW	05-11-88	14.5	3	685	696	7.70	331	.100	.040	< .010	--	< .20	.830
6	SW	05-11-88	20.0	2	540	526	7.90	260	.070	.030	< .010	--	1.4	.110
7	SW	05-11-88	20.0	2	540	424	8.00	210	.040	.020	< .010	--	.30	< .100
Wm:O-7	D	05-12-88	16.0	1	640	634	7.25	292	.110	.070	< .010	--	< .20	< .100
Wm:O-8	D	05-12-88	16.0	2	790	791	7.10	346	.130	.110	< .010	--	.70	< .100
Wm:O-9		05-11-88	14.0	2	670	720	7.00	317	1.30	1.30	.020	1.48	1.8	1.50
Wm:O-9	S	11-21-88	14.5	<5	--	642	7.17	282	E .110	0.110	E .010	--	.52	E2.70
Wm:O-9		05-09-89	14.5	<5	585	639	7.27	293	.220	0.190	.010	1.39	.33	1.40
Wm:O-10	S	05-11-88	20.5	4	540	521	7.00	252	.050	.060	.020	--	< .20	< .100
Wm:O-10		11-21-88	15.0	<5	320	389	7.55	190	.010	.020	< .010	--	< .20	.080
Wm:O-11	S	05-12-88	14.5	3	700	664	7.50	319	.070	.030	< .010	--	< .20	.650
Wm:O-11		11-23-88	14.0	<5	--	672	7.69	283	E .020	.050	E .010	--	E .52	E2.20
Wm:O-12	O	11-23-88	15.0	<5	--	708	7.63	326	E .100	E .100	E .010	--	.64	E1.40
Wm:O-12		05-11-89	16.0	<5	530	441	7.33	192	.010	< .010	.010	.360	< .20	.370
Wm:O-13	O	11-22-88	16.0	5	--	846	7.41	289	E .630	E .630	E .030	--	E2.8	E .060
Wm:O-13		05-11-89	15.5	<5	--	639	7.58	284	.490	.480	.020	.160	.51	.180
Wm:O-14	O	11-23-88	15.0	<5	700	780	7.54	365	.210	E .210	.020	.020	E .52	.040
Wm:O-14		05-11-89	16.0	<5	580	583	7.37	271	.220	.220	.010	.070	.34	.080
Wm:O-15	O	11-22-88	15.0	5	--	833	7.10	335	E .030	E .030	E .010	--	E .83	E .610
Wm:O-15		05-07-89	15.5	<5	605	615	7.31	293	.020	.010	< .010	--	.21	.210
Davidson County														
Dv:F-1	D	05-12-89	15.5	<5	--	675	7.41	267	.010	< .010	.010	.500	< .20	.510

Table 2.--*Water-quality analyses*--Continued

Site, well, and spring number (see figure 1)	Date	Phos-phorous, total (mg/L as P)	Phos-phorous, dis-solved (mg/L as P)	Phos-phorous, organic total (mg/L as P)	Phos-phorous ortho, dis-solved (mg/L as P)	Carbon, organic total (mg/L as C)	Hard-ness, total (mg/L as $CaCO_3$)	Hard-ness noncarb, wh wat tot fld (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlo-ride, dis-solved (mg/L as Cl)	Sulfate, dis-solved (mg/L as SO_4)	Fluo-ride, dis-solved (mg/L as F)
Williamson County															
2	05-10-89	0.590	0.250	0.59	0.240	3.0	260	21	89	9.3	11	1.6	12	46	0.40
2	05-11-88	.270	.230	.27	.190	5.2	230	30	79	7.9	12	1.9	13	46	.40
4	05-11-88	.160	.160	.16	.100	2.1	360	25	130	8.6	13	0.90	13	34	.30
6	05-11-88	.020	.030	.02	.030	2.9	270	5	100	6.1	1.8	.80	2.6	26	.30
7	05-11-88	.020	.030	.02	.020	2.7	270	9	100	5.6	1.6	.40	2.6	24	.30
Wm:O-7	05-12-88	.010	.010	.01	.010	.8	320	31	88	25	13	2.2	13	38	.40
Wm:O-8	05-12-88	.010	.020	.01	.010	.5	400	52	100	36	7.8	3.0	38	36	.40
Wm:O-9	05-11-88	.600	.650	.60	.560	5.7	360	40	130	8.5	19	1.5	20	34	.30
Wm:O-9	11-21-88	E .180	E .120	--	.110	2.5	300	23	110	7.3	11	1.0	12	39	.20
Wm:O-9	05-09-89	.190	.150	.19	.150	1.7	310	0	110	7.9	12	1.3	15	33	.30
Wm:O-10	05-11-88	.010	.010	.01	.010	2.0	300	26	110	5.1	1.4	.20	2.4	16	.30
Wm:O-10	11-21-88	E .020	< .020	--	.010	2.5	200	9	73	4.0	1.1	.20	2.1	15	.20
Wm:O-11	05-12-88	.040	.040	.04	.020	3.0	360	320	130	7.9	12	.70	12	28	.30
Wm:O-11	11-23-88	E .110	E .060	--	.040	2.2	300	22	110	7.3	16	.80	23	37	.20
Wm:O-12	11-23-88	E .090	E .030	--	.020	1.7	310	0	100	14	6.3	1.5	11	44	.30
Wm:O-12	05-11-89	.040	.020	.04	.020	.9	370	0	130	12	5.0	1.5	6.2	35	.20
Wm:O-13	11-22-88	E1.40	E .060	--	.030	1.3	300	7	51	41	62	10	5.6	150	1.5
Wm:O-13	05-11-89	.130	.020	.13	.020	1.6	270	0	49	35	35	8.7	3.0	64	1.5
Wm:O-14	11-23-88	E .070	E .030	--	.010	.9	310	0	45	47	4.5	6.0	17	47	.50
Wm:O-14	05-11-89	.030	.020	.03	.010	.9	390	0	78	48	4.4	6.6	9.8	43	.60
Wm:O-15	11-22-88	E .180	E .040	--	.030	1.9	400	69	130	19	16	4.4	33	67	.30
Wm:O-15	05-07-89	.030	.020	.03	.020	.6	320	23	110	11	6.0	.60	16	27	.20
Davidson County															
Dv:F-1	05-12-89	.080	.080	.08	.090	0.9	340	40	100	21	11	1.4	16	81	.70

Table 2.--*Water-quality analyses*--Continued

Site, well, and spring number (see figure 1)	Date	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Coliform, fecal, 0.7 UM-MF (cols./100 mL)	Streptococci fecal, KF agar (cols. per 100 mL)	Solids, residue at 180 deg C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Carbon, organic total (mg/L as C)
Williamson County									
2	05-10-89	6.2	<10	40	--	--	327	321	3.0
2	05-11-88	5.6	14	94	400	2300	288	286	2.1
4	05-11-88	4.9	11	4	880	3900	405	410	2.9
6	05-11-88	4.2	6	<1	22	760	305	304	2.7
7	05-11-88	4.2	4	2	29	670	249	297	5.2
Wm:O-7	05-12-88	6.3	30	6	<1	<1	358	361	.8
Wm:O-8	05-12-88	7.5	390	18	<1	<1	460	437	.5
Wm:O-9	05-11-88	5.1	73	93	3200	900	412	420	5.7
Wm:O-9	11-21-88	4.8	10	10	--	--	414	354	2.5
Wm:O-9	05-09-89	5.0	180	100	2700	750	390	491	1.7
Wm:O-10	05-11-88	4.3	<3	7	[a]14	1800	264	302	2.0
Wm:O-10	11-21-88	3.6	<10	<10	--	--	250	213	2.5
Wm:O-11	05-12-88	5.2	6	19	2000	700	376	219	3.0
Wm:O-11	11-23-88	5.0	10	<10	--	--	429	369	2.2
Wm:O-12	11-23-88	6.2	<10	<10	--	--	478	379	1.7
Wm:O-12	05-11-89	5.4	10	10	26	190	436	434	.9
Wm:O-13	11-22-88	8.2	10	<10	--	--	534	503	1.3
Wm:O-13	05-11-89	8.1	50	30	65	380	382	407	1.6
Wm:O-14	11-23-88	8.6	<10	<10	--	--	491	395	.9
Wm:O-14	05-11-89	8.8	20	10	43	130	433	437	.9
Wm:O-15	11-22-88	6.6	10	<10	--	--	549	477	1.9
Wm:O-15	05-07-89	5.8	10	<10	<1	<1	367	356	.6
Davidson County									
Dv:F-1	05-12-89	8.3	<10	<10	<1	<1	448	420	.9

[a]Not an ideal count.

orthophosphate). The results of the analyses indicated higher than background concentrations of these nutrients in several of the samples (table 2). Elevated nitrite plus nitrate (1.5 mg/L as N), ammonia (1.3 mg/L as N), and ammonia plus organic nitrogen (1.8 mg/L as N) concentrations were measured in water from spring Wm:O-9. Concentrations of these water-quality constituents were not noticeably elevated in samples from the domestic wells, the other springs, and the surface-water sites sampled in May 1988.

Some of the samples collected in November 1988, however, did indicate a possible effect of nutrients from septic-tank effluent upon ground-water quality. Samples from springs Wm:O-9 and Wm:O-11, and from well Wm:O-12 had slightly elevated concentrations of nitrite plus nitrate (2.7, 2.2, and 1.4 mg/L as nitrogen, respectively) that may have been due to field-line effluent. Analyses of May 1989, however, indicated no discernable effect from septic-tank effluent. Although in May 1989, spring Wm:O-9 did have a nitrite plus nitrate concentration of 1.4 mg/L as nitrogen, the data are inconclusive as to whether the slightly elevated concentration of nitrite plus nitrate was due to septic-tank effluent.

The November 1988 analyses of water from well Wm:O-13 revealed somewhat elevated concentrations of ammonia plus organic nitrogen (2.8 mg/L), total phosphorus (1.4 mg/L as P), and sulfate (150 mg/L as SO_4). These were the highest concentrations of these constituents measured in any of the samples from any of the sites. Analyses of samples collected from this well in May 1989 indicated much lower concentrations of these constituents. Because of the depth of this well and its low yield, purging is difficult; therefore, the sample collected from this well in November 1988 possibly did not represent ambient conditions. Variations in analyses between samples collected in November 1988 and May 1989 may be due in part to inadequate purging of drilling fluid from the adjacent aquifer prior to the November 1988 sampling.

Organic Substances

No synthetic organic compounds were detected in any of the samples collected. Scans for methylene chloride-extractable organic substances were conducted on all samples collected at the Williamson County site in May 1988. The scans were conducted using a gas chromatograph (GC) equipped with a flame-ionization detector (FID). The FID is a non-specific detector that responds to a broad range of organic substances that pass through the GC. A positive result appears as an anomalous, compound-unidentifiable peak. Peaks were not present in any of the scans of samples from the Williamson County site.

Analysis for total organic carbon (TOC) is a determination of the total concentration of organic carbon in a water sample. Analysis for TOC does not separate natural from synthetic organic carbon occurring in ground water. Concentrations of TOC in septic-tank effluent can be as high as 69 to 200 mg/L (Waller and others, 1987; Canter and Knox, 1986). TOC concentrations measured at sites in Williamson and Davidson Counties ranged from 0.5 to 5.7 mg/L. The highest concentration was measured in water from spring Wm:O-9 in May 1988; however, because this concentration is within the range of TOC concentrations for some natural waters, TOC data cannot be used to confirm the presence of septic-tank effluent.

Optical Brighteners

To demonstrate whether or not a hydraulic connection exists between field lines and the springs in the study area, a qualitative dye test for optical brighteners was conducted. Sampling devices consisting of surgical white

cotton swabs attached to wire secured to a concrete base were placed in the discharge of the springs. These swabs were later tested for fluorescence under ultraviolet light (a characteristic of optical brighteners) using methods described by Mull and others (1988).

Four optical-brightener sampling devices were placed in the three springs (Wm:O-9, Wm:O-10, and Wm:O-11) at the Williamson County site, and in the spring at the Davidson County site (Dv:F-2) in April 1989. These devices were retrieved after 3 days. Of the four devices, only the one from spring Wm:O-9 fluoresced under ultraviolet light, indicating the presence of optical brighteners in the discharge. Another device was placed in spring Wm:O-9, and left for 14 days. The second swab also fluoresced, confirming the presence of optical brighteners which are commonly found in septic-tank effluent. Based on the results of this test, a hydraulic connection between field lines and spring Wm:O-9 was shown to exist. Hydraulic connection between field lines and the other springs could not be demonstrated.

Bacteria

Both fecal coliform and fecal streptococci bacteria are present in the gastrointestinal tract of humans and other warm-blooded animals. The presence of these bacteria in natural water indicates degradation by human or animal waste and may be related to septic-tank waste.

Samples collected in May 1988 from domestic wells Wm:O-7 and Wm:O-8, four surface-water sites, and three springs were analyzed for fecal streptococci and fecal coliform. Samples collected in May 1989 from the four observation wells, spring Wm:O-9, and domestic well Dv:F-1 also were analyzed for these bacteria. Sample collection and analyses were in accordance with the methods of Britton and Greeson (1987). Results are included in table 2.

Water from the four surface-water sites had fecal streptococci counts ranging from 670 to 3,900 colonies per 100 milliliters (mL) of sample. Fecal coliform counts in the samples from these sites ranged from 22 to 880 colonies per 100 mL of sample.

Water from the three springs (Wm:O-9, WM:O-10, and WM:O-11) had 700 to 1,800 colonies of fecal streptococci, and 14 to 3,200 colonies of fecal coliform per 100 mL of sample. The sample from spring Wm:O-10 contained 14 colonies of fecal coliform and 1,800 colonies of fecal streptococci per 100 mL of sample.

Samples from springs had much higher bacterial counts than those from wells. Water from spring Wm:O-9 contained 3,200 colonies of fecal coliform per 100 mL of sample in May 1988 and 2,700 colonies per 100 mL in May 1989. Water from spring Wm:O-11 contained 2,000 colonies per 100 mL of sample in May 1988. Spring Wm:O-11 is located in a cow pasture and is used by cows as a source of drinking water; consequently, its water quality may be influenced not only by septic-tank effluent but also by animal excreta.

None of the samples from the three domestic wells contained fecal coliform or fecal streptococci bacteria. Bacterial concentrations in water from the four observation wells ranged from less than 1 to 65 colonies of fecal coliform per 100 mL and from less than 1 to 380 colonies of fecal streptococci per 100 mL. The sample from observation well Wm:O-15 did not contain either fecal coliform or fecal streptococcus bacteria.

SUMMARY AND CONCLUSIONS

The results of analyses for major chemical constituents and nutrients in water from

domestic wells, observation wells, and springs do not conclusively show the presence or absence of septic-tank effluent in ground water in northern Williamson County and southern Davidson County. Concentrations of constituents commonly thought to be a product of effluent from field lines did not greatly exceed concentrations common in natural ground water in the area. Slightly elevated concentrations of nitrite plus nitrate and total ammonia in spring Wm:O-9 could be the result of septic-tank effluent.

Organic substances were not detected, but the absence of such substances in ground water does not demonstrate nor eliminate a possible direct hydraulic connection between the field lines and ground water. Results from these analyses are inconclusive as to whether or not septic-tank effluent is affecting ground-water quality.

Bacteria were not detected in any of the three domestic wells sampled for this study. The highest concentrations of fecal coliform colonies were in water from springs Wm:O-9 and Wm:O-11.

Only the results of sampling for optical brighteners gave conclusive evidence that septic-tank effluent is affecting ground-water quality. One of the four springs tested in the study areas contained optical brighteners. This indicated that this spring (Wm:O-9) is hydraulically connected to the septic-tank field lines.

REFERENCES CITED

Aley, T.J., 1985, Optical brightener sampling; a reconnaissance tool for detecting sewage in karst groundwater: American Institute of Hydrology, v. 1, no. 1, p. 45-48.

Britton, L.J., and Greeson, P.E., eds., 1987, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A4, p. 53-67.

Canter, L.W., and Knox, R.C., 1985, Septic tank system effects on ground water quality: Chelsea, Mich., Lewis Publications, Inc., 336 p.

Geldreich, E.E, and Kenner, H.L., 1969, Concepts of fecal streptococci in stream pollution: Journal of the Water Pollution Control Federation 41; part 2, A336-352.

Hollyday, E.F., and Goddard, P.L., 1980, Ground-water availability in carbonate rocks of the Dandridge area, Jefferson County, Tennessee: U.S. Geological Survey Water Resources Investigations Report 79-1263, 50 p.

Madison, R.J., and Burnett, J.O., 1985, Overview of the occurrence of nitrate in ground water of the Unites States, in National Water Summary: U.S. Geological Survey Water-Supply Paper 2275, 467 p.

Miller, D.W., 1980, Waste-disposal effects on ground water: Berkley, Calif., Premier Press, 512 p.

Mull, D.S., Lieberman, T.D., Smoot, J.L., and Woosley, L.H., 1988, Application of dye-tracing techniques for determining solute-transport characteristics of ground water in karst terranes: U.S. Environmental Protection Agency, Region 4, Manual EPA 904/6-88-001, 103 p.

Pitt, W.A.J., Jr., Mattraw, H.C., Jr., and Klein, H., 1975, Ground-water quality in selected areas serviced by septic tanks, Dade County, Florida: U.S. Geological Survey Open-File Report 75-607, 82 p.

Waller, B.G., Howie, Barbara, and Causaras, C.R., 1987, Effluent migration from septic tank systems in two different lithologies, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4075, 22 p.

Wilson, T.M., Reinhard, J.D., Gordon, J.A., and Ogden, A.E., 1988, A study of septic tank systems in Sullivan County, Tennessee: Tennessee Valley Authority Report TV 65598a, 89 p.