GROUND-WATER QUALITY AND ITS RELATION TO HYDROGEOLOGY, LAND USE, AND SURFACE-WATER QUALITY IN THE RED CLAY CREEK BASIN, PIEDMONT PHYSIOGRAPHIC PROVINCE, PENNSYLVANIA AND DELAWARE

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96-4288

prepared in cooperation with

RED CLAY VALLEY ASSOCIATION

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CHESTER COUNTY WATER RESOURCES AUTHORITY

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Lemoyne, Pennsylvania
1996

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
840 Market Street
Lemoyne, Pennsylvania 17043-1586

Copies of this report may be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, Colorado 80225-0286

CONTENTS

ILLUSTRATIONS

Plates [In Pocket]

FIGURES

ILLUSTRATIONS—CONTINUED

TABLES

TABLES—CONTINUED

TABLES—CONTINUED

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
million gallons (Mgal)	3,785	cubic meter
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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

Abbreviated water-quality units used in report:

mg/L, milligrams per liter
µg/L, micrograms per liter
µm, micrometer
µS/cm, microsiemens per centimeter at 25 degrees Celsius
pCi/L, picoCuries per liter

Ground-Water Quality and Its Relation to Hydrogeology, Land Use, and Surface-Water Quality in the Red Clay Creek Basin, Piedmont Physiographic Province, Pennsylvania and Delaware

by Lisa A. Senior

ABSTRACT

The Red Clay Creek Basin in the Piedmont Physiographic Province of Pennsylvania and Delaware is a 54-square-mile area underlain by a structurally complex assemblage of fractured metamorphosed sedimentary and igneous rocks that form a water-table aquifer. Ground-water-flow systems generally are local, and ground water discharges to streams. Both ground water and surface water in the basin are used for drinking-water supply.

Ground-water quality and the relation between ground-water quality and hydrogeologic and land-use factors were assessed in 1993 in bedrock aquifers of the basin. A total of 82 wells were sampled from July to November 1993 using a stratified random sampling scheme that included 8 hydrogeologic and 4 land-use categories to distribute the samples evenly over the area of the basin. The eight hydrogeologic units were determined by formation or lithology. The land-use categories were (1) forested, open, and undeveloped; (2) agricultural; (3) residential; and (4) industrial and commercial. Well-water samples were analyzed for major and minor ions, nutrients, volatile organic compounds (VOC's), pesticides, polychlorinated biphenyl compounds (PCB's), and radon-222.

Concentrations of some constituents exceeded maximum contaminant levels (MCL) or secondary maximum contaminant levels (SMCL) established by the U.S. Environmental Protection Agency for drinking water. Concentrations of nitrate were greater than the MCL of 10 mg/L (milligrams per liter) as nitrogen (N) in water from 11 (13 percent) of 82 wells sampled; the maximum concentration was 38 mg/L as N. Water from only 1 of 82 wells sampled contained VOC's or pesticides that exceeded a MCL; water from that well contained 3 µg/L chlordane and 1 µg/L of PCB's. Constituents or properties of well-water samples that exceeded SMCL's included iron, manganese, dissolved solids, pH, and corrosivity. Water from 70 (85 percent) of the 82 wells sampled contained radon-222 activities greater than the proposed MCL of 300 pCi/L (picoCuries per liter).

Differences in selected major and minor ion concentrations and radon-222 activities were statistically significant between some lithologies and are related to differences in mineralogy. Ground water from felsic gneiss and schist generally contained higher radon-222 activities than the other lithologies; activities as high as 10,000 pCi/L were measured in a water sample from the felsic gneiss.

Differences in the concentrations of nitrate, sodium, and chloride, and the frequency of pesticide detections in ground water were statistically significant between samples from wells in some land-use categories. Concentrations of nitrate generally were greatest in agricultural and in industrial and commercial areas and can be attributed to the use of fertilizers on the land surface and other agricultural activities. Much of the industrial and commercial land use is in areas previously used for or related to mushroom production. Concentrations of chloride and sodium also were greatest in water from wells in agricultural and industrial and commercial areas, probably because of the use of fertilizer and road salt. Concentrations of nitrate, chloride, and sodium in water samples from wells in forested and residential land use did not differ statistically significantly from each other. The herbicides metolachlor and atrazine were the most frequently detected pesticides and were detected more frequently in agricultural areas than in areas with other land uses; their presence is related to their use in crop production. VOC's were detected infrequently and only in residential and industrial and commercial areas.

The relation between ground-water quality and surface-water quality is assessed by comparing nitrate and chloride concentrations in the 1993 ground-water samples and 1993-94 base-flow samples. Base-flow samples were collected at eight stream sites in the headwaters of the West Branch of Red Clay Creek in 1994 and at two long-term stream-monitoring sites on the East and West Branches of the Red Clay Creek in 1993-94. The average concentrations of chloride and nitrate in ground-water samples from wells in areas above the headwater stream sites and two long-term stream-monitoring sites were similar to the concentrations of chloride and nitrate in base flow at those sites. An observed increase in nitrate concentration in base flow at the long-term monitoring site on the West Branch of Red Clay Creek from 1970 to 1995 may be related to an increase in nitrate concentrations in ground water in that area of the basin.

INTRODUCTION

In the Piedmont Physiographic Province of southeastern Pennsylvania and northern Delaware, ground-water discharge sustains the majority of streamflow. Thus, the quality of both streams and ground water can be affected by soluble contaminants that infiltrate to the ground-water system. Because ground water and surface water in the Red Clay Creek Basin are used for drinking-water supply, degradation of these resources is of concern

The Red Clay Creek is known to be degraded by point-source discharges and runoff from industrial sites and agricultural land. Polychlorinated biphenyls (PCB's); pesticides, such as DDT; and metals, such as zinc, have been detected in the stream sediments (Rice, 1993; Hardy and other, 1995). Some stream reaches exhibit low benthic macroinvertebrate diversity (Moore, 1987; Hardy and others, 1995), indicating poor water-quality conditions that may include the presence of toxins, excessive sediment, elevated temperature, low dissolved-oxygen concentrations, elevated nutrient loads, or other problems.

Although the quality of stream water and sediments has been studied and continues to be monitored by state and federal agencies, (U.S. Environmental Protection Agency, Pennsylvania Department of Environmental Protection (PaDEP), Delaware Division of Natural Resources and Environmental Conservation, U.S. Fish and Wildlife Service, and the U.S. Geological Survey (USGS)), data on ground-water quality prior to 1993 in the Red Clay Creek Basin were limited to samples collected near suspected point sources of contamination. The effects of nonpoint-source pollution associated with land-use activities on ground-water quality in the basin were unknown. Results of other studies in the Piedmont in Pennsylvania (Fishel and Lietman, 1986) and in Maryland (McFarland, 1994) indicate that ground-water quality is related to land use.

A study to assess ambient ground-water quality and relate ground-water quality to hydrogeologic and land-use factors and to surface-water quality was begun in 1992 to provide basic data required to help manage the water resources of the basin. This study was conducted by the USGS in cooperation with the Chester County Water Resources Authority. Impetus and one half of the funding for the study came from the Red Clay Valley Association.

PURPOSE AND SCOPE

This report describes ground-water quality in the Red Clay Creek Basin in 1993 and the relation between ground-water quality and hydrogeologic and land-use factors and surface-water quality. The study area is restricted to the crystalline metamorphic rocks of the Piedmont Physiographic Province that underlie the majority of the Red Clay Creek Basin. Ground-water quality is characterized from results of chemical analyses of water samples collected from 82 wells during July through November 1993 in order to provide a baseline for continuing assessment of ground-water quality.

Chemical analyses of water samples included major ions, selected minor ions and trace metals, nutrients, volatile organic compounds (VOC's), pesticides, and radon-222. Sample selection was based on a stratified random scheme that incorporated land use and geology as grouping variables. Summary statistics are presented for each land-use and geologic group, and differences among groups are evaluated by use of statistical methods. The relation between ground-water quality and land-use and hydrogeologic factors is tested statistically. The relation between ground-water and base-flow quality is evaluated by comparing nitrate and chloride concentrations.

DESCRIPTION OF THE RED CLAY CREEK BASIN

The Red Clay Creek Basin drains 54 mi^2 of the lower Delaware River Basin (fig. 1) in Chester County, Pa., and New Castle County, Del. The headwaters of the Red Clay Creek, the East and West Branches and their tributaries, are in southeastern Chester County. The East and West Branches are confluent 0.75 mi north of the Pennsylvania-Delaware state line. The Red Clay Creek flows southeast to the White Clay Creek just south of Stanton, Del.; White Clay Creek is a tributary to the Christina River, which flows into the Delaware River near Wilmington, Del.

The Red Clay Creek Basin lies in the Piedmont and Atlantic Coastal Plain Physiographic Provinces. The two physiographic provinces are distinguished by differences in geology and topography (pl. 1). The Piedmont part (52.8 mi^2) of the

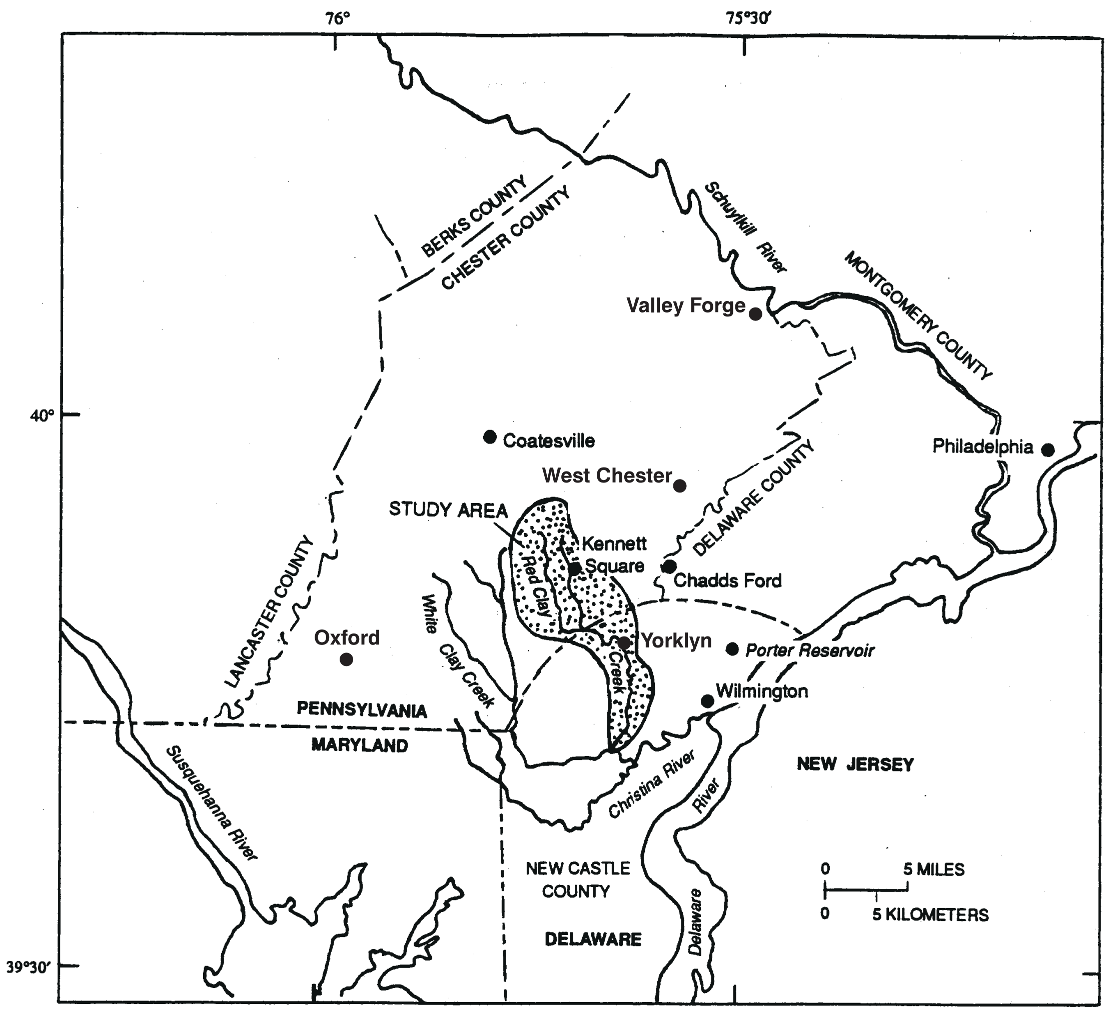


Figure 1. Location of the Red Clay Creek Basin, Pennsylvania and Delaware.

basin is underlain predominantly by metamorphic rocks. The Atlantic Coastal Plain part (1.2 mi^2) of the basin is underlain by unconsolidated sediments that are younger than and were deposited on the metamorphic rocks. The boundary between the two provinces commonly is marked by waterfalls and rapids on most streams crossing it and has been termed the Fall Line. The Fall Line generally coincides with the Baltimore and Ohio Railroad tracks north of Stanton, Del., in the southern part of the basin.

The topography of the Piedmont Physiographic Province is characterized by gently rolling uplands dissected by narrow valleys. North of the Fall Line, the uplands slope gently to the southeast. Elevation in the Piedmont uplands ranges from 557 ft above sea level at the Red and White Clay Creek drainage divide near Upland, Pa., to 70 ft above sea level at the Fall Line.

The Red Clay Creek Basin has a modified humid continental climate. Winters are mild to moderately cold and summers are warm and humid. Normal mean annual air temperatures at National Oceanic and Atmospheric Administration (NOAA) weather stations in West Chester, Pa. (a few miles northwest of the basin), and at Porter Reservoir near Wilmington, Del. (fig. 1), for 1961-90 are 52.9°F (11.6°C) and 53.4°F (11.9°C), respectively. Normal mean temperatures for 1961-90 for January, the coldest month, are 29.5°F (-1.4°C) and 30.1°F (-1.1°C) for the West Chester and Porter Reservoir stations, respectively. Normal mean temperatures for July, the warmest month, for 1961-90 are 74.8°F (23.8°C) and 75.2°F (24.0°C) for the West Chester and Porter Reservoir stations, respectively (Owenby and Ezell, 1992a, b). Normal mean annual precipitation for 1961-90 is 45.88 in. at both West Chester and Chadds Ford (a few miles to the east of the basin near the Pennsylvania-Delaware State line) and 46.06 in. at Porter Reservoir. Precipitation is distributed fairly evenly throughout the year.

Kennett Square, Pa., is the largest town in the Red Clay Creek Basin and is near the center of the basin south of U.S. Route 1 (fig. 1). Municipalities in the basin include East Marlborough, West Marlborough, Kennett, and New Gardens Townships, and Kennett Borough in Chester County, Pa., and areas north of Wilmington in New Castle County, Del.

Most areas outside of Kennett Square rely on ground water from on-site wells as a source of water supply. Wells supply water for residential, agricultural, municipal, industrial and commercial use. The borough of Kennett Square buys water from the Chester Water Authority (imported surface water from other basins to the west) and pumps ground water from a municipal well. Most wastewater from areas outside Kennett Square and the urbanized part of the basin north of Wilmington is discharged on-site to the subsurface through septic systems. In Kennett Square, and other areas served by sewers, wastewater is collected, treated, and discharged to streams.

Well-Numbering System

The well-numbering system used in this report consists of an abbreviation prefix followed by a sequentially-assigned local well number. In Pennsylvania, the prefix is a county abbreviation, and the prefix “CH” denotes a well in Chester County. In Delaware, the prefix refers to a specific 1-minute square block in a state-wide grid. Delaware is divided into 5-minute quadrangles of latitude and longitude. The quadrangles are lettered north to south with capital letters and west to east with lower case letters. Each 5-minute quadrangle is further subdivided into 25 1-minute-square blocks that are numbered from north to south in series of tens from 10 to 50 and numbered from west to east in units from 1 to 5 (fig. 2). The prefix in Delaware is an upper and lower case letter designating the 5-minute-square block and followed by two numbers designating the 1-minute-square block in which the well is located. For example, well number Gd34-2 is assigned to the second well to be scheduled in the 1-minute-square block that has the coordinates Gd-34 (fig. 2).

In addition to the local well number, each well or spring is assigned a unique 15-digit site identification number, on the basis of the latitude and longitude (in degrees, minutes, and seconds) of the well and a two-digit site sequence number. Locations of wells sampled by USGS for this study are shown on plate 1. Records of wells listed by local number are at the end of the report in table 18 for Pennsylvania and table 19 for Delaware.

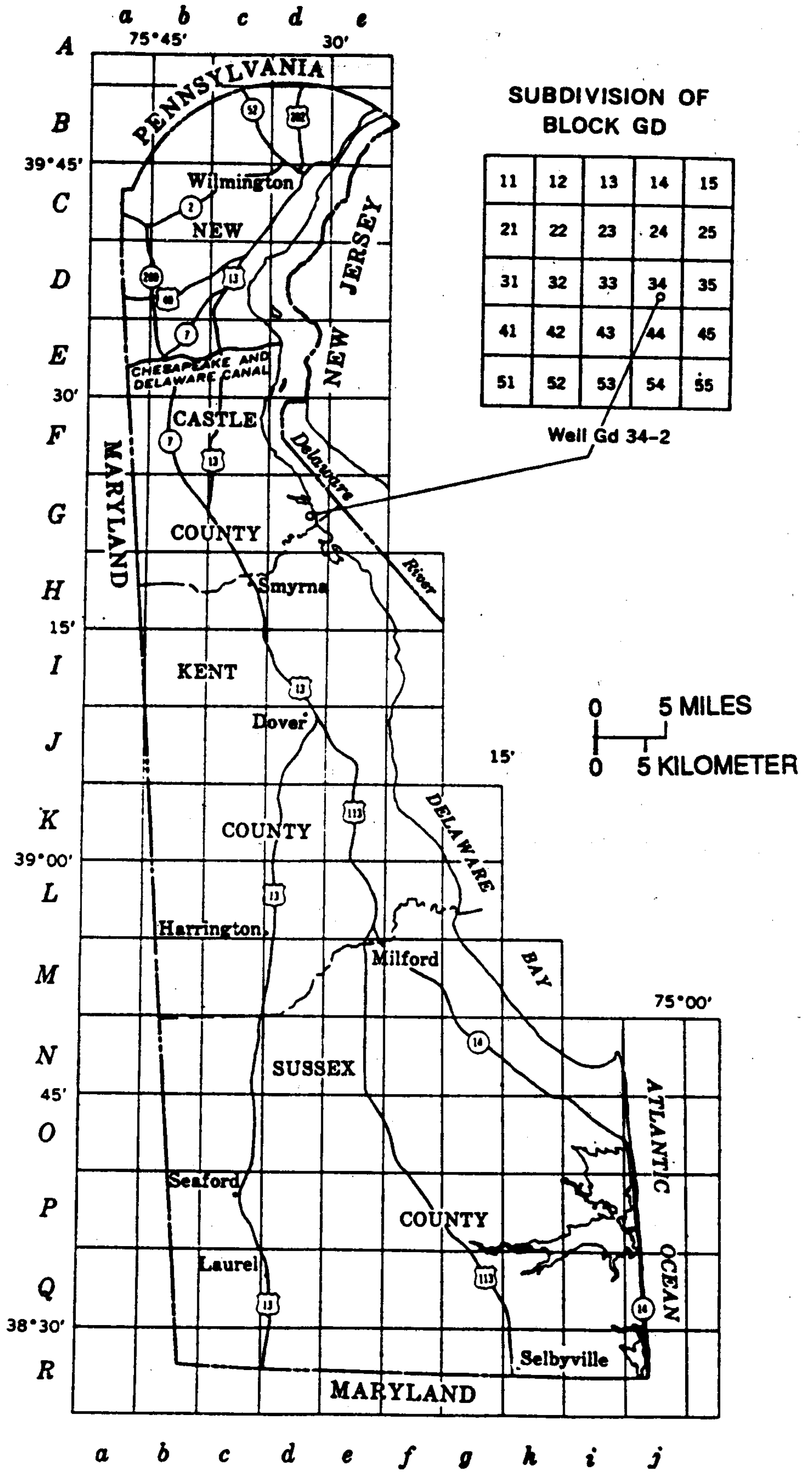


Figure 2. Coordinates for the State of Delaware well-numbering system. (From Rima and others, 1964, p. 6.).

METHODS OF DATA COLLECTION AND ANALYSIS

Data collection was designed to fulfill the study objectives which were to (1) characterize ground-water quality in the Red Clay Creek Basin and (2) determine the association between ground-water quality and hydrogeologic and land-use factors. Ground-water quality data collected prior to 1993 were not sufficient to meet the study objectives. Samples collected prior to 1993 generally were from wells located near suspected point sources of contamination and, therefore, were not evenly distributed throughout the basin. Also, the types of chemical analyses differed among samples. In addition, the available data had been collected over a period of more than 50 years and in different seasons, introducing the possibility of the presence of seasonal or other temporal changes in the data.

An areally-weighted stratified random sampling scheme with geologic units and land-use categories as factors was used to determine the number and distribution of samples. The sampling scheme provided spatially distributed samples (data) throughout the basin in each of the geologic unit and land-use categories. All samples were collected by the same sampling procedures and analyzed for the same chemical constituents. Geologic units were chosen as a sampling category because soil and bedrock chemical and hydrologic characteristics affect susceptibility of aquifers to contamination, as well as naturally occurring chemical reactions. Land use was chosen as a sampling category because human activities contribute specific contaminants associated with each land use.

Geologic units were determined from available geologic mapping. Land-use categories were determined from land-use maps prepared by townships in Chester County, Pa., and from digitized land use obtained from the New Castle County Water Resources Authority, Del. All map data were transferred to 7.5-minute USGS topographic quadrangle maps and digitized to create digital land-use and geologic unit spatial data sets in a Geographic Information System (GIS). The geologic units and land-use classifications are described in later sections of this report.

To provide data on the relation between ground-water and surface-water quality, base-flow samples were collected at eight sites in the headwaters of the West Branch of the Red Clay Creek in summer 1994. Additional base-flow samples were collected in autumn 1993-94 at two long-term monitoring sites on the East and West Branches of the Red Clay Creek as part of the Chester County stream-quality monitoring program.

SAMPLE SELECTION

The stratified random sampling scheme for well selection included eight geologic units and four land-use categories. Areas of the basin underlain by each geologic unit and land-use category were calculated from digitized data in GIS spatial data sets (table 1). The number of samples from each category was determined by distributing a total of 86 samples by percentage of total area that each category represented in the basin (table 2). Although the sample design was for 86 wells, only 82 wells were actually sampled. Some land-use and geologic categories (such as the urbanized southern part of the basin underlain by the Wilmington complex) are in areas served by public water supplies where wells were not available. The exact distribution of samples differs slightly from that of the sample design because of well availability.

Most wells selected for sampling in each category had been previously inventoried by the USGS but had not been previously sampled. Data on well construction (depth and length of casing), well yield, and specific capacity were generally from driller reports and were available for most wells.

Table 1. *Area and percentage of land underlain by seven geologic units and covered by four land-use categories in the Red Clay Creek Basin, Pennsylvania and Delaware*

Geologic unit[1]	Residential	Commercial/ industrial	Agricultural	Open	Total
		Land-use area (square miles)			
Wissahickon Formation (north)	0.73	0.15	2.69	0.71	4.28
Cockeysville Marble	.36	.56	1.72	.39	3.03
Mafic gneiss	.85	.03	1.24	.55	2.67
Felsic gneiss	2.39	.56	4.27	1.84	9.06
Setters Quartzite	.85	.3	2.24	.33	3.72
Wissahickon Formation (south)[2]	6.02	.39	11.11	7.80	24.32
Wilmington complex	2.19	1.07	.13	.85	4.24
Total	13.39	3.06	23.4	12.47	52.32
		Percentage of basin area in land use			
Wissahickon Formation (north)	1.4	0.3	5.1	1.4	8.2
Cockeysville Marble	.7	1.1	3.3	.7	5.8
Mafic gneiss	1.6	.1	2.4	1.1	5.1
Felsic gneiss	4.6	1.1	8.2	3.5	17.3
Setters Quartzite	1.6	.6	4.3	.6	7.1
Wissahickon Formation (south)	11.5	.8	21.2	14.9	48.4
Wilmington complex	4.2	2.	.2	1.6	8.1
Total	25.6	5.8	44.7	23.8	100

[1] Mapped area underlain by serpentinite is about 0.03 square miles and is covered by residential or forested land use; this unit was not included in the table because of its small area.

[2] Wissahickon Formation includes an 0.82 square-mile area underlain by a unit mapped in Delaware as Wmg, Wissahickon gneiss.

Table 2. *Number of samples in each category for areally-weighted stratified random sampling scheme in the Red Clay Creek Basin, Pennsylvania and Delaware*

Geologic unit	Number of samples - design (actual)				
	Land use				All uses
	Residential	Commercial/ Industrial	Agricultural	Open	
Wissahickon Formation (north)	1 (3)	0 (0)	4 (4)	1 (1)	6 (8)
Cockeysville Marble	1 (1)	1 (3)	3 (4)	1 (0)	6 (8)
Mafic gneiss	1 (1)	0 (0)	2 (2)	1 (1)	4 (4)
Felsic gneiss	4 (5)	1 (2)	7 (7)	3 (2)	15 (16)
Setters Quartzite	1 (1)	0 (0)	4 (6)	1 (1)	6 (8)
Wissahickon Formation (south)	10 (9)	1 (0)	18 (18)	13 (7)	42 (34)
Wilmington complex	4 (3)	2 (0)	0 (0)	1 (0)	7 (3)
All units[1]	22 (23)	5 (5)	38 (41)	21 (12)	[2]86 (81)

[1] Mapped area underlain by serpentinite, about 0.03 square miles and covered by residential or open/forested land use, is not represented in this table.

[2] Samples were collected from a total of 82 wells, including 1 well completed in serpentinite and not shown on this table.

Sample Collection

Samples from 82 wells were collected from July to November of 1993 in Pennsylvania and Delaware. In addition, 10 of the 82 wells were resampled from July to August of 1994; these samples were collected to confirm detection of pesticides or VOC's. Most of the sampling sites were domestic wells equipped with submersible pumps. The depth to water was measured in the well prior to pumping, and the rate and duration of pumping prior to sampling were recorded. Most pumping rates ranged from about 4 to 10 gal/min. All filters and treatment systems were bypassed. Wells were pumped until temperature, pH, and specific conductance stabilized, usually after 30 to 60 minutes. Probes to monitor pH, temperature, and specific conductance were placed below the surface of a continuously overflowing sampling container supplied by the well discharge; use of the overflowing container reduced contact of the water with the atmosphere.

Field measurements of pH, temperature, alkalinity, dissolved-oxygen concentration, and specific conductance of ground-water samples were made by established methods (Wood, 1976). Alkalinity was determined by titration to the point of inflection (usually between 4.5 and 5.0 pH units) and is reported as milligrams per liter of calcium carbonate ($CaCO_3$). Bicarbonate (HCO_3) is assumed to be the dominant component of alkalinity in dilute ground waters with neutral to acidic pH and (or) organic content. Dissolved-oxygen concentration was determined by use of the azide modification of the Winkler titration method (American Public Health Association and others, 1976).

Samples of ground water for inorganic chemical analysis were filtered through a 0.45-µm filter. Samples for dissolved organic carbon (DOC) analysis were filtered through a 0.1-µm silver filter by use of a peristaltic pump. Sample preservation included acidification with nitric acid for cation and metals analysis, chilling for DOC analysis, and addition of mercuric chloride and chilling to 4°C for nutrient analysis. Concentrated nitric acid was used for all acidified samples. Samples for radon-222 analysis by liquid scintillation were collected with a syringe from a continuously overflowing beaker (U.S. Environmental Protection Agency, 1978).

Stream samples were collected from eight sites in the headwaters of the West Branch of Red Clay Creek in July of 1994. Stream discharge was measured at the time of sample collection. Field measurements of pH, temperature, alkalinity, dissolved-oxygen concentration, and specific conductance were made by the methods described above. Samples of stream water for nutrient and anion analysis were filtered through a 0.45-µm filter. Through a separate cooperative program with Chester County, stream samples at two long-term monitoring sites on the East and West Branches of the Red Clay Creek have been collected in the autumn since 1970.

Laboratory Analysis

Ground-water samples collected in 1993 were analyzed for dissolved major ions, nutrients, selected minor ions, metals, VOC's, pesticides, and radon-222. The 10 ground-water samples collected in 1994 also were analyzed for arsenic in addition to selected inorganic constituents, pesticides, or VOC's, and selected radionuclides. Analysis of ground-water samples for inorganic constituents including nutrients, DOC, VOC's, and pesticides was done by the USGS National Water-Quality Laboratory (NWQL) by use of standard methods (Fishman and Friedman, 1989; Wershaw and others, 1987; Faires, 1993; Zaugg and others, 1995). The NWQL has set a minimum reporting level (MRL) for inorganic compounds based on the accuracy of the laboratory's methods. Stream samples collected in 1994 were analyzed for dissolved nutrients and anions by the NWQL by use of standard methods. Gamma-ray spectroscopy (for radionuclide analysis) of ground-water samples collected in 1994 was done on contract for NWQL by a private laboratory—U.S. Testing, Richland, Wa.

Laboratory analysis of organic compounds in water commonly involves extraction of the organic compounds from the aqueous (water) phase. The extraction process does not necessarily recover 100 percent of the organic compound present in the water samples. Surrogate compounds that are similar in chemical behavior to the analytes of interest can be added to the sample in the laboratory and estimates of percentage recovery for target analytes are then based on the calculated percentage recovery of the surrogate compounds. The NWQL does not correct results for percentage recovery, and, therefore, the reported concentrations commonly are less than or equal to actual concentrations in the water sample. Data available for recoveries of surrogate pesticide compounds ranged from 59 to 125 percent, with mean recoveries of 82, 80, and 94 percent for surrogates of organochlorine insecticides, organophosphorus insecticides, and the triazine herbicides, respectively.

Some pesticides were detected but not accurately quantified at concentrations below the method detection limit (MDL). The accuracy of the MDL is determined statistically. Greater uncertainty is associated with quantifying the reported concentrations below the MDL than those above the MDL. Reported concentrations below the MDL indicate that the pesticide was detected and present in the sample at very low (trace) concentrations less than the MDL. These concentrations below the MDL are reported as estimated trace quantities in tables 23 and 24.

Statistical Analysis

Nonparametric statistics were used in data analysis. Nonparametric statistical analyses use ranked values of variables, whereas parametric statistical analyses use the actual values of variables. Parametric statistics traditionally are used in the analysis of normally distributed data sets; however, hydrologic data, and water-quality data in particular, commonly are not normally distributed (Helsel, 1987, p. 180). In normally distributed data sets, the mean and median are equivalent or very close in value; in data sets that are not normally distributed, the mean and median are not equivalent. Water-quality data commonly are positively skewed (mean is greater than median). Nonparametric statistics are powerful and robust when used to analyze nonnormally distributed data, such as environmental data that can be badly skewed. In addition, some data for trace metals are bounded at the detection limit of the analytical method and concentrations are reported as less than the detection limit; nonparametric statistical analysis can handle less-than values because calculations are performed on ranked data rather than actual values.

Nonparametric statistical analyses used ranked values for each physical property and chemical constituent analyzed including pH; alkalinity; dissolved-oxygen concentration; temperature; specific conductance; dissolved concentrations of major and minor ions, nutrients, and trace metals; and radon-222 activities. For pesticides and volatile organic and industrial compounds, detection or nondetection (presence or absence) of a compound is used in the analysis instead of concentration. A reported estimated concentration less than the MDL was considered to be a detection of that compound.

Differences between groups, on the basis of the categories of land use and lithology, were determined by nonparametric analysis of variance (ANOVA) for unbalanced design (uneven number of samples in each group) described by Helsel and

Hirsch (1992, p. 179). Significant relations between a factor, such as well depth and depth to water, and the observed water-quality variable are determined by use of two-tail nonparametric Spearman rho (r_s) correlation statistical tests. The selected significance level of statistical tests was 0.05, which corresponds to a 95-percent confidence interval.

PREVIOUS STUDIES

Several general studies include data on ground-water quality and aquifer characteristics in the Red Clay Creek Basin in Pennsylvania (Hall, 1934; Poth, 1968; Sloto, 1989; Sloto, 1994). The ground-water-flow system in the Red Clay Creek Basin was described and simulated by use of the computerized numerical techniques of Vogel and Reif (1993), who also presented all historical ground-water quality data collected by USGS through 1992. In 1990 and 1991, the PaDEP collected ground-water samples from 11 sites in the Red Clay Creek Basin as part of a state ground-water monitoring program in selected basins (Scott Lookingbill, Pennsylvania Department of Environmental Protection, written commun., 1993).

Moore (1987) interpreted trends in benthic macroinvertebrate diversity indices for streams in Chester County, including Red Clay Creek. Data on stream chemistry for two sites on the Red Clay Creek are published annually by water year for 1974-94 (U.S. Geological Survey, 1974-94). Moore (1989) presented stream chemical and biological data for samples collected each autumn during 1972-80. The effects of change in land use on stream-water quality are discussed for the Red Clay Creek and other streams in Chester County, Pa., by Hardy and others (1995). Pesticides and trace metals in soils and stream sediments of the Red Clay Creek were analyzed in a 1988-89 U.S. Fish and Wildlife Service study (Rice, 1993).

Studies of the relation between land use and ground-water quality done elsewhere in the northeastern United States include Barton and others (1987), Eckhardt and others (1989), and Helsel and Ragone (1984). Vowinkel and Siwiec (1991) summarized results of these studies.

ACKNOWLEDGMENTS

James W. Libby, Robin Vannote, of the ground-water committee, and Robert G. Struble Jr., Executive Director, of the Red Clay Valley Association are acknowledged for conceiving the need for the study and providing oversight. Support for the study was provided by the Red Clay Valley Association.

The cooperation of well owners who made their wells accessible for water samples and water-level measurements is greatly appreciated. The author acknowledges David Racca of the New Castle County Water Resources Authority, who provided digitized land-use data for the Red Clay Creek Basin in Delaware; Donna Snyder of the Pennsylvania Topographic and Geologic Survey, who provided information about well construction for several wells in Pennsylvania; and John Talley of the Delaware Geological Survey, who provided information about well construction for several wells in Delaware.

FACTORS AFFECTING GROUND-WATER QUALITY

Pumping wells can draw contamination from areas upgradient of the well toward the well and can reverse or alter the natural ground-water flow direction. Generally, wells pumped at low rates and for short periods, such as domestic wells, will draw water from areas nearer the well than wells pumped at high rates for long periods, such as municipal and industrial wells. Ground-water quality near most wells in the Red Clay Creek Basin probably is most affected by the local geology and land use.

Hydrogeology

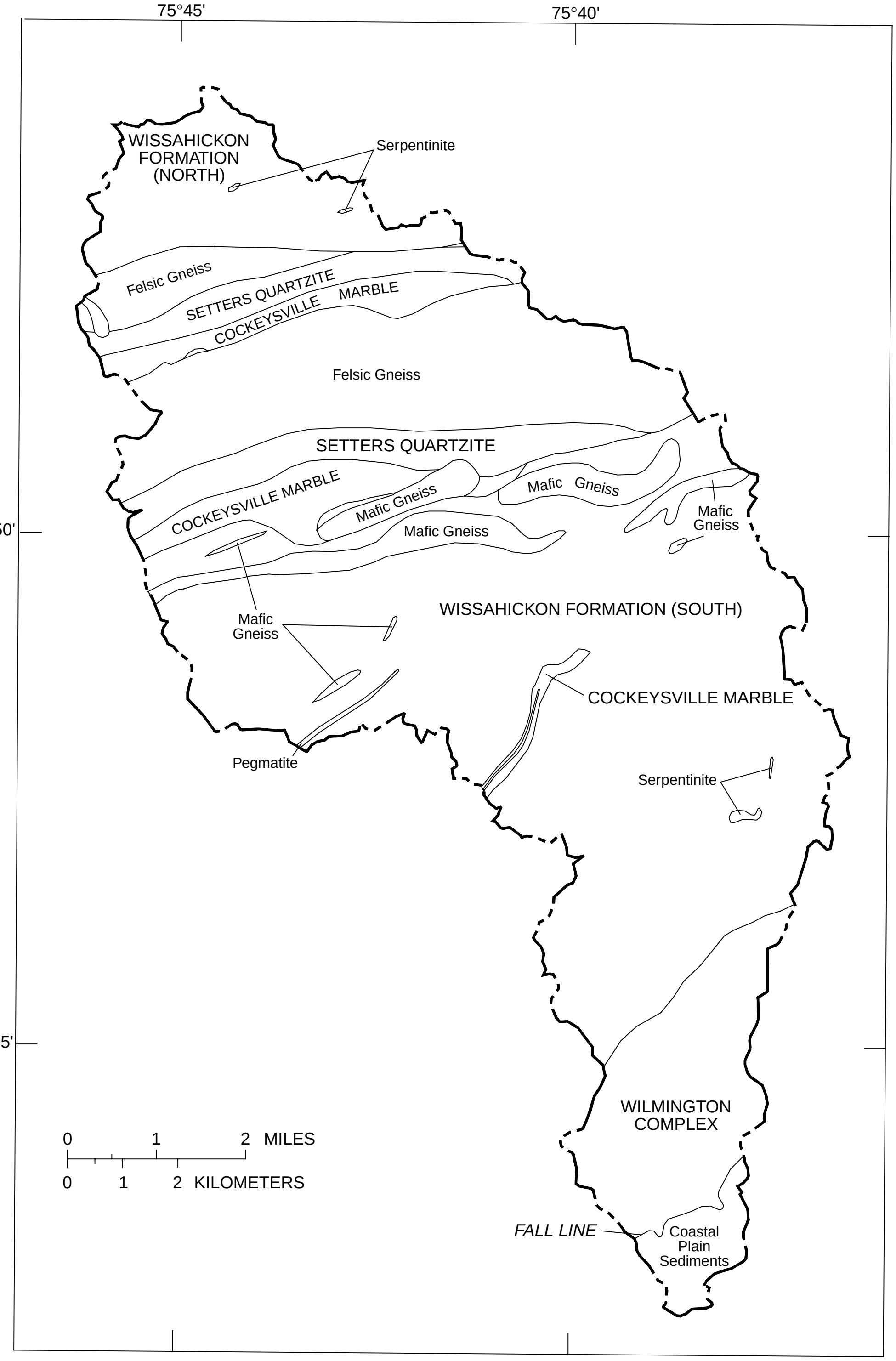
The geology of the basin is an important control of the chemical and physical characteristics of the ground-water system. Ground water commonly has a chemical composition that reflects the mineralogy of the aquifer materials. The chemical composition of rocks differs according to their origin and metamorphic history. In addition, the composition of ground water may be affected by reactions and processes in a flow path. The hydrologic characteristics of each geologic unit partly determine direction and rate of ground-water recharge and flow. Rocks that are relatively resistant to chemical and physical erosion form highlands (ridges and hilltops) and rocks relatively prone to erosion form lowlands (valleys). Ground water in geologic units underlying valleys is a mixture of ground water from ridge and valley sources.

In the Red Clay Creek Basin, as elsewhere in the Piedmont Physiographic Province, the fractured crystalline bedrock is an unconfined aquifer that is recharged by precipitation and discharges to streams. The bedrock is overlain by soils and saprolite (weathered bedrock) that are typically 20 to 40 ft thick over most geologic units, and together, the bedrock and overlying saprolite act as a single unconfined water-table aquifer (Vogel and Reif, 1993). Lithology, geologic structure, and ground-water flow are described below to provide a basis for understanding relations between the occurrence, chemistry, and movement of ground water in the basin. The physical hydrogeology and ground-water flow system in the Red Clay Creek Basin are described in detail by Vogel and Reif (1993).

Lithology

The geologic units mapped in the Red Clay Creek Basin are listed in table 3 for Pennsylvania and table 4 for Delaware. The geologic map of the study area (fig. 3; pl. 1) is a composite of the mapped geology for Pennsylvania (Berg and others, 1981) and Delaware (Woodruff and Thompson, 1972, 1975). Much of the original mapping of Bascom and Stose (1932) and Bascom and Miller (1920) is retained. Stratigraphic nomenclature for the geologic units in Pennsylvania is from Sloto (1994). USGS nomenclature for geologic units in Pennsylvania is given by Lyttle and Epstein (1987).

The oldest rocks are the Precambrian-age felsic gneisses that crop out in the northern half of the basin in two belts (fig. 3, pl. 1). The felsic gneisses have been metamorphosed to different degrees and, thus, have somewhat different mineralogies. Higgins and others (1973) used aeromagnetic data and field relations to roughly locate a previously unmapped dome of gneiss in Delaware that extends into Pennsylvania north of Hockessin, Del. The Delaware Geological Survey (DGS) is presently mapping the gneiss in the Yorklyn, Del., area (John Talley, Delaware Geological Survey, oral commun., 1993). Because mapping of the gneiss in this area is not complete, it is not shown on plate 1. The felsic gneiss is unconformably overlain by a metasedimentary sequence of rocks of the Glenarm Group.



Geology by Berg and others, 1981; Woodruff and Thompson, 1972; Woodruff, 1975

Figure 3. Generalized geologic map of the Red Clay Creek Basin, Pennsylvania and Delaware.

Table 3. *Description of geologic units in the Red Clay Creek Basin in Pennsylvania*

Age[1]	Geologic unit	Lithologic description[1]
Quarternary	Alluvium	Fine- to medium-grained unconsolidated material deposited in and along stream valleys consisting mostly of silt and sand with some admixture of pebbles and locally derived cobbles.
Early Jurassic	Diabase	Dark-gray, fine-grained rock consisting mainly of plagioclase and pyroxene.
Early-Middle Ordovician	Wissahickon Formation	Light- to medium-gray, quartzo-aluminous schist and gneiss. Composition ranges from quartz-orthoclase-biotite and orthoclase-quartz-muscovite schist to quartz-biotite-plagioclase and quartz-plagioclase-biotite schistose gneiss. Moderately high metamorphic grade, mostly in the amphibolite facies.
Cambrian	Cockeysville Marble	White, medium- to coarse-grained, saccharoidal marble and light-gray, fine-grained, banded marble. Commonly contains scattered golden-brown phlogopite.
Late Precambrian	Setters Formation	White to light-gray quartzite, quartzose schist, and potassic-feldspar-quartz-biotite-muscovite schist. A lower part is a darker biotite-quartz-orthoclase(?)-muscovite schist.
Precambrian	Pegmatite	Light-colored, very-coarse- to coarse-grained dikes of granitic rock, containing mostly alkali feldspars and quartz with subordinate amounts of muscovite or biotite.
	Mafic gneiss, amphibolite facies	Very-dark-gray, medium- to coarse-grained amphibolite, interlayered with some felsic laminae and layers.
	Felsic gneiss, amphibolite facies[2]	Light- to medium-gray, medium-grained, finely to coarsely layered quartz-plagioclase-biotite-potassium-feldspar-garnet +/- hornblende gneiss.
	Felsic gneiss, granulite facies[2]	Rather variable composition; plagioclase-quartz-orthoclase-garnet-biotite-hypersthene/clinopyroxene gneiss (strongly lineated) to light-gray, fine- to medium-grained quartz-mesoperthite-garnet +/- biotite +/- hypersthene gneiss. Quartz-kyanite and quartz-garnet +/- kyanite rocks are present locally.

[1] Sloto (1994).

[2] Baltimore Gneiss of Bascom and Stose (1932).

The Glenarm Group consists of the Setters Formation, Cockeysville Marble, and Wissahickon Formation. The age of the Glenarm Group rocks has been interpreted as late Precambrian to Cambrian and possibly Ordovician (Crawford and Crawford, 1980). The Setters Formation is overlain by the Cockeysville Marble, which in turn is overlain by the Wissahickon Formation. The Setters Formation and Cockeysville Marble are approximately 1,000 and 200 ft thick, respectively (Bascom and Stose, 1932). The Wissahickon Formation in southeastern Pennsylvania and northern Delaware is 5,000-8,000 ft thick (Bascom and Stose, 1932) and includes rocks probably deposited in several different tectonic environments (Wagner and Srogi, 1987, p. 115). The Glenarm Group rocks were deposited in a basin that developed on the southeastern edge of the continental margin. The Setters Formation and Cockeysville Marble were deposited near the continental margin as a thin basal

Table 4. *Description of geologic units in the Red Clay Creek Basin in Delaware*

Age[1]	Geologic unit	Lithologic description [2]
Quarternary	Holocene sediments and Columbia Formation	Sediments in present-day stream valleys and marshes are Holocene age fine sands, silts, and clay including fresh, poorly sorted, micaceous sands and gravels in and near the Piedmont, derived mainly from underlying or nearby crystalline rocks. Columbia Formation (Pleistocene age) includes gravelly coarse and medium sands with some interbedded silts. Thickness of the Columbia Formation and Holocene sediments mapped in the Red Clay Creek Basin is up to 10 feet.
Early to Late Cretaceous	Potomac Formation	Variegated red, gray, purple, yellow, and white, commonly lignitic silts and clays containing interbedded white, gray, and rust-brown quartz sands and some gravel. Individual beds usually laterally restricted.
Cambrian-Ordovician?	Serpentinite	Massive antigorite, chromite, and talc with minor vermiculite.
	Pegmatite	Quartz-microcline-muscovite-albite lenses and dikes, both concordant and discordant. Usually present in Wissahickon Formation.
	Wissahickon Formation	Metagraywacke facies: interbedded felsic, unfoliated quartz-oligoclase-hornblende-almandine gneiss and foliated quartz-biotite-oligoclase-almandine schist. Gneisses commonly contain nonparallel foliations suggesting primary sedimentary structures. Usually finely phaneritic. Pelitic facies: felsic, biotite-oligoclase-quartz-almandine-microcline schist and occasional gneiss. Usually coarsely phaneritic and strongly foliated. Contains numerous small pegmatites.
	Cockeysville Marble[3]	Marble, predominantly calcitic with some dolomitic marble. Coarsely phaneritic and weakly foliated with small scale folding.
Precambrian?	Felsic and mafic gneiss[4] (Wilmington complex)	Felsic and mafic gneiss and minor schist. Felsic gneiss is a quartz-oligoclase to andesine-microcline-hornblende-hypersthene gneiss. Mafic gneiss is a quartz-andesine to labradorite-augite-hypersthene +/- hornblende gneiss. Strongly to weakly foliated, coarsely to finely phaneritic.

[1] Woodruff and Thompson (1975).

[2] Woodruff and Thompson (1972).

[3] Woodruff and Thompson (1972, 1975) refer to this unit as the Cockeysville Formation but the name Cockeysville Marble has been used in the text for consistency.

[4] James Run Formation of Hager (1976) and Thompson (1979).

clastic sequence and a carbonate bank, respectively (Rodgers, 1968). The Wissahickon Formation was originally deposited as deep-water clastic sediments. The Setters Formation and Cockeysville Marble crop out along the flanks of the felsic gneiss. In some areas, the Setters Formation and Cockeysville Marble are missing, and the felsic gneiss is in direct contact with the Wissahickon Formation.

Several small elongated bodies of mafic gneiss that trend northeast are found within the Wissahickon Formation. Pegmatite bodies trending northeast crop out within the Wissahickon Formation in Pennsylvania and in the Cockeysville Marble in Delaware. A small body of serpentinite is found within the Wissahickon Formation just north of Hoopes Reservoir in Delaware (pl. 1).

A belt of Precambrian to early Paleozoic granulite-facies felsic and mafic gneisses of the Wilmington complex lies southeast of the Wissahickon Formation. The felsic and mafic gneisses are in fault contact with the Wissahickon Formation (Woodruff and Thompson, 1975; Hager, 1976, p. 65; Wagner and Srogi, 1987, p. 121). The gneisses of the Wilmington complex are interpreted to be metavolcanic units and metamorphosed volcaniclastic sediments (Hager, 1976, p. 60; Thompson, 1979, p. 120; Crawford and Crawford, 1980, p. 319).

STRUCTURE AND METAMORPHISM

The structure of the geologic formations in the Red Clay Creek Basin is complex. The geologic formations are not flat-lying, but folded and faulted, often steeply dipping in places. Because of the complex structural setting, wells may penetrate more than one geologic formation; in some cases, water contributing to a well may be derived from more than one geologic formation or from a formation that is not exposed at the surface, as has been observed in some wells drilled near geologic contacts with the Cockeysville Marble (Woodruff and Planck, 1991, p. 6-7), which is a highly productive aquifer.

Wagner and Srogi (1987) and Crawford and Crawford (1980) have interpreted the southeastern Pennsylvania and northern Delaware Piedmont Physiographic Province as the site of a collision between a magmatic arc and the North American continent. The Wilmington complex was the infrastructure of the magmatic arc. Gneisses to the northeast of the study area were the basement of the continental margin. Between these two plates are nappes of allochthonous remobilized basement (Woodville Dome, Avondale Anticline, and Mill Creek Dome) and highly deformed basin sediments. The nappes and thrust faults trend northeast (fig. 4, pl. 1).

Two Precambrian felsic gneiss belts, flanked by metamorphosed sediments, crop out in the Red Clay Creek Basin in Pennsylvania. The northern gneiss belt forms the core of the Woodville Dome (pl. 1). Wagner and Crawford (1975) and Crawford and Crawford (1980) map the northern gneiss belt as amphibolite-facies gneiss, but the Pennsylvania Geological Survey (PAGS) maps the northern gneiss belt as granulite-facies gneiss. The southern gneiss belt consists of amphibolite-facies felsic and intermediate gneiss and forms the core of the Avondale Anticline (fig. 4)(pl. 1). A schematic cross-section of the Avondale Anticline shows that the structures dip to the southeast (fig. 4). Both gneiss belts originally were mapped as Baltimore Gneiss by Bascom and Stose (1932) because their stratigraphic relations and petrographic character are similar to the Baltimore Gneiss domes in Maryland. The gneiss that forms the core of the Mill Creek Dome near Yorklyn, Del., has been called Baltimore gneiss (Woodruff and Planck, 1991, p. 6-3; Wagner and others, 1991, p. 91).

The Wissahickon Formation north of Route 926 is separated from other formations to the south in the basin by the east-west trending Street Road Fault. For the analysis of variance in this study, the Wissahickon Formation was divided into northern and southern sections that are north and south of the Street Road Fault (pl. 1), respectively, on the basis of hydrologic differences determined in an earlier study by Vogel and Reif (1993). Hager (1976, p. 42-44) identified two types of faults that cut across the Wissahickon Formation in the Hoopes Reservoir area. Medium-angle reverse faults parallel northeast-trending structures in the area. High-angle normal or reverse faults trend northwest and affect both Wissahickon Formation and Wilmington complex rocks. Stream valleys follow both types of faults in the study area.

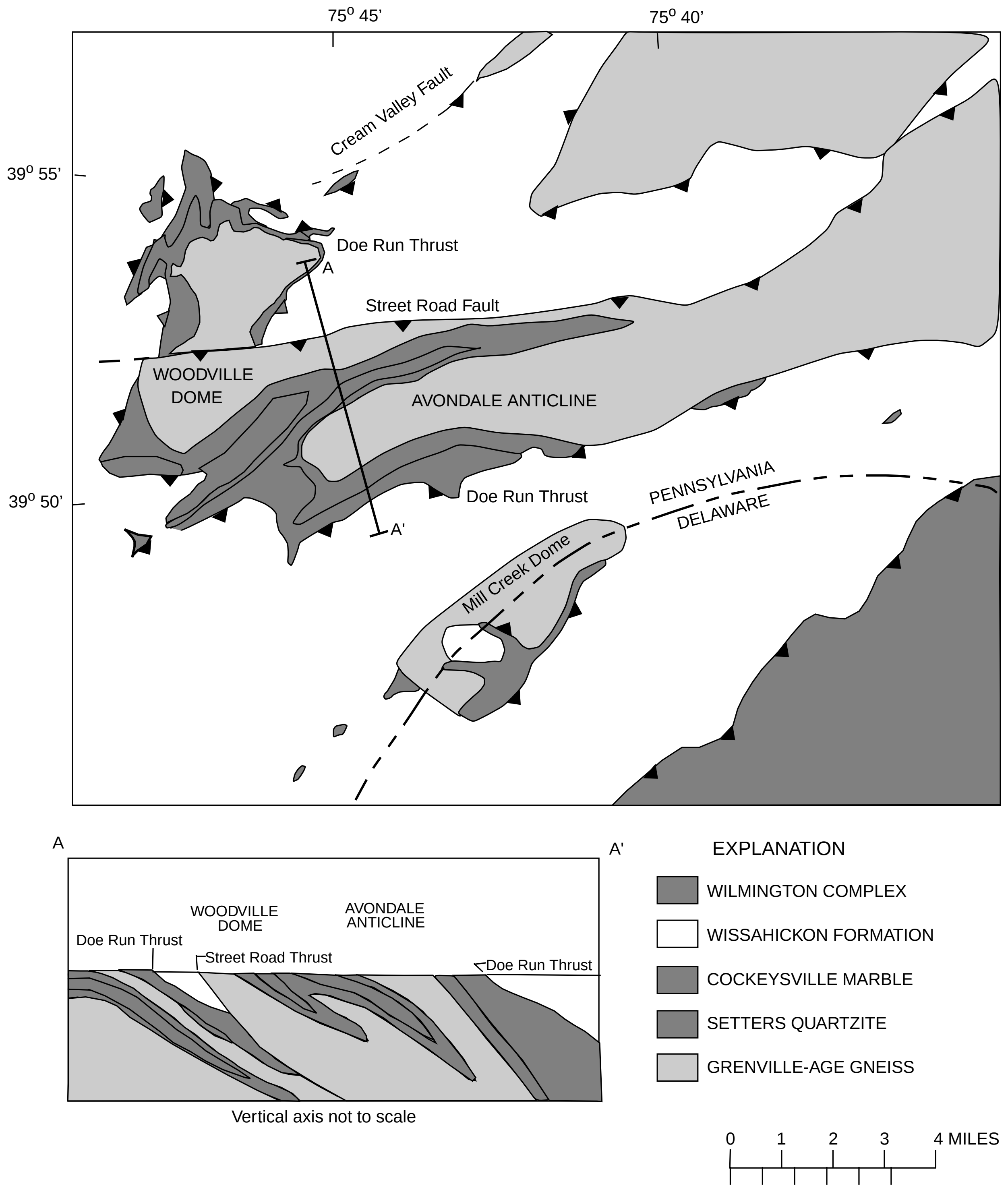


Figure 4. Schematic of major structures and cross-section of the Avondale anticline near the Pennsylvania-Delaware border (modified from Alcock, 1991).

Evidence of three metamorphic events are present in the Piedmont rocks of southeastern Pennsylvania and northern Delaware (Crawford and Crawford, 1980). The first event was a high pressure granulite-facies episode of Grenville age. Crawford and Crawford (1980) believe it affected the felsic gneisses northeast of the study area. Wagner and Srogi (1987) believe it also affected the felsic and intermediate gneisses exposed in the study area. The felsic and intermediate gneisses were later overprinted by a Taconic age amphibolite-facies metamorphic event. Two high-grade metamorphic events took place during the Taconic orogeny; the Wilmington complex was metamorphosed at moderate pressure and high temperature to granulite facies, and the felsic and intermediate gneisses and Glenarm Group rocks were metamorphosed to amphibolite facies during a regional metamorphic event. The regional metamorphic grade is highest (second sillimanite isograd) adjacent to the Wilmington complex (Wagner and Srogi, 1987).

Ground-Water Flow

The fractured crystalline rock aquifers are recharged by precipitation that infiltrates through the overlying soils and saprolite. Saprolite, generally composed of rock fragments and sandy clay, is derived from the weathering of the underlying bedrock. Ground water flows through the open spaces (primary porosity) in unconsolidated soils and saprolite and through fractures, faults, joints, and(or) bedding planes (secondary porosity) in the crystalline rocks. Recharge rates vary seasonally and may vary by land-use and soil type. Typically, recharge is greatest during the late fall, winter, and early spring and least during late spring, summer, and early fall.

As recharge infiltrates into the saprolite and bedrock, the chemical composition of the water (originally precipitation) can change through a series of naturally occurring chemical reactions. These reactions may include microbially mediated or inorganic reduction and oxidation; mineral weathering, dissolution, or precipitation; ion adsorption and exchange; and radioactive decay. Much of the chemical character of ground water in unconfined aquifers may be acquired during its passage through the saprolite.

The saprolite has high primary porosity, and ground water can be stored in the pore spaces in the saprolite before being transmitted to the fracture system of the underlying crystalline bedrock. The crystalline rock probably has little to no primary porosity but has low secondary porosity in the form of fractures, cleavage planes, joints, and faults, which may be less than 1 percent for gneisses and schists and somewhat greater for the Cockeysville Marble. In the Cockeysville Marble, secondary openings may be enlarged by solution. The greater the density and interconnection of the secondary openings, the greater the permeability of the crystalline rock. The average residence time of ground water in the Georgia Piedmont was estimated to be about 25 years in the saprolite (Rose, 1992) and more than 35 years in the fractured bedrock below (Rose, 1990). The Georgia Piedmont has hydrogeology similar to that of the Piedmont in Pennsylvania and Delaware.

Soils and saprolite with high permeabilities can transmit recharge rapidly to the ground-water system. Contamination of ground water occurs more readily where soils and saprolite are thin and permeable. The degree of interconnection of the pores determines the permeability (ability to transmit water) of the aquifer. Most saprolite has low permeability because of the abundance of clay. Saprolite associated with the

Cockeysville Marble commonly is very sandy and has a high permeability, which suggests that the Cockeysville Marble may be more vulnerable to contamination from the land surface than the other geologic units in the Red Clay Creek Basin.

For unconfined aquifers, such as the fractured crystalline rocks in the Red Clay Creek Basin, ground water flows from areas of high water-table altitude to areas of low water-table altitude. Because the water table generally is a subdued replica of the land surface in the basin (Vogel and others, 1991), ground water flows from hill and ridge tops toward valleys. Ground-water-flow systems are local, with relatively short flow paths from recharge areas to discharge areas that include seeps, springs, and streams. Actual flow paths probably are complex, as ground water moves through interconnected fractures in the different geologic formations that underlie the Red Clay Creek Basin. The chemical character of ground water may continue to evolve along a flow path, especially if the flow path passes through different lithologies. Some variability in ground-water composition in any given geologic formation may be expected because of differences in the ground-water-flow paths, as well as variability in the mineral composition of the geologic unit.

In the Red Clay Creek Basin, the hills underlain by schists and gneisses (noncarbonate rocks) are primarily recharge areas that discharge to streams and into rocks underlying the valleys below. Three valleys are underlain by carbonate rocks of the Cockeysville Marble—the east-west trending valleys near Willowdale and Kennett Square, Pa., and a northeast-trending valley near Yorklyn, Del. (pl. 1). Ground water in the noncarbonate rocks derives its composition by interaction only with those rocks and the effects of human or biologic activities, whereas ground water in the carbonate rocks is a mixture of water that infiltrates directly and ground water that flows from the noncarbonate rocks.

In some areas, ground water does not discharge to the streams but, rather, the stream water infiltrates to the ground-water system; these stream segments are called losing reaches. Segments that receive water through ground-water discharge are called gaining reaches. Losing stream reaches were identified in some places where the Red Clay Creek crosses the Cockeysville Marble during fall 1989 (Vogel and Reif, 1993). The relation between ground water and surface water may change seasonally with fluctuations in the water table. For example, during the spring when the water table is high, a stream segment may gain water from ground-water discharge, whereas, during the fall when the water table is low, that segment may lose water to the ground-water system.

Land Use

Human activities can generate contaminants that may infiltrate to the ground-water system. The quantities and types of potential contaminants differ by activity, which is related to land use. Where land remains undeveloped, contaminants from human activities at the land surface generally are not present. However, some contaminants from human activities emitted to the atmosphere elsewhere can be transported and deposited on the land surface far from their source. In addition to the chemical loads imposed by human activities on the land surface, ground-water quality may be affected by water-use activities, such as pumping and discharging, that affect the direction of ground-water flow and contaminants in the ground-water system.

Areas that contribute water to a pumping well include areas upgradient and in the immediate vicinity of the well. The extent of a contributing area depends on aquifer properties and the rate of pumping. Most wells sampled for this study are domestic wells that pump at relatively low rates on an intermittent basis. For the purposes of this study, recharge is assumed to be primarily local, and land use in the area near the well is assumed to have a greater effect on ground-water quality than land use in areas upgradient, but far, from the well.

However, the assumption that local land use has a greater effect than does distant land use on ground-water quality may be less valid for in areas of the basin underlain by the Cockeysville Marble than in areas underlain by other formations. Contaminants may travel in ground water farther from source areas underlain by the Cockeysville Marble than by the other formations because permeability in the Cockeysville Marble is greater than in the other formations. Further, the areas underlain by the Cockeysville Marble are valleys, such that ground water in the Cockeysville Marble is a mixture of locally derived recharge and recharge from adjacent formations. In addition, contaminants in surface water carried from source areas in the headwaters of the basin may enter the ground-water system through losing stream reaches underlain by the Cockeysville Marble.

Classification and Distribution

Land use in the Red Clay Creek Basin is classified into one of four major categories: undeveloped (forested), agricultural, residential, and commercial and industrial. Each of these land-use categories can be further subdivided on the basis of factors such as crop type, residential density, or type of undeveloped land (wetland or forested, for example). However, for the purposes of this study, only four categories were used. Land use in the Red Clay Creek Basin is predominantly agricultural or rural, with successively smaller areas that are residential, undeveloped, and commercial and industrial (table 1).

The spatial distribution of the four land-use categories is shown in figure 5. Agricultural land is distributed unevenly in the basin; most agricultural land is in the northern part of the basin, where slopes are gentler than in the southern part of the basin. Crops grown in the basin include corn, hay, soybeans, wheat and other grains, and mushrooms. Most grain production is in the northern basin. Mushroom production is most active in the central and western parts of the basin. The area surrounding the Borough of Kennett Square is the largest mushroom-producing region in the nation. A few large tracts of forested land are in the northwestern and southern areas of the basin. Generally, forested land lies on isolated hilltops in northern areas of the basin and flanks the stream valleys in southern areas of the basin. Residential areas are generally centered around towns and along roads, although some developments have been built in fields that were recently part of farms. Most of the high-density residential, commercial, and industrial development is concentrated in the Borough of Kennett Square, along U.S. Route 1 in Pennsylvania, and south of Faulkland Road (State Route 34) in Delaware (pl. 1).

Sources of Contamination

Potential contaminants associated with agricultural activities include pesticides and fertilizer. The type, time, and application rate of a pesticide differs by crop and pest problem. For crops such as corn, pre-emergent herbicides, such as atrazine, are commonly applied in the late spring. Row crops commonly are fertilized with manure or synthetic nitrogen compounds. The elements nitrogen, phosphorus, and potassium are basic components of many fertilizers. Mushrooms also require nitrogen sources, commonly from chicken and horse manure, and carbon, commonly from straw and cottonseed hulls. Gypsum (calcium sulfate) is added to mushroom compost as a

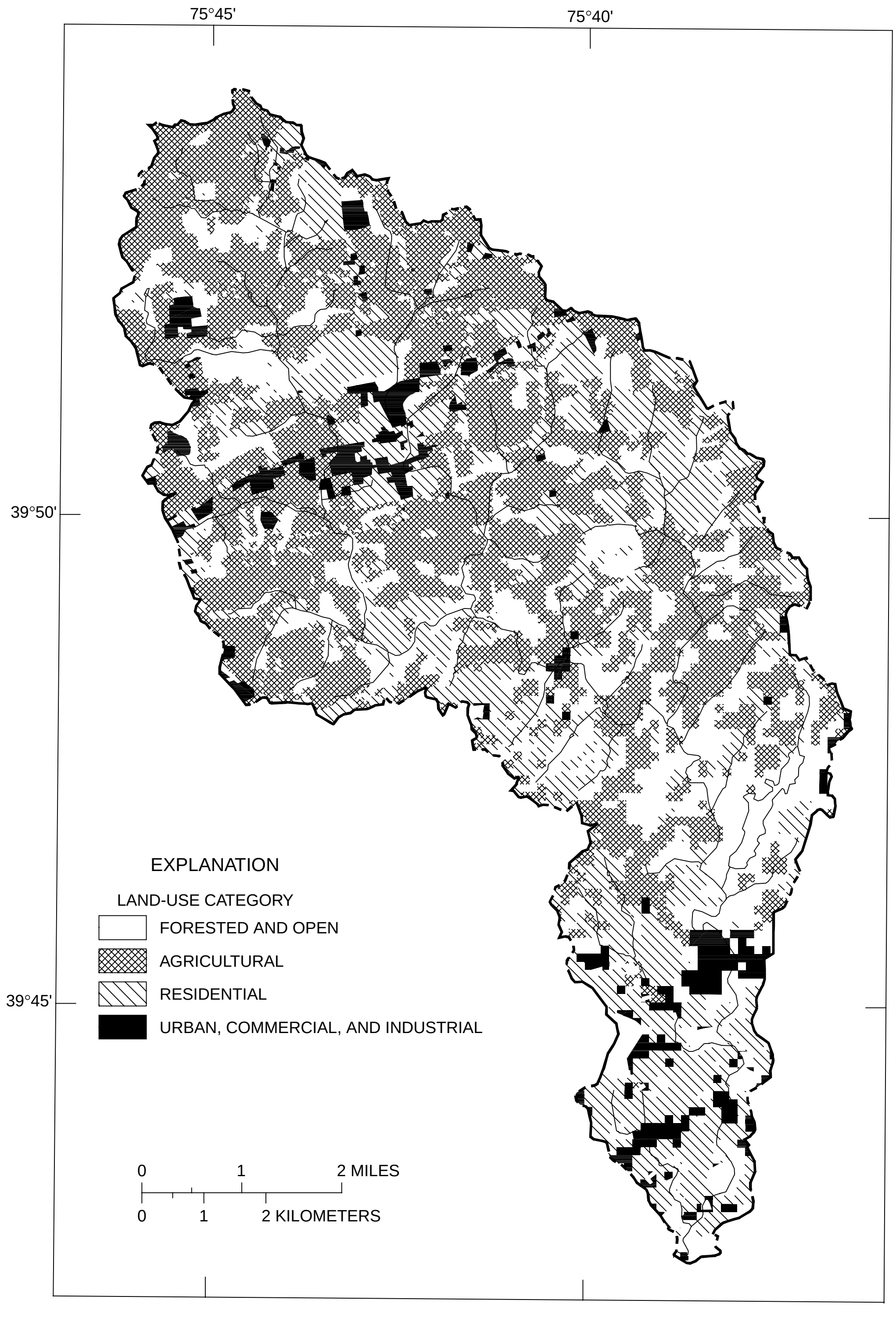


Figure 5. Land use in the Red Clay Creek Basin, Pennsylvania and Delaware.

conditioner, and salt (sodium chloride) sometimes is used as a disinfectant. Mushroom growers have applied organochlorine insecticides such as DDT, dieldrin, and lindane to control fly populations in the past and more recently have applied organophosphorus insecticides, such as malathion. Spent compost may contain all of the potential contaminants associated with mushroom houses. Because spent compost is aged for reuse or disposed of by spreading it on fields and allowing it to leach, contaminants from the compost may infiltrate to ground water.

Potential contaminants associated with residential land use include household solvents, detergents, nitrate, chloride, and bacteria in septic-tank effluent; fertilizers and pesticides from lawn care; and pesticides from termite and other insect control at or near houses. Wastewater in unsewered areas of the basin commonly is discharged to the subsurface by on-lot septic systems, a disposal method in which sorption and biochemical breakdown reactions are supposed to occur in subsurface saprolite and soil. However, subsurface processes do not remove all contaminants from septic-system effluent, which can contain nitrogen and phosphorus compounds, metals, salts, solvents, organic matter, bacteria, and viruses. Deicing salts (calcium chloride and sodium chloride) used on roads and highways in winter can also infiltrate to ground water.

Potential contaminants associated with industrial and commercial land use include solvents, metals, and benzene and other components of fuels. VOC's, such as trichloroethylene (TCE) and tetrachloroethylene (PCE) are common industrial solvents that are slightly soluble in water. TCE, PCE, trans-1,2-dichloroethylene (1,2-DCE), and 1,1,1-trichloroethane (TCA) commonly are used as degreasers in the metals, electronics, and plastics industries. TCE also has been used as a septic tank cleaner and a solvent for paints and varnishes. It has been used extensively in the dry cleaning, chemical, and pharmaceutical industries. Awareness of VOC's presence in ground water began in the late 1970's when analytical techniques became available to detect low concentrations of TCE and other organic compounds. PCE, also known as perchloroethylene, commonly is used in dry cleaning. Some industries or commercial activities use metals and generate waste that contains elevated concentrations of metals. Metals, such as copper and mercury, have been used in pesticides. Benzene, toluene, and xylene are fractional components of gasoline, diesel fuel, and fuel oil. Most compounds in gasoline and fuel oil float on water, but benzene, toluene, and xylene can dissolve to a limited degree. Benzene and toluene also are used as industrial solvents and in the manufacture of pharmaceuticals and organic chemicals. Methyltertbutylether (MTBE) is a gasoline additive and solvent that is volatile and soluble in water; MTBE has been detected in the atmosphere and has been detected in ground water as a result of leaking underground-storage tanks.

Wastewater disposal by spray irrigation has been proposed for several municipalities and sites in the Red Clay Creek Basin, and the contaminants in the wastewater may include those present in domestic (residential), industrial, and commercial wastewater. Potential effects of spray irrigation of wastewater include loading of nitrogen, chloride and others salts, metals, and other constituents of wastewater to the ground-water system.

In addition to land disposal, some wastewater in the basin is discharged after treatment to streams. Effluent discharged to streams with losing reaches can enter the ground-water system. Losing reaches on the East Branch and West Branch of Red Clay Creek were identified in the fall of 1989 (Vogel and Reif, 1993). Treated sewage effluent is discharged to the West Branch Red Clay Creek or its tributaries by the University of Pennsylvania New Bolton Center in East Marlborough Township and by the Borough of Kennett Square.

CHANGE IN LAND USE

Much of the observed and projected change in land use in the basin in Pennsylvania is from agricultural to residential and urban (Chester County Planning Commission, 1988). In the West Branch of the Red Clay Creek Basin above Kennett Square, agricultural land decreased by 14 percent and residential land increased by 11 percent from 1967 to 1987 (Hardy and others, 1995). From 1970 to 1990, agricultural land decreased by about 9 percent, residential land increased by about 6 percent, commercial and other developed land increased by about 3 percent, and forested or open land remained about the same in Pennsylvania municipalities in the basin (table 5) (Delaware Valley Regional Planning Commission, 1994). Most development in the Red Clay Creek Basin in Delaware is along the basin edges (New Castle County Department of Planning, 1994), where residential use replaced agricultural and forested land use.

The basin population in 1980 was about 39,600 (Martin Wollaston, New Castle County Water Resources Agency, oral commun., 1992; David Yaeck, Chester County Water Resources Agency, oral commun., 1991). Projected increases in population for 1980-2000 are 23 and 11 percent for the Pennsylvania and Delaware parts of the basin, respectively (Roy F. Weston, Inc., 1988, p. 2-17).

Table 5. *Change in land use in Pennsylvania municipalities in the Red Clay Creek Basin, 1970-90*

[Areas of land use given in square miles; data from Delaware Valley Regional Planning Commission (1994)]

	Total area	Open or forested			Agricultural			Residential			Industrial or commercial		
		1970	1990	Change 1970-90	1970	1990	Change 1970-90	1970	1990	Change 1970-90	1970	1990	Change 1970-90
East Marlborough Township	15.58	3.85	3.44	-0.41	10.25	8.75	-1.50	0.87	2.16	1.28	0.50	1.14	0.64
Kennett Borough	1.09	.18	.15	-.03	.13	.22	.09	.47	.35	-.12	.30	.36	.06
Kennett Township	15.60	5.05	5.15	.10	7.68	6.28	-1.40	2.03	2.84	.81	.65	1.22	.57
New Garden Township	15.92	4.02	4.33	.31	10.01	8.57	-1.44	.91	1.67	.76	.81	1.17	.36
All areas	48.19	13.1	13.07	-.03	28.07	23.82	-4.25	4.28	7.02	2.74	2.26	3.89	1.63
Percentage	100	27.2	27.1	-.06	58.2	49.4	-8.8	8.8	14.6	5.7	4.7	8.1	3.3

GROUND-WATER QUALITY

The quality of water is determined chiefly by the type and quantity of substances dissolved in it. Precipitation is the primary source of water for the ground-water and surface-water systems and contains trace and major elements that are scavenged from the atmosphere. The source of constituents in precipitation can be natural, such as sodium and chloride from the ocean, or anthropogenic, such as sulfate (in high concentrations) from burning coal. As water moves through the hydrologic cycle, it dissolves gases and mineral matter from the atmosphere, soil, and rock, and organic compounds produced by decay of plants and other biological processes. Additional substances may be added by human activities.

Ground-water composition evolves through a series of chemical interactions with minerals in the aquifer. Major and minor ions, trace metals, radionuclides, and gases in ground water are derived from interactions with soils, rocks, or the atmosphere. Mineral dissolution releases ions and other constituents into ground water and can change the pH of the water. The inorganic chemical reactions that control ground-water quality include mineral dissolution and precipitation, mineral weathering, ion adsorption and exchange, and natural radioactive decay. Most reactions are thermodynamically and(or) kinetically controlled. Some chemical reactions are biologically mediated, such as denitrification. Sources of many elements in natural waters and general and important chemical reactions governing water chemistry are summarized by Hem (1985).

Water quality may be characterized by physical properties and the concentration of dissolved and suspended constituents. One measure of water quality is the set of standards established by the U.S. Environmental Protection Agency (USEPA) for public drinking-water supplies. For privately-owned drinking water supplies, such as domestic wells, USEPA regulations are not enforceable but may be used as guidelines to assess water quality. The USEPA has established maximum contaminant levels (MCL’s) and secondary maximum contaminant levels (SMCL’s) for some constituents in drinking water (U.S. Environmental Protection Agency, 1988a, 1988b, 1996). MCL’s generally are set because elevated concentrations of these constituents may cause adverse health effects. SMCL’s generally are set for aesthetic reasons; elevated concentrations of these constituents may impart an undesirable taste or odor to water. The USEPA has classified 113 organic compounds, known as priority pollutants, as toxic or carcinogenic. These compounds are divided into four fractions by gas chromatography-mass spectroscopy analysis: (1) volatile, (2) acid, (3) base-neutral, and (4) pesticide.

Many inorganic and organic substances that are toxic (or otherwise damaging) to living organisms are also relatively insoluble, such as the metal lead, the pesticide DDT, and the industrial PCB compounds; these substances sorb onto soils, sediment, and aquifer materials. Therefore, concentrations of these substances may be limited by their solubility in ground water. Other constituents, such as chloride and nitrate, that have low to moderate toxicity but are relatively soluble, can infiltrate in recharge to the ground-water system, be transported in ground-water flow, and persist in the ground-water system.

Because atmospheric precipitation recharges the ground-water system, constituents in precipitation affect ground-water quality. The median concentration of major ions in precipitation collected near Valley Forge, Pa., about 20 mi northeast of the Red Clay Creek Basin are shown in table 6. Because of the proximity, the chemistry of precipitation at Valley Forge should be similar to that in the Red Clay Creek Basin.

Although many inorganic compounds are from natural sources, elevated concentrations in ground water of some inorganic constituents, such as chloride, in ground water and detection of industrial organic compounds are indicative of anthropogenic sources. Data on ground-water composition for the Red Clay Creek Basin, including physical and chemical properties, major and selected minor ions, trace metals, pesticides, VOC's, and radon-222 are listed at the end of the report in tables 20-25.

Table 6. *Mean annual concentration of major ions in precipitation at Valley Forge, Pennsylvania, 1982-91*

[From Lynch and others (1992)]

Constituent or property	Mean annual concentration (milligrams per liter)
Calcium	0.136
Magnesium	.063
Sodium	.187
Potassium	.033
Chloride	.386
Sulfate	2.68
Ammonium (as N)	.236
Nitrate (as N)	.395
pH	[1]4.236

[1] Median pH, in standard units.

Physical Properties and Chemical Constituents Measured in the Field

Physical properties and chemical constituents determined in the field include temperature, pH, specific conductance, alkalinity, and dissolved-oxygen concentration; these properties are unstable and are measured in the field at the time of sample collection. Data on physical properties and chemical constituents determined in the field for ground-water samples collected in 1993 from 82 wells in the basin are summarized in table 7 and given in table 20 at the end of the report.

Ground-water temperature is about equal to the regional mean annual air temperature and remains relatively constant throughout the year in the unconfined aquifers in the Piedmont. Most ground-water samples were collected during the summer and early fall when sampling equipment may be warmed by air temperatures. The median ground-water temperature of 13.5°C (56.3°F) is slightly higher than the mean annual air temperature of about 11.8°C (53.2°F) in the basin; the lowest ground-water sample temperature of 11°C (51.8°F) is similar to the mean air temperature. Generally, ground-water temperature increases with depth below about 200 ft because of the geothermal gradient.

The acidity of water is related to the concentration of hydrogen ions. The pH is the negative logarithm of measured hydrogen ion concentration or activity in water. Water with a pH of 7 is considered neutral; water with a pH less than 7 is acidic; water with a pH greater than 7 is basic. In southeastern Pennsylvania and northern Delaware, atmospheric precipitation is acidic; in this region, where emissions from combustion of fossil fuels contribute to acidity of atmospheric precipitation, the pH commonly is less than 5 (median pH 4.24, table 6). In comparison, the pH of distilled water in contact with the atmosphere is about 5.6 because of dissolution of carbon dioxide gas from the air. Many mineral-weathering reactions result in an increase in

Table 7. *Summary of physical and chemical properties, major and selected minor ion, and nutrient concentrations and radon-222 activities in ground water from 82 wells sampled July-November, 1993, Red Clay Creek Basin, Pennsylvania and Delaware*

[Number of samples = 82 except for chloride (n=81), orthophosphate (n=81), and total dissolved solids (n=78); USEPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25°C; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

Physical property or dissolved constituent	Minimum	10th percentile	Median (50th percentile)	90th percentile	Maximum	USEPA **MCL** or SMCL	Number (percentage) of samples exceeding **MCL** or SMCL
Physical or chemical property (field measurement)							
Temperature (°C)	11	13	13.5	15	17.5	--	--
Dissolved oxygen (mg/L)	<.1	.2	4.6	9.4	12.1	--	--
pH	5.7	6.0	6.5	7.8	8.7	6.5 - 8.5	41 (50)
Alkalinity (mg/L as $CaCO_3$)	5	22	47	145	258	--	--
Specific conductance (µS/cm)	43	132	216	599	1,010	--	--
Major ions							
Calcium (mg/L)	.8	9.8	20	65	150	--	--
Magnesium (mg/L)	.8	2.8	6.6	28	150	--	--
Sodium (mg/L)	1.3	4.8	7.3	15	25	--	3 (4)
Potassium (mg/L)	.1	1.3	2.7	4.5	8.7	--	--
Chloride (mg/L)	1.4	3.6	7.5	32.6	110	250	0
Fluoride (mg/L)	<.1	<.1	.1	.17	.3	2	0
Sulfate (mg/L)	.2	8.5	26	66	160	250	0
Silica (mg/L)	10	16	23	30	43	--	--
Minor ions							
Barium (µg/L)	2	6	27	89	380	**2,000**	0
Iron (µg/L)	3	10	14	1,043	7,500	300	12 (15)
Manganese (µg/L)	1	1	13.5	154	910	50	28 (34)
Strontium (µg/L)	6	49	99	234	900	--	0
Nutrients							
Ammonia (mg/L as N)	<.01	<.01	.02	.04	.12	--	--
Nitrite (mg/L as N)	<.01	<.01	.01	.03	1.90	**10**	0
Nitrate (mg/L as N)	<.05	<.05	2.45	11.7	38	**10**	**11 (13)**
Orthophosphate (mg/L as P)	<.01	<.01	.01	.04	.08	--	--
Other constituents and properties							
Radon-222 (pCi/L)	80	200	1,000	3,300	10,000	[1]**300**	**70 (85)**
Total dissolved solids[2]	30	88	236	371	656	500	2 (2)
Corrosivity index	-4.79	-2.94	-1.88	.10	.50	[3]noncorro-sive	68 (83)
Hardness	10	38	77	232	502	[4]>100	26 (32)

[1] Proposed MCL, U.S. Environmental Protection Agency (1991).

[2] Measured residue on evaporation to dryness at 180°C.

[3] Noncorrosive corresponds to Langlier index values of greater than -0.5.

[4] Guideline value of 100 mg/L hardness used by most public-water supplies (Hem, 1985, p. 159).

pH (decrease in acidity). Acidic precipitation can react aggressively with some minerals to accelerate mineral weathering. In ground-water samples collected in 1993 in the Red Clay Creek Basin, the lowest measured pH was 5.7, and the median was 6.5 (table 7), indicating that weathering reactions neutralize the acidity (increase the pH) of the infiltrating precipitation. The USEPA SMCL for pH is a range of 6.5-8.5; waters with pH out of this range may be corrosive. The measured pH was less than 6.5 in 50 percent of the ground-water samples from 82 wells in the basin, and only one sample had a measured pH greater than 8.5.

Specific conductance is a measurement of the ability of water to conduct an electric current. It is expressed in units of microsiemens per centimeter at 25°C. Specific conductance is directly related to the concentration of dissolved solids; the greater the concentration of dissolved solids, the higher the specific conductance. The specific conductance of ground water commonly is related to the relative solubility of minerals in the geologic units. Added salts, such as sodium chloride and calcium chloride, from road salt, septic systems, or other anthropogenic sources, can significantly increase the specific conductance of water. Total dissolved solids (TDS) is a measurement of the total solutes in water. TDS can be calculated from the sum of the concentrations of dissolved major ions or measured by determining the mass of residue left after evaporation (ROE). Two of the 82 ground-water samples exceeded the USEPA SMCL of 500 mg/L for TDS in drinking water (table 7) and probably have elevated TDS because of salts added to ground water by human activities.

The alkalinity of water is the capacity for solutes (bases) it contains to react with and neutralize acid and is expressed in terms of an equivalent amount of calcium carbonate ($CaCO_3$). Alkalinity is produced by dissolution of minerals or reactions that generate bicarbonate, carbonate, or other basic anions. Bicarbonate alkalinity predominates in most natural ground and surface water.

The corrosivity of water can be related to pH and alkalinity. Corrosive water can leach metals from plumbing, which can result in elevated concentrations of copper, zinc, lead, and other metals and deterioration of pipes. The Langlier index, based on the degree of saturation with respect to $CaCO_3$, is a measure of the corrosivity of water and indicates the tendency of water to corrode metal plumbing. Negative Langlier indexes indicate undersaturation and increased potential for corrosion, and positive indexes indicate supersaturation and reduced potential for corrosion (Uhlig, 1948, p. 502) Water that is saturated with respect to the mineral $CaCO_3$ is less likely to corrode metal plumbing than water undersaturated with respect to $CaCO_3$. The Langlier index is calculated from the negative logarithms (p) of alkalinity equivalents, hydrogen ion, and calcium concentrations as follows:

$$\text{Langlier Index} = pH_m - pH_s,$$

where pH_m is measured pH of water, and
pH_s is 2.1 + pCa^{2+} + pAlkalinity [for soft water at 20°C (Uhlig, 1948, p. 502)].

Hardness was not measured in the field but can be calculated from the concentrations of dissolved calcium and magnesium and commonly is reported as $CaCO_3$ (Hem, 1985, p. 158-9). Hard water (greater than 121 mg/L hardness) may form a precipitate or scale when heated whereas soft water (60 mg/L or less of hardness) may be corrosive. Ground water in the Red Clay Creek Basin ranges from soft to very hard (greater than 180 mg/L). The median hardness of 77 mg/L is moderately hard, as determined from calculated values of hardness (table 7).

The presence of dissolved oxygen in ground water can indicate rapid or recent recharge or short residence time, although oxygen may be consumed by redox reactions in the soil zone or aquifer at any time under appropriate conditions. Dissolved-oxygen concentrations in ground-water samples in the Red Clay Creek Basin ranged from near zero to 12.1 mg/L; the median concentration was 4.6 mg/L.

The saturated concentration of dissolved oxygen decreases with increases in temperature; for the range of observed ground-water temperatures, saturated dissolved-oxygen concentration is about 11.1 mg/L at 11°C, 10.5 mg/L at 13.5°C, and 9.7 mg/L at 17°C (American Public Health Association and others, 1976, p.446-7). Dissolved-oxygen concentrations exceeding 11 mg/L are supersaturated, probably because of aeration during pumping; concentrations less than 11 mg/L are undersaturated because of the consumption of oxygen by chemical reactions in the soil and aquifer. Only one sample contained dissolved oxygen in a concentration greater than 11 mg/L, and bubbles, indicating aeration or degassing, were noted during pumping. The median dissolved-oxygen concentration of 4.6 mg/L is less than that reported for some other areas in the Piedmont in southeastern Pennsylvania (Senior and Vogel, 1995; Senior and others, in press).

MAJOR IONS AND NUTRIENTS

Major ions dissolved from soil and rock make up most of the dissolved solutes naturally present in ground and surface water; the remainder comes mostly from constituents in atmospheric precipitation, human activities, or is biological in origin. The major cations (positively charged ions) include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}). The major anions (negatively charged ions) include bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}), sulfate (SO_4^{2-}), chloride (Cl^-), and fluoride (F^-). Silica (SiO_2) is a major constituent that commonly is present as undissociated silicic acid (H_4SiO_4), which is an uncharged ion below a pH of 10.

Nutrients in ground water include nitrogen and phosphorus species. The presence of elevated concentrations of nutrients in ground water generally is caused by human activities. Nutrient sources in ground water include fertilizers, storm runoff, animal wastes, and effluent from septic systems. Nitrogen is found in water principally as nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). Nitrate is the predominant species in environments in which oxygen is present. Ammonia commonly is oxidized to form nitrate and is rarely found in uncontaminated ground water in concentrations greater than about 0.5 mg/L as nitrogen (N). Nitrate can be reduced to nitrogen gas by denitrification, a reaction that consumes oxygen; denitrification may also be associated with reduction of iron compounds.

The summary of major ion concentrations found in the 82 wells sampled (table 7) shows that concentrations are much greater in ground water than in atmospheric precipitation (table 6). Ion concentrations in recharge are greater than those in precipitation because of water loss to evapotranspiration and because solutes are added to the ground water from human activities and through chemical reactions with soils and aquifer materials. In precipitation (table 6), the dominant anions are sulfate and nitrate, and the dominant cations are hydrogen (H^{+}) and ammonium (NH_4^{+}), although ion concentrations vary seasonally and by storm. Summer storms are relatively enriched in sodium and chloride from the ocean, and winter storms are relatively enriched by sulfur and nitrogen compounds from the burning of fossil fuels (Lynch and others, 1992). Atmospheric precipitation, without other anthropogenic sources, commonly is a major source of chloride and nitrogen, unlike the other major ions that are derived primarily from mineral weathering. The atmospheric contribution of chloride and nitrogen to recharge would result in ground-water concentrations of about 1 to 2 mg/L for either chloride or nitrate as N, assuming about 50 percent water loss by evapotranspiration, conservative transport of ions, and conversion of all nitrogen species to nitrate.

Most ground-water samples contain chloride in concentrations greater than estimated natural background concentrations (about 2 mg/L), although more than half the samples contain relatively low (less than 10 mg/L) concentrations of chloride (table 7). Because sodium chloride is commonly used by humans and introduced into the region in atmospheric precipitation, the concentration of chloride is related to the concentration of sodium; however, both sodium and chloride may be derived from other sources. For example, calcium chloride also is used in road salting and sodium can be leached from sodium-bearing minerals, such as albite. The relation between sodium and chloride concentrations (fig. 6) shows that both sodium and chloride must have sources other than common salt in the basin, as indicated by concentrations that do not fall on the line of equivalence.

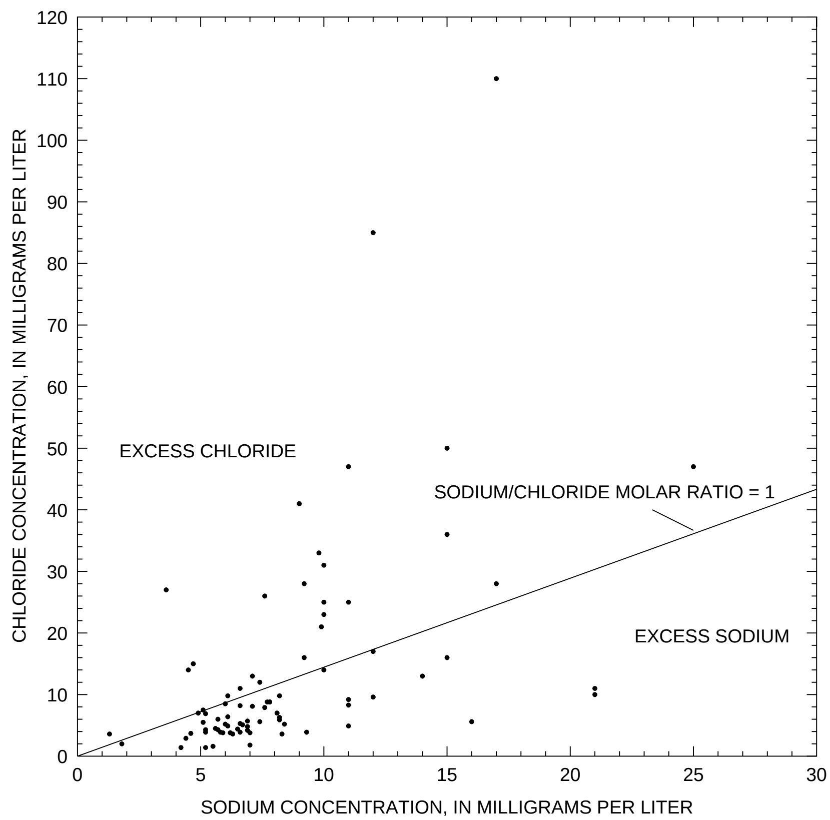


Figure 6. Relation between sodium and chloride concentrations in ground water from 82 wells sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

Nitrate is the most prevalent nitrogen species in ground water in the Red Clay Creek Basin. Only seven samples contained nitrite or ammonia in concentrations greater than 0.05 mg/L as N, and those that did had low dissolved-oxygen concentrations. The concentrations of nitrate range from less than the detection level of 0.05 mg/L as N up to 38 mg/L as N (table 7). The median concentration of nitrate for the 82 well samples was 2.45 mg/L as N (table 7). Nitrate concentrations of 3 mg/L as N in ground water or more commonly indicate human or animal sources of nitrate, as determined in a review of nitrate in ground water in the United States (Madison and Brunett, 1985); some contribution of nitrate from human or animal sources may be indicated for concentrations ranging from 0.21 to 3 mg/L as N.

About 11 percent of the 82 well-water samples in the basin contain nitrate in concentrations greater than the USEPA MCL of 10 mg/L as N (table 7). This percentage of samples containing nitrate in concentrations greater than 10 mg/L is less than the 18 percent that had been reported in the basin for data that was collected earlier without a statistically based sampling scheme (Vogel and Reif, 1993, p. 25); the earlier data may have been biased toward suspected sources of contamination but differences in the data sets may be due, in part, to expected variation in possible outcomes of the sampling design. In a survey of 1,600 private water systems (wells and springs) in Pennsylvania, 9 percent of sampled systems contained nitrate concentrations greater than 10 mg/L as N and nearly all of those that exceeded the MCL for nitrate were in the south-central and southeastern region of the state (Swistock and others, 1993).

Elevated concentrations of nitrate in ground water generally are caused by nitrogen loads from human activities. Very low nitrate concentrations (less than the detection level of 0.05 mg/L as N) in ground water do not neccessarily indicate the absence of nitrogen loads on the land surface. Nitrogen retention in soils and plants, nitrate reduction (to nitrite or ammonia), and denitrification can decrease the amount of nitrate that enters or remains in ground water. Denitrification is a process that consumes oxygen by oxidation of a carbon source (or other electron donor) and reduces nitrate, producing nitrogen gas and carbon dioxide. In the Red Clay Creek Basin, the lowest nitrate concentrations are observed in samples with low dissolved-oxygen concentrations (fig. 7), indicating that nitrate may be removed by denitrification. A few elevated concentrations of nitrate also were observed in water samples (from wells CH-3426, CH-4730, CH-770) with low dissolved-oxygen concentrations and detectable ammonia or nitrite concentrations, indicating reducing water. For example, the sample from well CH-4730 contained 1.9 mg/L nitrite as N, 24 mg/L nitrate as N, 0.70 mg/L dissolved oxygen. The sample from well CH-3426 contained 11 mg/L nitrate as N, 0.12 mg/L ammonia as N, and 0.40 mg/L dissolved oxygen. In these few samples, denitrification of the nitrate load may be limited by availability of oxygen or other electron donors, such as a carbon source or iron and manganese oxides.

Metals and Other Trace Constituents

Most metals and other trace constituents in natural ground water are leached from the soil or dissolved from the underlying bedrock in minute quantities by circulating ground water. Some metals are present in precipitation. The concentrations of trace metals and constituents in ground water are related to their abundance in soils and aquifer materials (from natural or anthropogenic sources) and to their solubility. Many metals are more soluble in acidic water than in water with neutral pH. Some metals, especially iron and manganese, are more soluble in reducing waters typically associated with low dissolved-oxygen concentrations. Copper, lead, and zinc in tap water may be leached from household plumbing systems by acidic ground water. Copper leached from pipes commonly is deposited as blue or green precipitates on plumbing fixtures.

The metals iron and manganese and the trace constituents barium and strontium are naturally present in rocks and soils in the basin and were measured in concentrations greater than MRL’s in samples from all 82 wells (table 8; table 21 at the end of the report). Concentrations of iron and manganese exceeded the USEPA SMCL’s of 300 and 50 µg/L, respectively, in samples from 15 and 34 percent of the wells, respectively (table 8). Barium concentrations did not exceed the USEPA MCL in any samples. Elevated concentrations of iron and manganese are associated with low dissolved-oxygen concentrations (reducing waters) (fig 8). In the biologically mediated

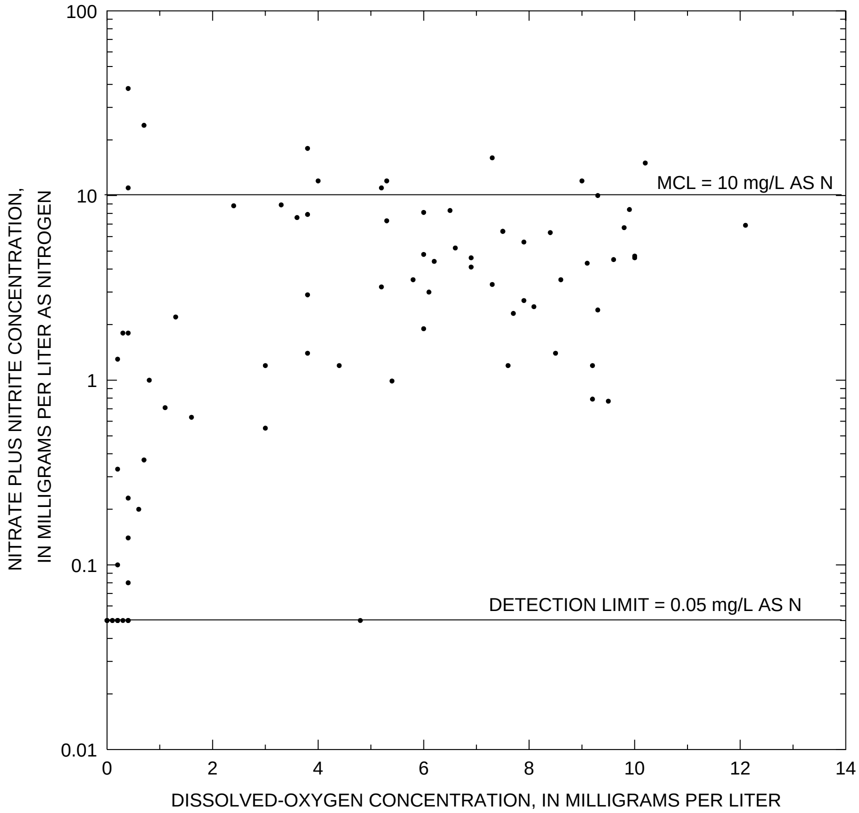


Figure 7. Relation between nitrate and dissolved-oxygen concentrations in water samples from 82 wells sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

sequence of reduction-oxidation (redox) reactions, nitrate reduction is followed by reduction of iron and manganese oxides and then sulfate (Stumm and Morgan, 1981, p. 460). Thus, elevated nitrate concentrations in ground water typically are incompatible with elevated concentrations of iron and manganese. Most concentrations of iron and manganese that exceeded the SMCL's were measured in ground-water samples with dissolved-oxygen concentrations less than 1 mg/L (fig. 8).

Of the trace metals analyzed, lithium, copper, and zinc were most frequently detected above the MRL. Lithium, an element that is naturally present in rocks and soils, is generally more soluble than some of the other metals and was detected in low concentrations (less than 20 µg/L) in about 35 percent of the samples (table 8). Copper and zinc also are naturally present as trace elements in rocks and soils. However, the presence of elevated concentrations of copper and zinc (greater than background concentrations estimated to be about 10 µg/L or less) in ground-water samples may be caused by leaching of those metals from the copper plumbing prevalent for water systems in the basin. Although wells were pumped for about 30 minutes to flush standing water from pipes, the effect of water interacting with copper pipes may not have been completely eliminated in the sampling procedure. The detectable concentrations of copper are associated with water samples that have a relatively low pH and a negative corrosivity index, indicating that waters are sufficiently aggressive to corrode the copper plumbing (fig. 9). The elevated concentrations of zinc, unlike copper, do not appear to be related to low pH or corrosivity, and may demonstrate the greater solubility of zinc compared to copper for most water types (Hem, 1985, p. 142).

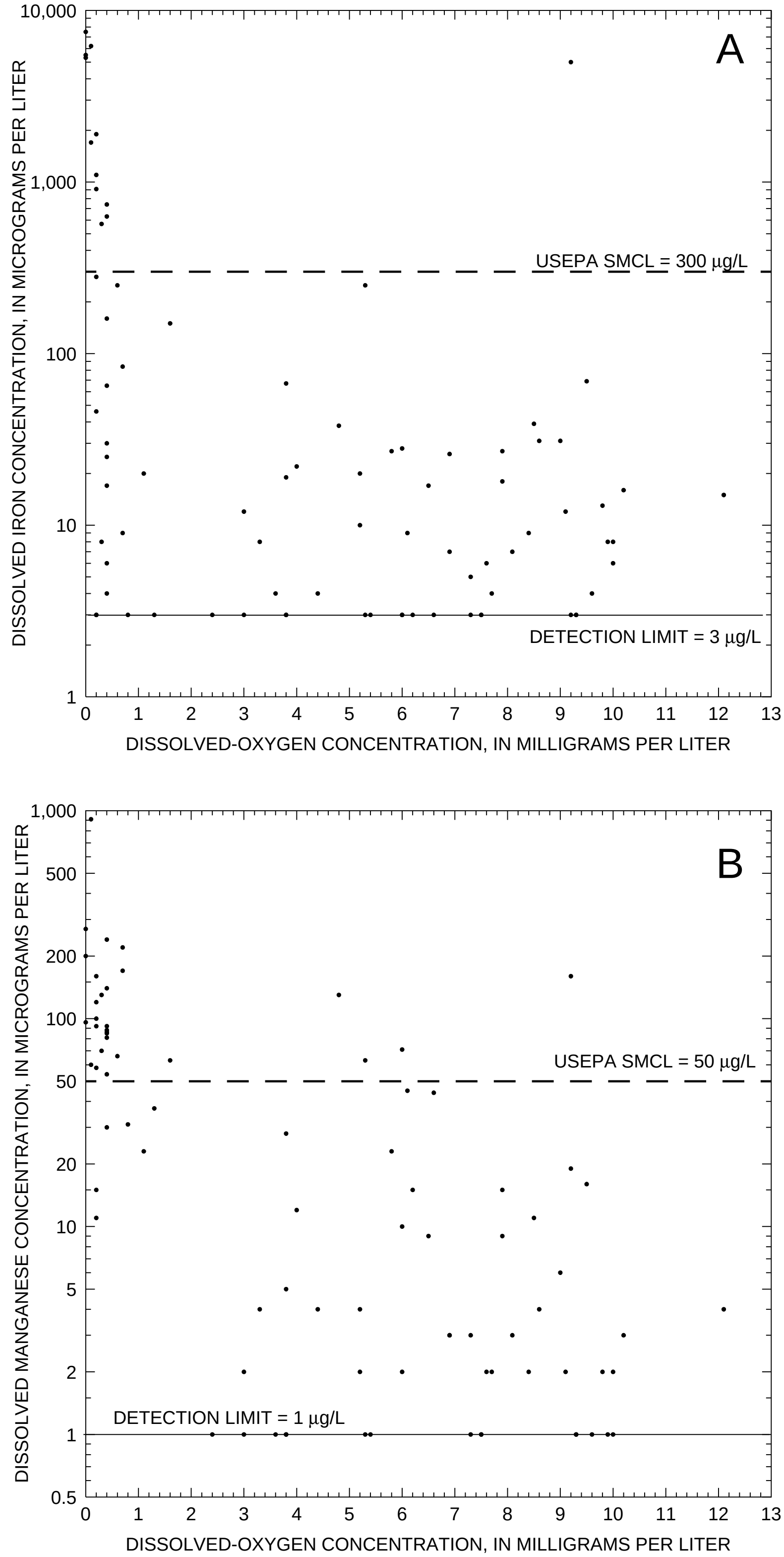


Figure 8. Relation between dissolved oxygen and (A) iron and (B) manganese concentrations in water samples from 82 wells sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

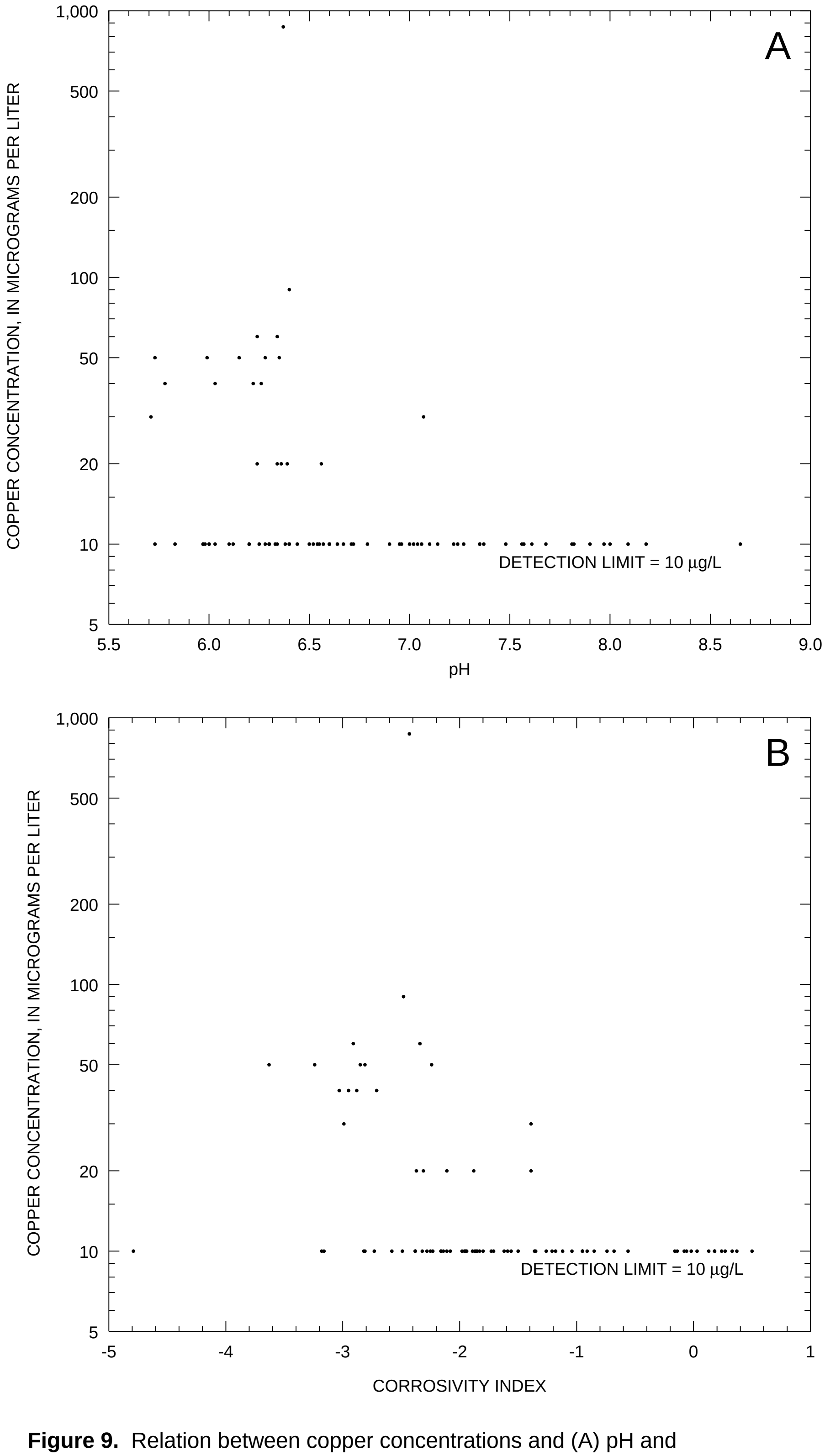


Figure 9. Relation between copper concentrations and (A) pH and (B) corrosivity in water samples from 82 wells sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

Table 8. *Summary of selected trace metal concentrations for ground-water samples from 82 wells sampled July-November, 1993, Red Clay Creek Basin, Pennsylvania and Delaware*

[Concentrations given in micrograms per liter; USEPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level]

Dissolved constituent	Minimum reporting level	Number of samples with detected concentrations	Maximum concentration detected	USEPA **MCL** or SMCL	Number (percentage) of samples exceeding **MCL** or SMCL
Beryllium	<0.5	0	--	**4**	0
Cadmium	<1	6	2	**5**	0
Chromium	<5	3	9	**100**	0
Cobalt	<3	4	20	--	--
Copper	<10	26	870	[1]**1,300**	0
Lead	<10	5	10	[1]**15**	0
Lithium	<4	28	16	--	--
Molybdenum	<10	1	10	-	--
Nickel	<10	1	50	**100**	0
Silver	<1	9	2	--	--
Vanadium	<6	0	<6	--	--
Zinc	<3	46	540	--	--

[1] Action level for water treatment or control of corrosivity.

Dissolved zinc was detected in more than half (about 56 percent) of the samples; the maximum concentration was 540 µg/L and the median concentration was 5 µg/L (median concentration greater than detection level was 12 µg/L). Lead, a metal also associated with plumbing, was detected at the MRL of 10 µg/L in samples from 5 of 82 wells and did not exceed the USEPA action level of 15 µg/L in any samples.

For other metals analyzed, concentrations in most samples were less than the MRL (tables 8, 21). Many metals and trace constituents generally do not appear to pose a wide-spread or regional water-quality problem in the Red Clay Creek Basin. The detected concentrations of cadmium, chromium, cobalt, and silver (tables 8, 21) probably represent natural background concentrations and are related to their presence in rocks and soils in the basin. Chromite (chromium oxide mineral) was mined in at least one location near Unionville, Pa., and chromite deposits associated with serpentine rocks occur elsewhere in the Piedmont Physiographic Province of Pennsylvania and Delaware (Pearre and Heyl, 1960). Nickel was detected at a concentration of 50 µg/L in a sample from only one well (CH-770) and may be related to local contamination of ground water in the area; the sample also contained elevated concentrations of nitrate, chloride, and sulfate.

Arsenic and mercury were not included in the analysis for the samples collected in 1993, but ground-water samples from 10 wells resampled in 1994 were analyzed for arsenic. In these 10 samples, arsenic was not measured in concentrations greater than the MRL of 1 µg/L (table 21, at end of report). Arsenic and mercury were analyzed by PaDEP in ground water from 13 wells sampled in 1991 in the Red Clay Creek Basin (Scott Lookingbill, written commun., 1993) and were not detected in concentrations greater than MRL's of 4 µg/L and 1 µg/L, respectively. On the basis of these data and those reported by Vogel and Reif (1993), arsenic and mercury probably are not widespread problems in the basin. The USEPA MCL is 50 µg/L for arsenic and 2 µg/L for mercury.

RADON-222 AND OTHER RADIONUCLIDES

Radon-222 is a colorless, odorless, inert, radioactive gas that is soluble in water; it also is present in air. The primary source of radon-222 is uranium-238, a radioactive isotope that is naturally present in rocks, soil, and water. Naturally occurring radioactivity in ground water is produced by the radioactive decay of isotopes in the uranium-238, uranium-235, and thorium-232 decay series. They disintegrate in steps, forming a series of radioactive nuclide “daughter” products, mostly short lived, until a stable lead isotope is produced. The uranium-238 decay series produces a substantial amount of the natural radioactivity in ground water. Daughter products in the uranium-238 series include the radioisotopes radium-226, its daughter, radon-222, and the end product, stable isotope lead-206. Both radium-226 and its daughter radon-222 emit alpha-particles during radioactive decay.

Radioactivity is the release of energy and energetic particles by changes in the structure of certain unstable elements as they break down to form more stable arrangements. Radioactive energy is released as (1) alpha radiation consisting of positively-charged helium nuclei, (2) beta radiation consisting of electrons or positrons, and (3) gamma radiation consisting of electromagnetic waves (Hem, 1985, p. 146-151). A commonly used unit for radioactivity in water is picoCuries per liter. One Curie is the activity of 1 gram of radium-226, which is equal to 3.7×10^{10} atomic disintegrations per second. Activity refers to the number of particles emitted by a radionuclide per unit of time. Activity is defined as being equal to $n \cdot \lambda$, where n is the number of atoms of the radionuclide and λ is the decay constant. The rate of radioactive decay is commonly expressed in terms of half-life, which is the amount of time elapsed for half of the original mass to decay. The decay constant, λ, is equal to the natural log of 2 divided by the half-life of the radionuclide. Thus, the activity of a radionuclide is proportional to the mass amount of the radionuclide and inversely proportional to the rate of its decay. For example, an activity of 1 pCi/L in water is equivalent to a mass concentration of 6×10^{-6} µg/L radon-222 (half-life 3.8 days); 1×10^{-3} µg/L radium-226 (half-life 1,620 years); or 3 µg/L uranium-238 (half-life 4.5×10^{9} years).

Although radionuclides occur naturally in ground water, they may pose a health problem if elevated activities are present. The USEPA has proposed an MCL of 300 pCi/L for radon-222 (U.S. Environmental Protection Agency, 1991). Activities of radon-222 in ground-water samples collected in 1993 in the Red Clay Creek Basin are summarized in table 7; complete analyses are given in table 20 at the end of the report. Measured radon-222 activities ranged from 80 to 10,000 pCi/L; the median was 1,000 pCi/L. These data are similar in values to those reported in other studies. In a compilation of the nationwide distribution of radon in ground water by county, the general range of radon activities was estimated to be 1,000-10,000 pCi/L for Chester County, Pa., and 500-1,000 pCi/L for New Castle County, Del. (Michel and Jordana, 1987. p. 231). Radon activities as high as 53,000 pCi/L have been measured by the USGS in western Chester County, Pa. The general estimated range of radon activities of 1,000-10,000 pCi/L for ground water in the Piedmont Physiographic Province is higher than in most other regions of the United States but are not as great as in some regions, such as northeastern New England, where radon activities in ground water are estimated generally to among the highest in the country (Micel and Jordana, 1987).

Radon-222 activities exceeded the proposed USEPA MCL of 300 pCi/L in ground water from 70 (85 percent) of the 82 wells sampled in the basin (table 7). The percentage of samples in the Red Clay Creek Basin that exceed 300 pCi/L is similar to that reported for Chester County as a whole (Sloto, 1994, p. 69) and the state of

Pennsylvania (Swistock and others, 1993), although the data are not strictly comparable because of differences in geologic units and sample distribution. Nearly 80 percent of wells sampled in a statewide survey in Pennsylvania contained radon activities greater than 300 pCi/L; results of the survey indicated that high radon concentrations in ground water were present in all regions of the state but most prevalent in the east-central regions (Swistock and others, 1993).

Although both radon-222 and its parent, radium-226, activities in ground water are related to the abundance and distribution of uranium and radium in aquifer materials, the magnitude of radon-222 activities in ground water does not necessarily indicate the potential for elevated activities of radium-226 or other uranium-238 series radioisotopes in ground water because radon-222 activities are largely controlled by physical phenomena, such as aquifer porosity, whereas radium-226 activities in ground water are largely controlled by the chemical environment that affects its solubility. Activities of radon-222 and its parent, radium-226, in ground water generally do not correlate.

Analyses for radium, uranium, and gross-alpha and beta activities were not performed for samples collected in 1993, but limited other data indicate that radium and uranium are present in ground water in the basin. One sample collected in 1987 was analyzed for radium, uranium, and gross-alpha and beta activities (Vogel and Reif, 1993), and 11 samples collected in 1994 were analyzed for selected radionuclides by use of gamma-ray spectroscopy (table 9). Of the radium and uranium isotopes

Table 9. *Results of radioanalysis by gamma spectroscopy for water samples from 11 wells sampled in 1994 in the Red Clay Creek Basin, Pennsylvania and Delaware*

[Units are in picoCuries per liter; --, no data]

Well number	Lithology	Date of sample	Potassium-40	Uranium-235	Uranium-238	Radium-226	Radium-228	Thorium-228
CH-3384	Felsic gneiss	7-13-94	<7.8	<1.12	<0.42	0.52	1.29	0.88
CH-3430	Felsic gneiss	7-12-94	23.8	.96	.63	1.12	3.88	1.18
CH-3482	Felsic gneiss	7-13-94	36.4	<1.40	<.58	<.64	<2.95	.98
CH-3484	Felsic gneiss	7-13-94	<9.8	<1.34	<.50	.18	1.33	<3.88
CH-3516	Cockeysville Marble	7-13-94	37.6	1.23	.49	.99	1.78	<.62
CH-4344	Setters Quartzite/Cockeysville Marble	7-7-94	29.0	<.63	.57	.48	2.39	<3.65
CH-4730	Setters Quartzite/Cockeysville Marble	7-11-94	<11.4	<1.0	.62	.53	3.13	1.22
CH-4809	Setters Quartzite	7-12-94	38.2	1.17	.72	.77	1.46	.72
CH-3445	Wissahickon Formation (south)	7-12-94	37.4	1.81	.74	.66	<.91	.67
CH-4345	Wissahickon Formation (south)	7-11-94	33.3	.94	<.68	.72	1.23	1.09
Bc42-16	Wissahickon Formation (south)	9-8-94	--	<.76	<.36	<.59	<1.32	--

analyzed in the 11 samples, the highest measured activities were for radium-228 (table 9). Radium-228 (half-life 6.7 years) is a product of the thorium-232 (half-life of 1.39×10^{10} years) decay series. The greatest concentration of uranium measured in the 11 samples was estimated to be about 3 µg/L (well CH-3445) as calculated from uranium-235 and uranium-238 activities; however, the estimate may be low because it does not include uranium-234 activity, which was not determined. The activity of uranium isotopes (table 9) can be converted to concentration, where 1 pCi/L is equivalent to about 3 µg/L for uranium-238 and 0.47 µg/L for uranium-235. None of the measured radium activities and uranium concentrations in these 12 samples (including the one in Vogel and Reif, 1993; table 9) exceeded established or proposed MCL's, although one of the samples (from well CH-3430) collected in 1994 contained combined activities of radium-226 and radium-228 that were equal to the established MCL of 5 pCi/L for combined radium-226 and radium-228 activity.

PESTICIDES

Pesticides are widely used in both rural and urban areas. Categories of pesticides include insecticides, herbicides, and fungicides. Many different pesticides are available and the number of pesticides in use continually changes as new ones are developed and old ones are abandoned. Pesticides may be banned or restricted because of toxicity-related effects on the environment or other negative health effects. Insecticides are used in agricultural areas to control crop-damaging insects and in urban areas to control household and garden insects. Herbicides are used to control weeds that compete with crops in agricultural areas and home gardens, to control broad-leaf weeds on lawns and turf, and to defoliate utility, railroad, and highway rights-of-way. In addition to direct application, some pesticides present in atmospheric precipitation are deposited on the land surface in rainfall. For example, atrazine has been measured in precipitation in southeastern Pennsylvania and northern Delaware; concentrations of 0.2 μg/L or greater were measured in 1991 (Majewski and Capel, 1995, p. 107).

In the Red Clay Creek Basin, samples collected from 39 of 82 wells in 1993 contained 1 or more pesticide(s) (tables 22-24 at the end of the report). Results of sampling in 1993 are summarized in table 10. Herbicides were detected in more samples than the organochlorine and organophosphorus pesticides. The differences in frequency of detection is due largely to differences in solubility and application rates in the basin. Many organochlorine pesticides, although persistent, have low solubility and are no longer in use, whereas herbicides like triazines have relatively greater solubility and are still in use. Few samples contained more than one type of pesticide. In samples from two wells (CH-4416, Bc25-28), both herbicide and organochlorine insecticides were detected; in samples from three wells (CH-3430, CH-4730, Bc31-10), both herbicide and organophosphorus insecticides were detected; and in a sample from one well (CH-3445), both organochlorine and organophosphorus insecticides were detected.

Organochlorine insecticides have low solubility in water, are persistent in the environment, and are strongly bioaccumulated by many organisms. The use of many organochlorine insecticides has been prohibited or restricted to limited uses by the USEPA. Analyses for organochlorine pesticides are listed in table 22 at the end of the report and include DDT, dieldrin, heptachlor, lindane, and methoxychlor, compounds that had been detected in ground-water samples during other studies in the basin (Vogel and Reif, 1993, p. 24). Four of 17 organochlorine insecticides analyzed—chlordane, dieldrin, lindane, and heptachlor expoxide—were detected in water samples from 6 of 81 wells sampled in 1993 (tables 10, 22). More than one organochlorine pesticide was detected in samples from two wells (Bc42-16, Cc11-16). Only one water sample contained concentrations of pesticide greater than a MCL; the sample from well Bc42-16 contained 3 μg/L of chlordane, a concentration that exceeds the MCL of 1 μg/L. Chlordane was used for termite control. All other detected organochlorine pesticides were measured in concentrations less than MCL's (tables 10, 22).

Table 10. *Summary of detected pesticides in ground water from 81 wells sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware*

[µg/L, micrograms per liter; MDL, method detection limit; MCL, maximum contaminant level; --, not available

Pesticide	Method detection limit (µg/L)	Number of samples with detection (but concentration less than MDL)	Range of detected concentration (µg/L)	USEPA MCL (µg/L)	Number of samples that exceed MCL
Organochlorine insecticides					
Chlordane	0.10	2	0.01 - 3	2	1
Dieldrin	.01	3	.02 - .40	--	--
Heptachlor epoxide	.01	2	.01 - .04	0.2	0
Lindane	.01	2	.01 - .04	.2	0
Organophosphorus insecticides					
Diazinon	.008	4 (1)	trace[1] - .057	--	--
Malathion	.014	5 (3)	trace - .047	--	--
Herbicides					
Alachlor	.009	2	.024-.46	2	0
Atrazine	.017	18 (9)	trace - .11	3	0
Deethylatrazine	.02	10	.028 - .25	--	--
Metolachlor	.009	20 (18)	trace -.017	--	--
Metribuzin	.012	2 (2)	trace -.011	--	--
Prometon	.008	3	.01 - .45	--	--
Simazine	.010	1	.022	4	0
Carbamate insecticides					
Carbaryl	.046	1	trace	--	--

[1] Trace refers to quantities of pesticide that were measured at concentrations less than the analytical method detection level.

Organophosphorus insecticides have been used as substitutes for the banned organochlorine insecticides because they are less persistent in the environment and more selective in their targets. Parathion was the first organophosphorus compound introduced for crop protection. Analyses of organophosphorus pesticides include diazinon, malathion, parathion, and phorate (table 23 at the end of the report), compounds that had been detected in ground-water samples from other studies (Vogel and Reif, 1993, p. 24). Two of 12 organophosphorus pesticides analyzed—diazinon and malathion—were detected in water samples from 7 of 82 wells in 1993 (tables 10, 23). More than one organophosphorus pesticide was detected in samples from two wells (CH-3445, Bc43-15). Malathion was measured at trace levels less than the method reporting limit in three of five samples where it was detected, and diazinon was measured at trace levels in one of four samples where it was detected. All detected organophosphorus pesticides were measured in concentrations less than the MCL's (table 10).

Herbicides analyzed include compounds in the triazine family of organic compounds. The triazine herbicides are mainly used for preemergence applications on corn, soybeans, and other crops for control of grassy and broadleaf weeds. Atrazine, which is sold under various commercial names, is the most widely used pesticide in Pennsylvania (Hartwig and others, 1980, p.8-9) and the United States. Herbicides analyzed for in 1993 samples are listed in table 24 at the end of the report and results are summarized in table 10. Six of 26 herbicides analyzed—alachlor, atrazine, metolachlor, metribuzin, prometon, and simazine—and one degradation product, deethylatrazine, were detected in samples from 32 of 82 wells sampled in 1993. Deethylatrazine is a microbial transformation product of atrazine (Agertved and others, 1992). Samples from 17 of 82 wells contained more than 1 herbicide, and the sample from well CH-4344 contained 5 herbicides. Atrazine and metolachlor were the most frequently detected herbicides, although many of the measured atrazine concentrations and most of the metolachlor concentrations were at trace levels (less than the method detection limit) (tables 10 and 24). In 9 of 18 samples in which atrazine was detected, deethylatrazine was also detected. All detected herbicides were measured in concentrations less than the MCL's (table 10).

VOLATILE ORGANIC COMPOUNDS

VOC's have been used extensively in industrial, commercial, and household applications for many years. The presence of VOC's and other human-made organic compounds in ground water may present a serious problem for public water suppliers, industries, and domestic well owners that rely on ground water. These compounds generally enter the ground-water system by spills, leakage from storage tanks, discharge from septic systems, and from lagoons and disposal sites. Many VOC's, including TCE and MTBE, are soluble in water. Once in the ground-water system, they are difficult to remove, and treatment generally is expensive.

Some of the organic compounds present in a water sample are degradation products of chemical and microbial transformations in the aquifer. Parsons and others (1984, p. 739-742) found that PCE degrades by reductive chlorination under aerobic conditions to TCE, and TCE degrades to cis- and trans-1,2,-dichloroethylene and vinyl chloride. Other studies have shown significant biodegradability of benzene and other VOC's (Tabak and others, 1981, p. 1514, for example). Chloroform may be formed by reactions involving chlorine-bearing compounds for chlorination (such as bleach and other disinfectants) and natural organic compounds in water (Oliver and Visser, 1980; Peters and others, 1980).

Eleven of the 29 VOC's analyzed were measured in concentrations greater than the MRL in samples from 14 wells (table 11, table 25 at end of report). Detected VOC's include chloroform, carbon tetrachloride, dichlorofluoromethane, methylene chloride, PCE, toluene, 1,1,1-TCA, TCE, xylene, and MTBE. Samples from five wells (CH-2067, CH-3210, CH-3543, CH-4345, and Cc11-16) contained more than one VOC, and the samples from the other nine wells contained only one VOC at detectable concentrations. The most frequently detected VOC's were chloroform (6 of 81 well-water samples, mostly at level of detection), MTBE (5 samples), and PCE (3 samples). Of the VOC's detected, none were measured in concentrations greater than USEPA MCL's and SMCL's. In comparison in general terms, for wells sampled by USGS from 1980-89 in Chester County, Pa., as a whole, the most frequently detected VOC's were TCE, 1,1,1-TCA, and 1,2-trans-dichloroethylene (Sloto, 1994, p. 31); however, the data sets for the county as a whole and Red Clay Creek Basin are not directly comparable because of differences in compounds analyzed, detection levels, and sampling strategies. For example, MTBE was not included in the analysis from 1980 to 1989; and most wells sampled by USGS in Chester County, Pa., are in areas where contamination was thought to be likely, whereas samples collected for this study were distributed areally and were not biased toward suspected point sources.

Although VOC's do not appear to be a widespread water-quality problem in the Red Clay Creek Basin, elevated concentrations of VOC's near point sources of contamination may pose local ground-water problems. For example, ground water from well CH-31, sampled in 1983 and 1984, contained more than 250 μg/L of PCE

(Vogel and Reif, 1993); this well is in Kennett Square at the National Vulcanized Rubber (NVF) Site, which was placed on the National Priority List (Superfund) by USEPA because of contamination.

Table 11. *Summary of detected VOC's and PCB's in ground water from 81 wells sampled July-November, 1993, Red Clay Creek Basin, Pennsylvania and Delaware*

[µg/L, micrograms per liter; MCL, maximum contaminant level; --, not available]

Compound	Method detection limit (µg/L)	Number of samples with detection	Range of detected concentration (µg/L)	USEPA MCL (µg/L)	Number of samples that exceed MCL
Carbontetrachloride	<0.2	2	0.2- 1.5	5	0
Chloroform	.2	6	.2 - 1.9	100	0
1,1-Dichloroethane	.2	1	.3	--	--
Dichlorodifluoromethane	.2	1	3.6	--	--
Methylene chloride	.2	2	.4 - .9	--	--
Tetrachloroethylene	.2	3	.4 - 2.2	5	0
Toluene	.2	2	.4 - .5	1,000	0
1,1,1-Trichloroethane	.2	3	.2 - .4	200	0
Trichloroethylene	.2	2	.2 - .5	5	0
Xylene	.2	2	.3 - .6	10,000	0
Methyltertbutylether	.2	5	.3 - 4.8	--	--
Gross PCB's	.1	1	1.0	.5	1

POLYCHLORINATED BIPHENYL AND NAPTHALENE COMPOUNDS

Polychlorinated biphenyls (PCB's) and polychlorinated napthalenes (PCN's) consist of families of organic compounds that have low solubility in water. PCB's and PCN's were manufactured for industrial use. PCB's have been used mainly as a coolant in electrical transformers, although PCB's have also been used in submersible electrical pumps (Fitzgerald, 1987). Determinations made for gross PCB's and gross PCN's include all polychlorinated compounds within each group. PCB's were detected in a sample from one well (Bc42-16) (table 11). PCN was not detected in any samples from wells in the Red Clay Creek Basin.

TEMPORAL CHANGE

The concentrations of constituents in ground water may change through time on a seasonal, short- or long-term basis. Seasonal changes can be caused by seasonal differences in recharge rates and chemical composition, land application of chemicals (common in agriculture), and microbial activity. Long-term changes or trends can result from changes in recharge rates or land use in the recharge area. Some effects on ground-water quality are apparent only after some lag time because of delayed passage through the soil and saprolite and mixing in the ground-water system.

Ten wells in the Red Clay Creek Basin were resampled in late summer 1994 to confirm the detection of some pesticides and VOC's and the concentration of some inorganic constituents, including nitrate, in the 1993 samples. Both sets of samples were collected under similar conditions at about the same time of year. Complete results of the chemical analyses of the samples are given in tables 20-25 at the end of the report. Selected results of the chemical analyses of the samples are given in table 12.

Table 12. *Results of repeat sampling and chemical analyses in 1993 and 1994 for detected pesticides and organic compounds in water samples from selected wells, Red Clay Creek Basin, Pennsylvania and Delaware*

[All concentrations are in micrograms per liter.]

Local well number	Date	Herbicide					
		Alachlor	Atrazine	De-ethylatrazine	Metolachlor	Metribuzin	Prometon
CH-3384	09-08-93	<0.009	<0.017	<0.020	<0.009	<0.012	<0.008
	07-13-94	<.009	<.017	<.005	<.009	<.012	<.008
CH-3430	08-04-93	<.009	.082	.250	<.009	<.012	<.008
	07-12-94	<.009	.100	.170	<.009	<.012	<.008
CH-3445	08-19-93	<.009	<.006	<.020	<.009	<.012	<.008
	07-12-94	<.009	<.017	<.005	<.009	<.012	<.008
CH-3482	07-27-93	<.009	<.006	<.020	.008	<.012	<.008
	07-13-94	<.009	<.017	.009	.009	<.012	<.008
CH-3484	08-03-93	<.009	.016	.100	.006	<.012	<.008
	07-13-94	<.009	.018	.096	.010	<.012	<.008
CH-3516	08-02-93	<.009	<.006	<.020	<.009	<.012	.043
	07-13-94	<.009	<.017	.003	<.009	<.012	.040
CH-4344	09-27-93	.46	.001	.028	.017	.011	<.008
	07-07-94	.52	<.017	.034	.014	.016	<.008
CH-4730	09-07-93	<.009	.002	<.020	<.009	<.012	<.008
	07-11-94	<.009	.003	.003	<.009	<.012	.013

Local well number	Date	Organochlorine insecticide and PCB's		
		Chlordane	Heptachlor epoxide	PCB's
Bc42-16	10-14-93	3.0	.04	1.0
	09-08-94	2.0	.04	1.0

Local well number	Date	Organophosphorus and carbaryl insecticides			
		Dimethoate	Malathion	Diazinon	Carbaryl
CH-3430	08-04-93	<0.024	<0.014	0.018	<0.046
	07-12-94	<.024	<.014	<.008	<.046
CH-3445	08-19-93	<.024	.047	.057	<.046
	07-12-94	<.024	<.014	<.008	<.046
CH-4730	09-07-93	<.024	<.010	<.008	<.046
	07-11-94	.035	.880	5.00	.570

The concentrations of most herbicides, organochlorine pesticides, VOC's, and PCB's were similar in the 1993 and 1994 samples, indicating persistence of the chemicals in the aquifer or source area or similar application rates from one year to the next. PCB's were detected in water from only 1 of 82 wells sampled in 1993; subsequent resampling of the well (Bc42-16) in 1994 confirmed the presence and concentration of gross PCB's in the well water (table 12). The concentrations of organophosphorus compounds differed in the 1993 samples from those in the 1994 samples. Organophosphorus compounds generally have a shorter half-life and are not as persistent as some of the other chemicals.

The concentrations of major ions, including nitrate, and activities of radon-222 were similar in most of the 1993-94 samples (table 20 at end of report). Relatively constant concentrations in ground water can result from constant loads or control by mineral solubility limits; in addition, the net variation in the rate and type of chemical reactions that occur during recharge and flow through the ground-water system may be small, at least on an annual basis. In samples from one well (CH-4730), nitrate concentrations increased by 10 mg/L as N from 1993 to 1994; such a large change in concentration may be caused by an increase in the amount of nitrogen applied on the land surface.

Two wells in the Red Clay Creek Basin were sampled quarterly to investigate seasonal differences in concentrations. In these two wells seasonal differences in the concentrations of major ions, nutrients, iron, and manganese and radon-222 activities were small (tables 20, 21). However, elsewhere in Chester County, seasonal fluctuations in the concentration of nitrate of more than 7 mg/L as N have been reported in ground water (Sloto, 1987, p. 68). In water from a well in Chester County, radon-222 activities varied by a factor of two seasonally with maximum radon-222 concentrations measured in water samples collected in the autumn when depth to water is greatest (Senior and Vogel, 1995).

RELATION OF GROUND-WATER QUALITY TO HYDROGEOLOGY

The relation between hydrogeologic factors and ground-water quality in the Red Clay Creek Basin is discussed below using results of statistical analysis to determine factors that are significantly related to observed water quality.

Lithology

The concentration of naturally occurring dissolved constituents in ground water is mostly controlled by aquifer mineralogy. Other factors related to lithology that can affect water quality include soil type, depth to bedrock, and aquifer permeability and porosity. In the Red Clay Creek Basin, the geologic formations were assigned to one of eight lithologic groups. Within each geologic formation, there are differences in composition, soil, and aquifer properties, but these differences are assumed not to obscure the differences among lithologic groups.

Many significant differences in water quality can be attributed to differences in rock type or lithology. In the carbonate rocks, magnesium and calcium carbonates (dolomite and calcite) are the most abundant minerals. Dissolution of these carbonate minerals causes an increase in concentrations of dissolved calcium, magnesium, and bicarbonate and is a reaction that provides pH buffering (near neutral pH). In the noncarbonate rocks, such as schist and gneiss, silicate minerals are the most abundant minerals. These minerals can include feldspars, micas, and quartz. Other minerals that may be present are pyrite (a sulfide), secondary iron and manganese hydroxides, and trace-element oxides. The weathering or dissolution of feldspars, micas, and other silicate minerals results in increases in silica and major cation (calcium, magnesium, sodium, or potassium) concentrations, pH, and bicarbonate alkalinity. The dissolution and oxidation of pyrite results in increases in concentrations of dissolved iron and sulfate and decreases in pH. Serpentinite consists chiefly of serpentine minerals (magnesium silicates) that, when weathered, release magnesium and silica into solution.

Mineral weathering reactions that consume hydrogen ions (H+) include

$CaCO_3 + H^+ = Ca^{2+} + HCO_3^-$	calcium carbonate dissolution
$3\ KAlSi_3O_8 + 2H^+ + 12\ H_20 = 2K^+ + KAl_3Si_3O_{10}(OH)_2 + 6H_4SiO_4$	K-feldspar to muscovite
$NaAlSi_3O_8 + H+ + 4.5\ H_20 = Na^+ + Al_2Si_2O_5(OH)_4 + 2H_4SiO_4$	albite to kaolinite
$Mg_3SiO_5(OH)_4 + 6H^+ = 3Mg^{2+} + 2H_4SiO_4 + H_2O$	serpentine dissolution

Any of these reactions could be rewritten to include reaction with carbonic acid (H_2CO_3), formed by the dissolution of carbon dioxide in the atmosphere or soil gas with water. Thus, each of the above mineral weathering reaction generates alkalinity or bicarbonate ion (HCO^{3-}). For example:

carbon dioxide and water	$CO_2 + H_20 = H_2CO_3 = HCO^{3-} + H^+$ makes carbonic acid
calcium carbonate and H^+ ion	$CaCO_3 + H^+ = Ca^{2+} + HCO^{3-}$ dissolves calcite, consumes acid
net dissolution with carbonic acid	$CaCO_3 + CO_2 + H_20 = Ca^{2+} + 2HCO^{3-}$ generates alkalinity

In the Red Clay Creek Basin, differences among ground water in eight lithologic groups were statistically significant for specific conductance; TDS; pH; alkalinity; corrosivity index; and dissolved calcium, magnesium, chloride, nitrate plus nitrite, sulfate, silica, iron, barium, lithium, copper, and radon-222. Differences among groups for most dissolved constituents, except for chloride, nitrate, and copper, are because of differences in natural sources. Of the eight lithologic groups, ground water in the Cockeysville Marble has the chemical composition that most differs from that of ground water from the other lithologic groups. However, significant differences were observed among ground water from the other noncarbonate lithologic groups as well. Median concentrations of selected ions in ground water from eight lithologic groups are given in table 13; statistically significant differences are indicated. Boxplots showing the distribution of major ion concentrations and selected other constituents that were statistically significantly different among lithologic groups are shown in figure 10.

Because the carbonate minerals in the Cockeysville Marble generally are more soluble than the minerals in the other rock types in the Red Clay Creek Basin, ground water in the Cockeysville Marble has higher concentrations of calcium, magnesium, bicarbonate, and TDS, and a higher specific conductance than ground water in the other formations. Also, ground water in the Cockeysville Marble typically contains higher concentrations of chloride, nitrate, and sulfate; lower concentrations of silica and iron; and has a higher specific conductance and pH than ground water in the other lithologic groups. The pH in the Cockeysville Marble is near neutral (median pH = 7.6) because of chemical reactions involving calcium and magnesium carbonate minerals, water, hydrogen ion concentration, and bicarbonate ions. Ground water in the Cockeysville Marble generally is non-corrosive (as measured by Langlier index) because it is near or at saturation with respect to calcium carbonate. The median sulfate concentration in the Cockeysville Marble is the highest among the eight lithologic groups. Possible natural sources of sulfate include gypsum (calcium sulfate mineral) or pyrite that has undergone oxidation. The dissolved silica and iron concentrations are lower in ground water in the Cockeysville Marble than in ground

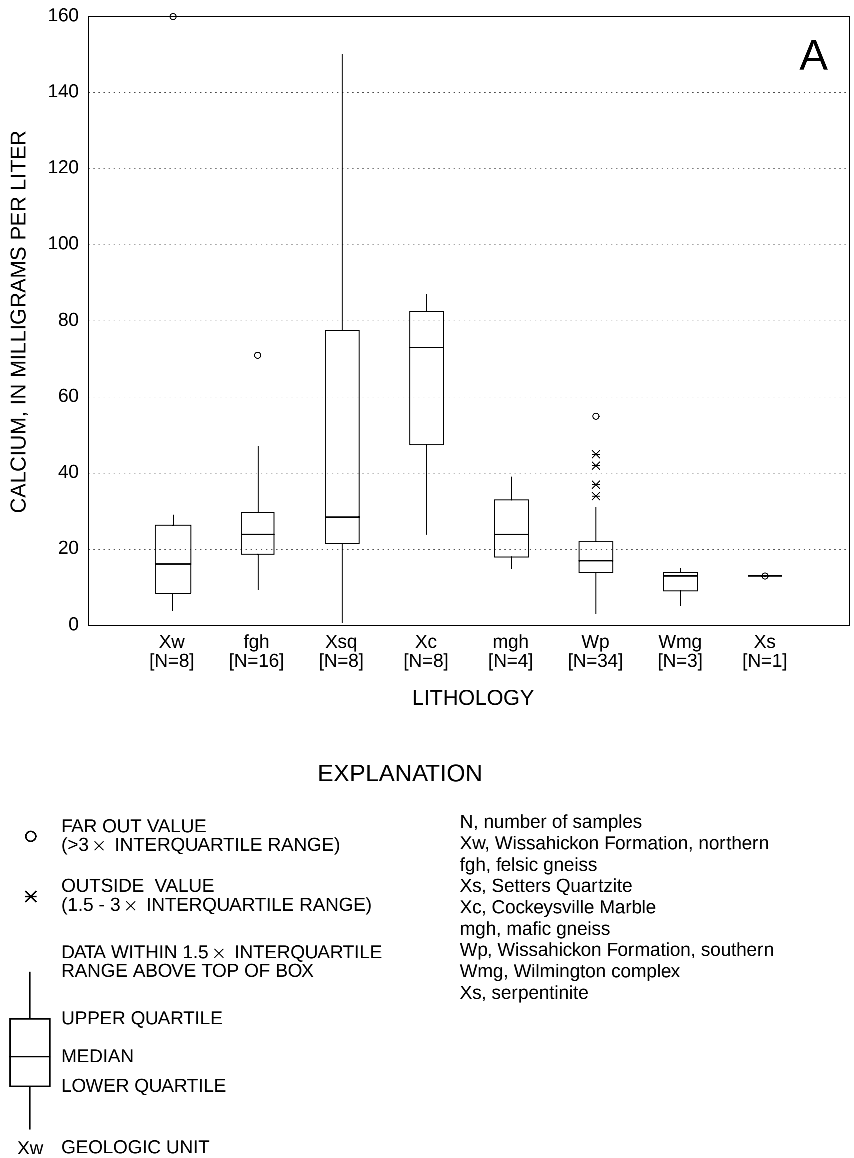
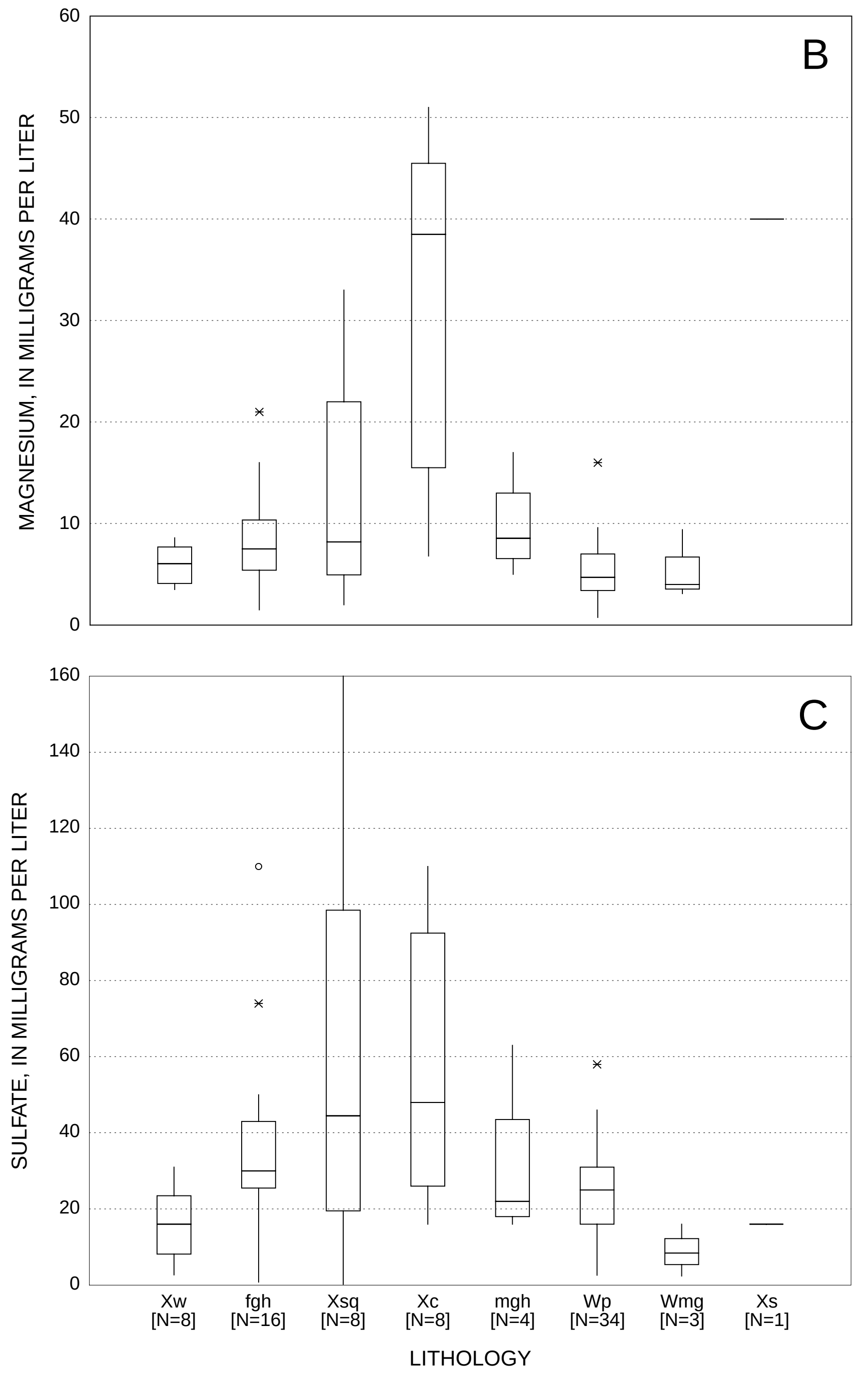


Figure 10. Distribution of (A) calcium, (B) magnesium, (C) sulfate, (D) alkalinity, (E) silica, (F) iron, and (G) total dissolved solids concentrations, (H) pH, and (I) corrosivity for ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.



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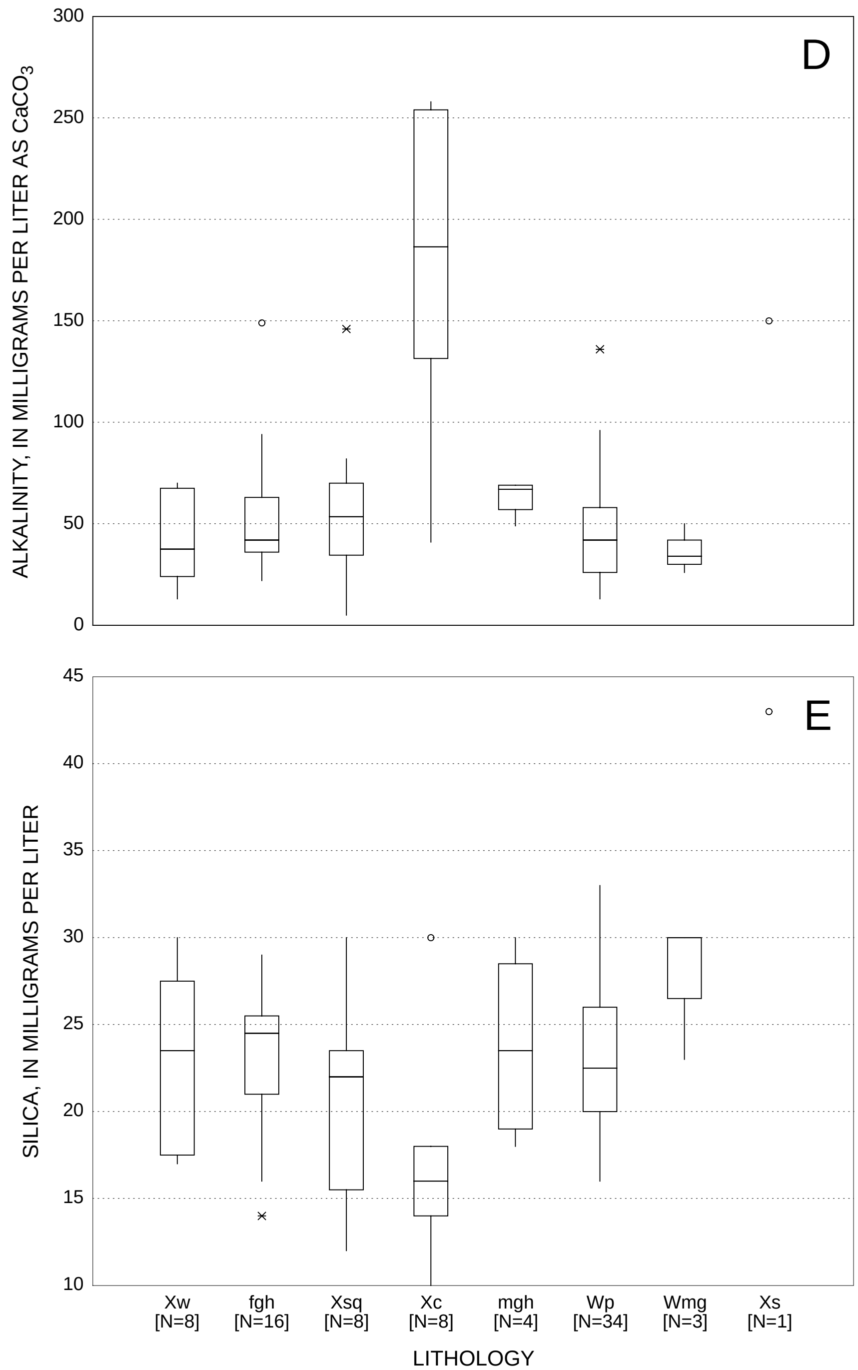

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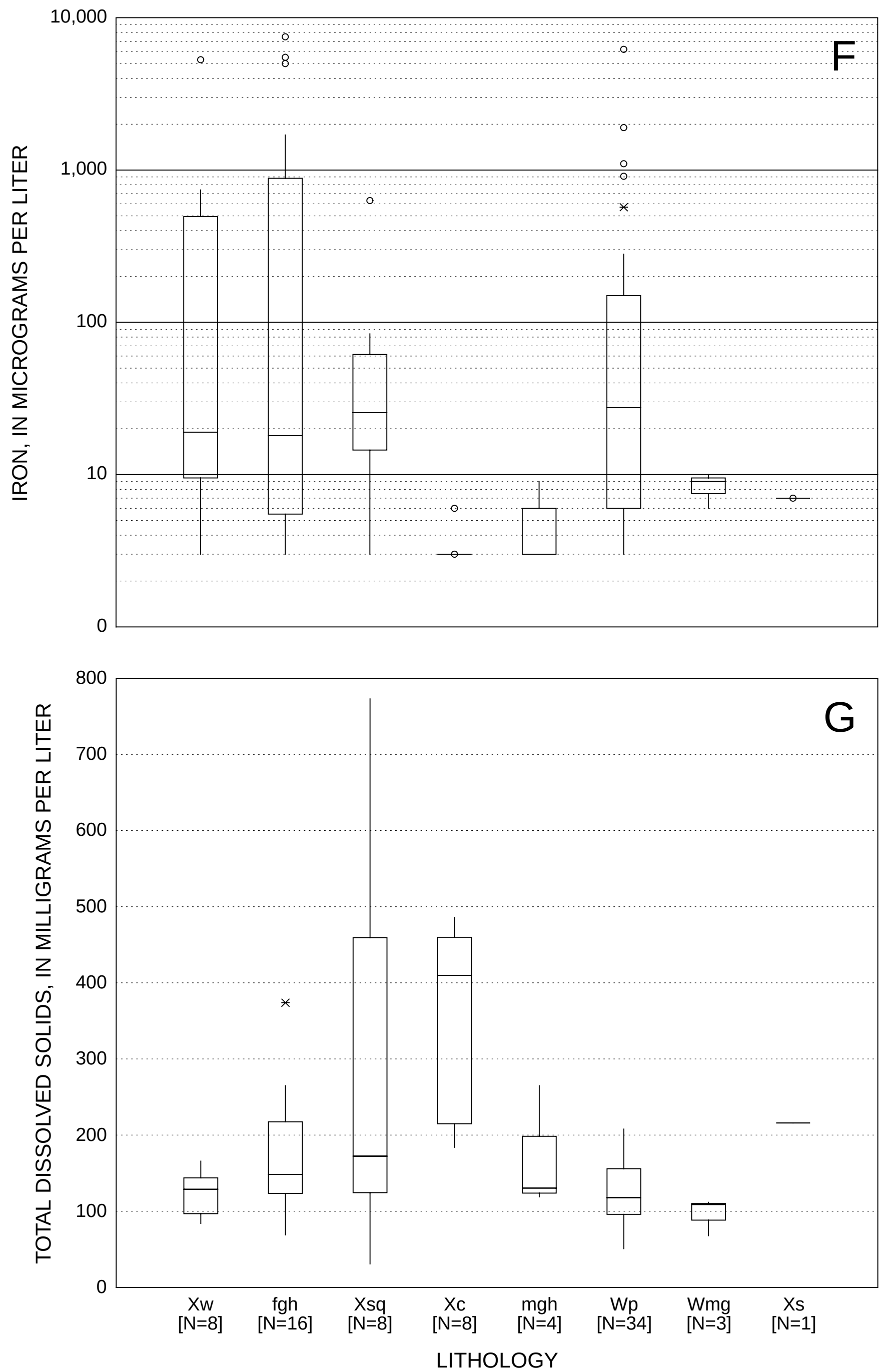

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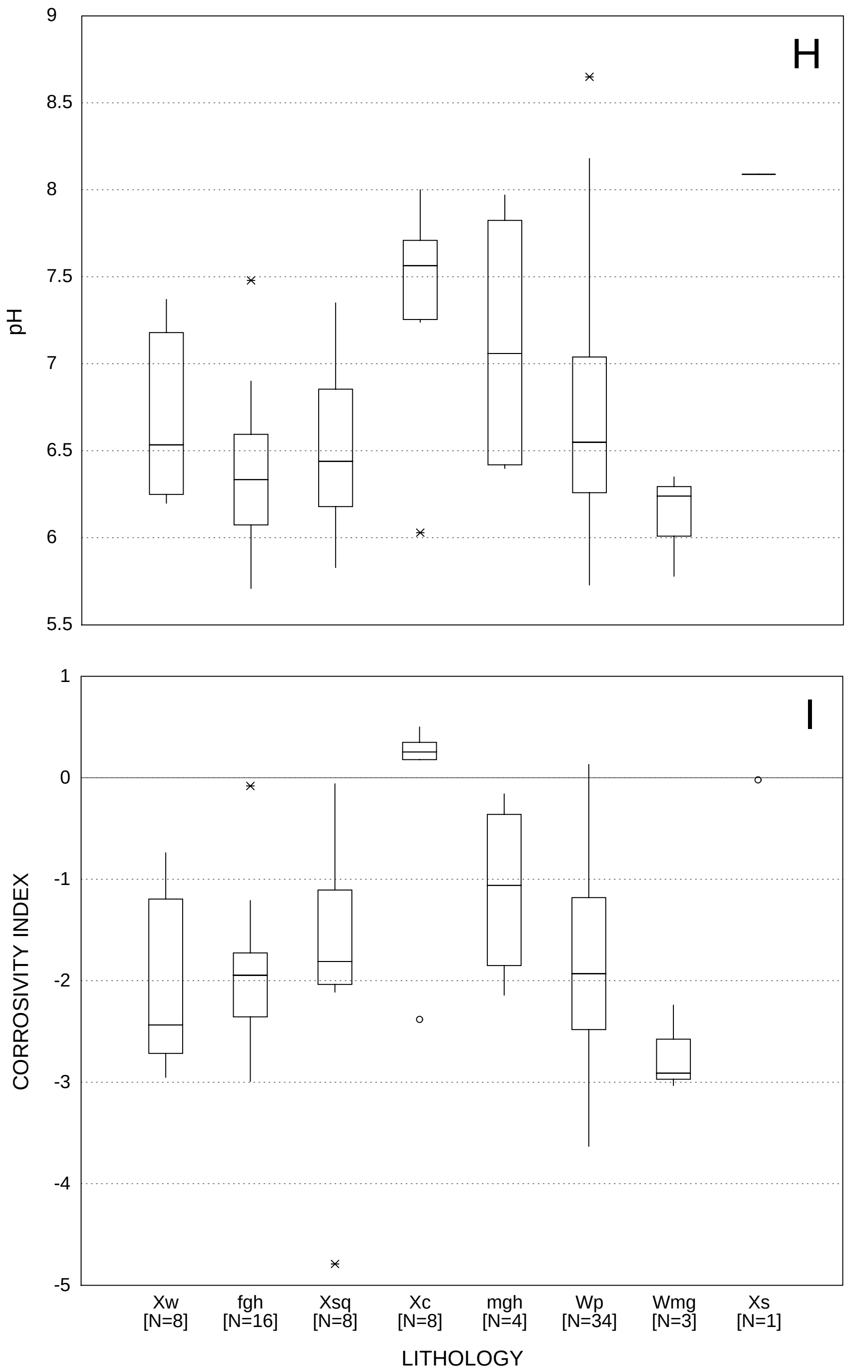

Figure 10. Distribution of (A) calcium, (B) magnesium, (C) sulfate, (D) alkalinity, (E) silica, (F) iron, and (G) total dissolved solids concentrations, (H) pH, and (I) corrosivity for ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware—Continued.

***Table 13.** Median physical and chemical properties measured in the field, selected dissolved constituent concentrations, depth to water, well yield, specific capacity, and well depth for 82 wells sampled in 1993 in 8 lithologic groups, Red Clay Creek Basin, Pennsylvania and Delaware*

[Shaded values are statistically significantly different from unshaded values for p-value <0.05; statistically significant differences in median values are indicated by degrees of shading; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picoCuries per liter; ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot]

Constituent or property	Median concentration or value for lithologic unit							
	Wissahickon Formation, north	Felsic gneiss	Setters Quartzite	Cockeysville Marble	Mafic gneiss	Wissahickon Formation, south	Wilmington complex	Serpentinite
Number of samples (n =)	8	16	8	8	4	34	3	1
pH	6.5	6.3	6.4	7.6	7.1	6.6	6.2	8.1
Specific conductance	181	248	278	640	215	181	159	358
Dissolved oxygen	3.2	4.9	6.8	3.8	7.4	3.0	7.6	8.1
Alkalinity (mg/L as $CaCO_3$)	37.5	42	53.5	186.5	67	42	34	150
Calcium (mg/L)	14.5	24	28.5	73	24	17	13	13
Magnesium (mg/L)	6.1	7.5	8.2	38.5	8.6	4.7	4.0	40
Sodium (mg/L)	8.3	7.2	9.3	8.3	6.3	7.1	6.0	1.3
Potassium (mg/L)	2.2	3.2	4.0	2.9	2.7	2.6	2.8	0.3
Chloride (mg/L)	9.5	9.0	9.1	25.5	5.3	5.7	3.7	3.6
Sulfate (mg/L)	16	30	45	48	22	25	8.4	16
Fluoride (mg/L)	.1	.1	.1	.1	.1	.1	.1	.1
Silica (mg/L)	23.5	24.5	22.0	16	23.5	22.5	30	43
Ammonia (mg/L as N)	.02	.02	.02	.02	.01	.02	.01	.01
Nitrite (mg/L as N)	.01	.01	.01	.01	.01	.01	.01	.01
Nitrate + nitrite (mg/L as N)	3.1	3.25	5.95	8.45	1.69	1.20	3.20	2.50
Phosphate (mg/L as P)	.01	.01	.015	.015	.01	.01	.03	.03
Iron (µg/L)	19	18	26	3	3	28	9	7
Manganese (µg/L)	27	16	28	1	1	30	2	3
Barium (µg/L)	16	59	72	41	18	17	26	9
Strontium (µg/L)	120	105	108	71	93	100	45	24
Zinc (µg/L)	3	7	6.5	4.5	3	3	11	30
Lithium (µg/L)	9.5	4	4	5	5.5	4	4	4
Radon-222 (pCi/L)	2,200	2,300	1,800	740	425	405	1,000	530
Depth to water (ft)	29	26	22	14	29	28	32	--
(number of samples)	(8)	(15)	(6)	(4)	(4)	(27)	(2)	(0)
Well yield (gal/min)	10	22	20	96	12.5	12.5	8	25
(number of samples)	(7)	(15)	(5)	(6)	(2)	(28)	(3)	(1)
Specific capacity [(gal/min)/ft]	.09	.31	5.21	100	.8	.2	.08	.36
(number of samples)	(1)	(10)	(2)	(2)	(1)	(12)	(1)	(1)
Well depth (ft)	225	185	160	98	155	220	100	160
(number of samples)	(8)	(16)	(7)	(8)	(3)	(32)	(3)	(1)
Casing length (ft)	67	54	60	52	37	60	33	120
(number of samples)	(6)	(15)	(6)	(6)	(2)	(26)	(1)	(1)

water in the other noncarbonate rocks partly because the Cockeysville Marble contains proportionately less silica- and iron-bearing minerals than the other aquifers, but also because iron commonly is more soluble in relatively acidic ground water, such as that in the schists and gneisses.

Although only one sample (Bc33-09) of ground water was collected in serpentinite, it is representative of the distinctive chemical composition common to ground water in that lithology; it contained relatively high concentrations of dissolved magnesium, silica, and alkalinity derived from dissolution of serpentine minerals. The pH (8.1) of the ground-water sample from the serpentinite was among the highest measured.

Generally, ground water in the noncarbonate rocks, excluding serpentinite, is more dilute, acidic, softer, and corrosive and contains more dissolved iron than ground water in the Cockeysville Marble. Ground water in the mafic gneiss generally has a higher pH and a lower concentration of dissolved iron than ground water in the other noncarbonate formations. Ground water in the Wilmington complex gneiss tends to contain higher concentration of copper than ground water from the other formations (fig. 11); higher copper concentrations may be related to the relatively low corrosivity index of ground water in the formation.

Differences in concentrations of trace elements may indicate differences in the origin or metamorphic history of the geologic formations and subsequent chemistry of ground water in those formations. Trace elements may be used as tracers of ground water from specific formations or as surrogates for other constituents that are chemically similar. The trace elements lithium and barium appear to differ in concentration in ground water by lithology in the Red Clay Creek Basin (fig 12). Lithium concentrations in ground water in the northern Wissahickon Formation are significantly greater than in ground water in other formations, including the southern Wissahickon Formation (table 13). The observed differences in lithium concentrations in two areas of outcrop of the Wissahickon Formation in the basin suggest differences in sedimentary source areas or metamorphism for these rocks.

Barium concentrations in ground water in the Setters Quartzite, felsic gneiss, and Cockeysville Marble are greater than in ground water in the other formations, presumably because of the relative barium content of aquifer materials. Barium is an alkaline earth element that is chemically similar to radium. In a study of radium and radon in the Chickies Quartzite, a quartzite in southeastern Pennsylvania that is similar in age to the Setters Quartzite, radium was found to correlate positively with barium and negatively with pH (Senior and Vogel, 1995). Elevated radium may be present in ground water where geochemical conditions favor mobility; low pH decreases adsorption of radium and other ions by silica, kaolinite (Riese, 1982), and other mineral surfaces, such as iron and manganese hydroxides. Both the felsic gneiss and Setters Quartzite have ground water that is relatively acidic. Therefore, it is possible that ground water in these formations may contain elevated radium activities. Of the 10 wells sampled in 1994, results of the gamma spectroscopy analysis indicate that activities of radium-226 and radium-228 were greatest for samples from a well drilled in the felsic gneiss and a well in the Setters Quartzite (table 9).

In the Red Clay Creek Basin, median radon-222 activities were greatest in ground water in the felsic gneiss, northern Wissahickon Formation, and Setters Quartzite and least in ground water in the Cockeysville Marble, Wilmington complex, southern Wissahickon, and mafic gneiss (fig. 13). Overall, radon-222 activities tended to decrease in ground water from north to south in the basin, which probably reflects the uranium distribution in the rocks. Radon-222 is present where its parents, uranium-238 or radium-226, are present in the aquifer. Radon-222 activities depend on radon-emanation rates, aquifer porosity and permeability, and the concentration and distribution of parent radionuclides in aquifer materials. For rocks of igneous origin, felsic rocks generally tend to contain more uranium than do mafic rocks. For

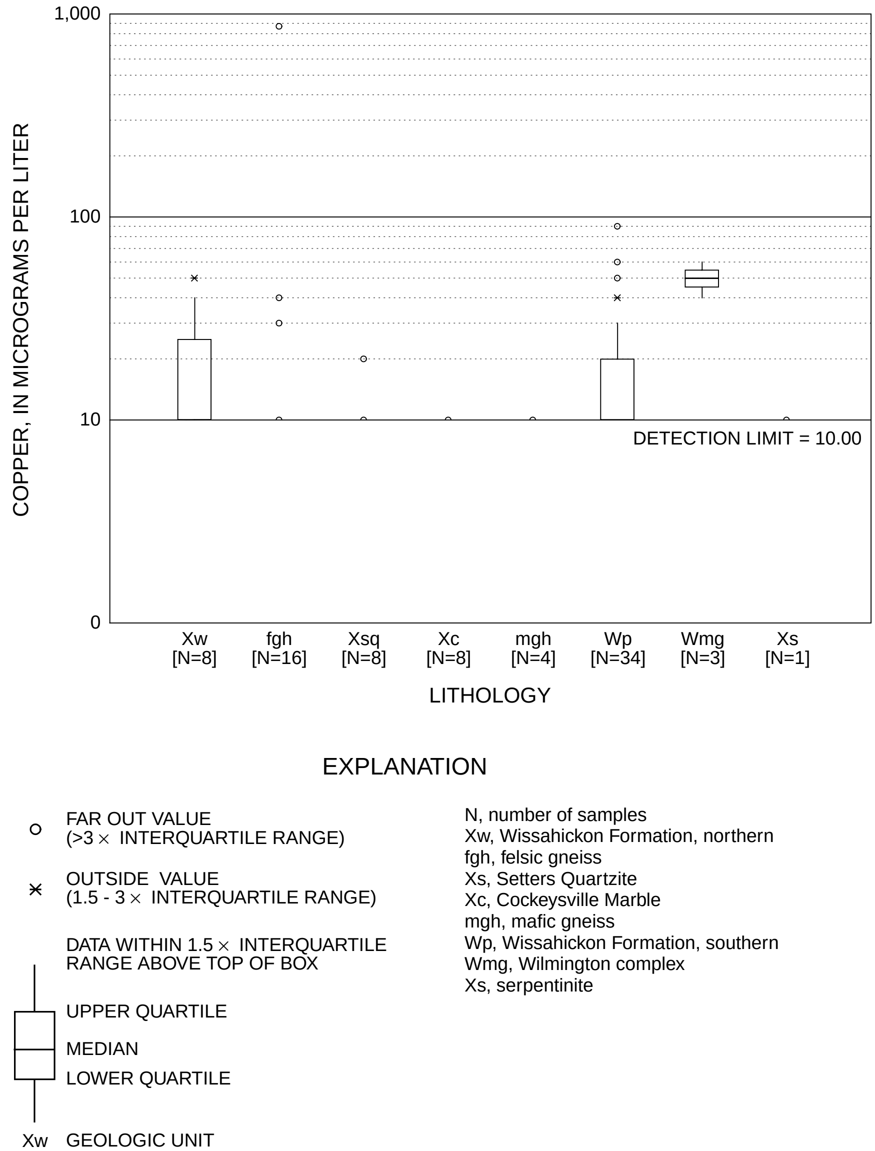

Figure 11. Distribution of copper concentrations in ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

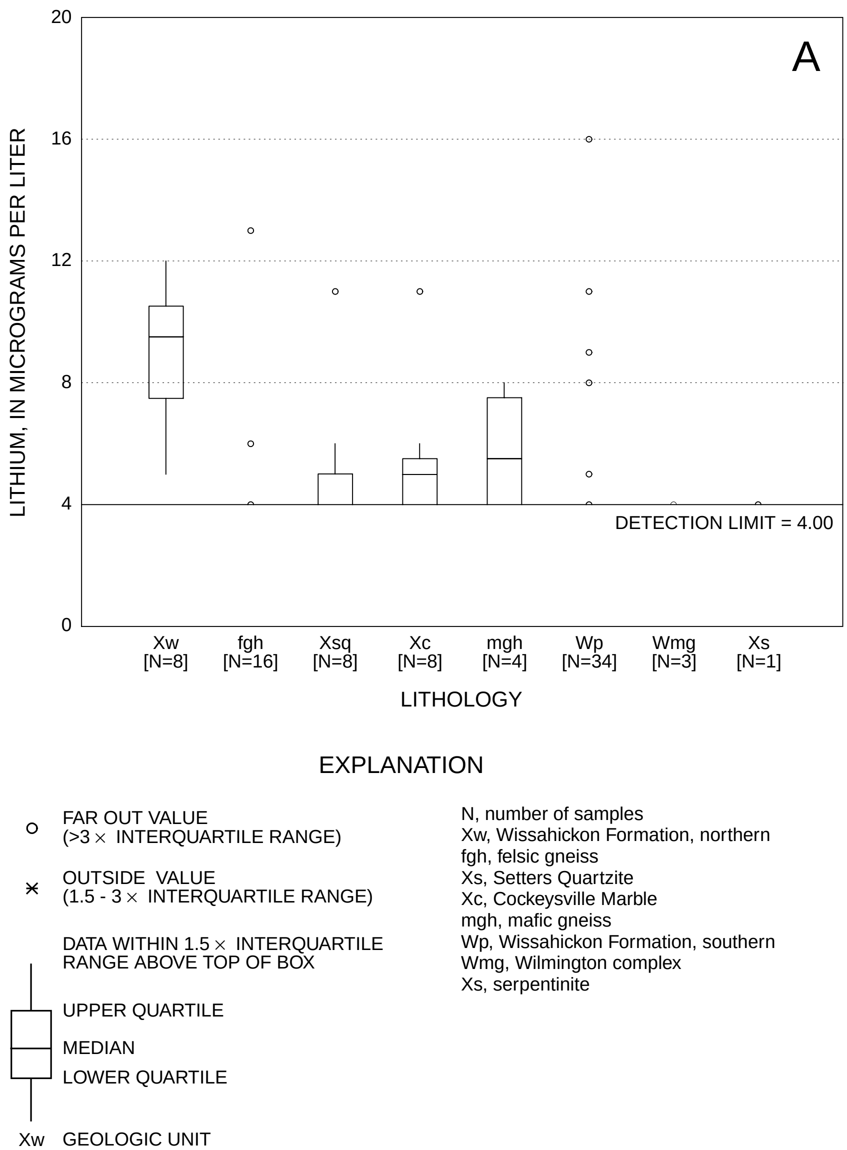

Figure 12. Distribution of (A) lithium and (B) barium concentrations in ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

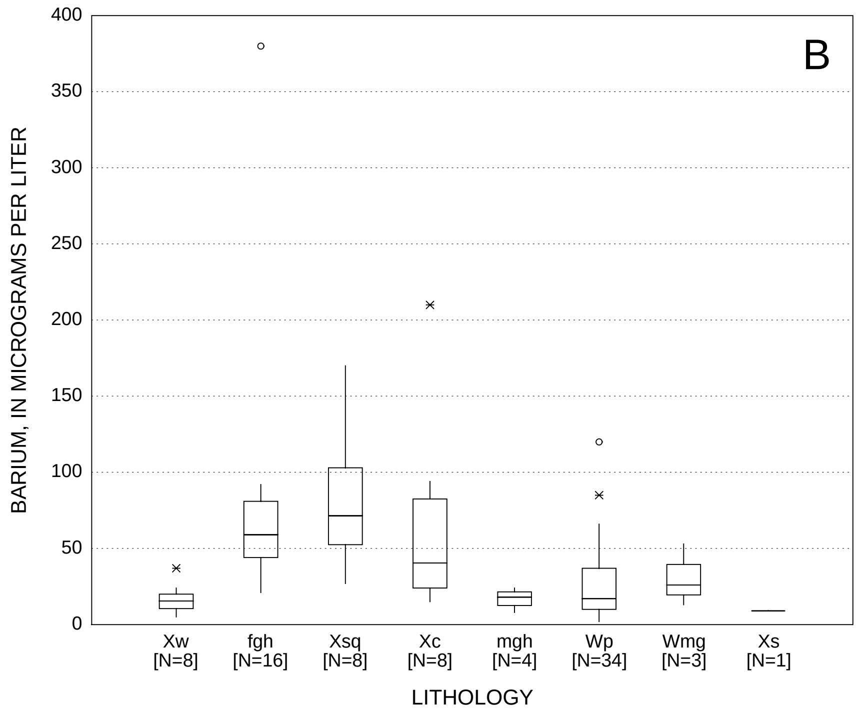

Figure 12. Distribution of (A) lithium and (B) barium concentrations in ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware—Continued.

rocks of sedimentary origin, uranium concentration varies but generally tends to be greater in shales than in limestones or sandstones. Although only one ground-water sample from the serpentinite was collected, the low radon-222 activity measured in that sample probably is indicative of low radon-222 activities in ground water from that rock type; serpentinite is derived from ultramafic rock, which typically has a low uranium content.

Concentrations of nitrate and chloride are statistically significantly greater in ground water in the Cockeysville Marble and Setters Quartzite than in ground water in the other lithologic groups (table 13; fig. 14). Because nitrate and chloride are primarily contributed from human activities associated with land uses, differences in the concentration of these constituents in ground water among the lithologies suggests differences in land uses or in the potential for contamination among the lithologies. The percentage of land underlain by the Cockeysville Marble and Setters Quartzite in combined agricultural, urban, and residential use was slightly higher than that underlain by other lithologic groups (table 2), which may account at least partly for the apparent differences in concentrations of nitrate and chloride in ground water among the eight lithologic groups.

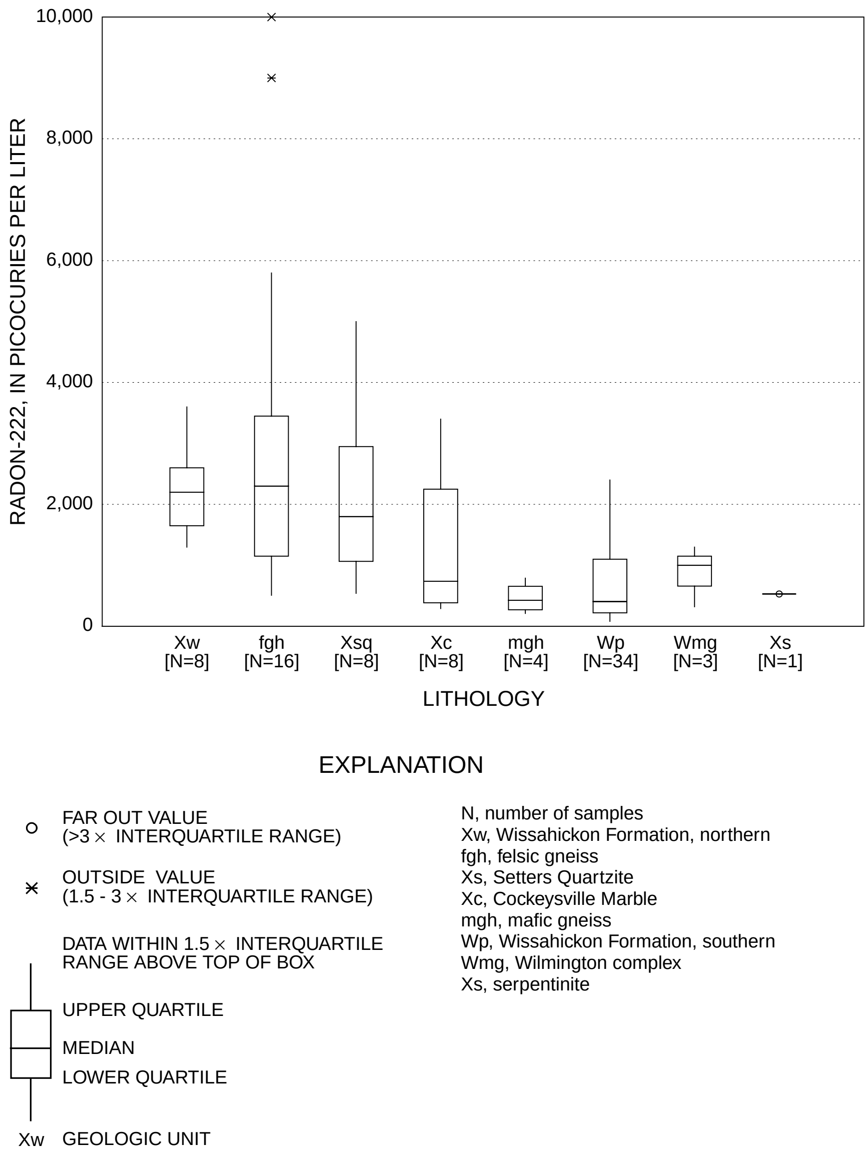

Figure 13. Distribution of radon-222 activities in ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

Ground water in aquifers with different mineralogies commonly have different characteristic chemical compositions. In addition to differences in absolute concentrations, the relative concentrations or proportion of the major cations and anions can be used to identify ground water of different types. Relative concentrations can be calculated in terms of total cation or anion milliequivalents. A milliequivalent is the charge on the ion multiplied by the quantity of millimoles. Differences in median major ion concentrations in ground-water samples from the eight lithologies are shown in a Piper diagram (fig. 15), on which the percentage relative concentration of cations and anions in milliequivalents per liter for each sample is plotted. Calcium, magnesium, and bicarbonate are the dominant ions in ground water from the Cockeysville Marble. The one sample from the serpentinite (Bc33-09) has a composition dominated by magnesium and bicarbonate ions. In ground-water samples from the other lithologic groups, ground-water compositions are not so strongly

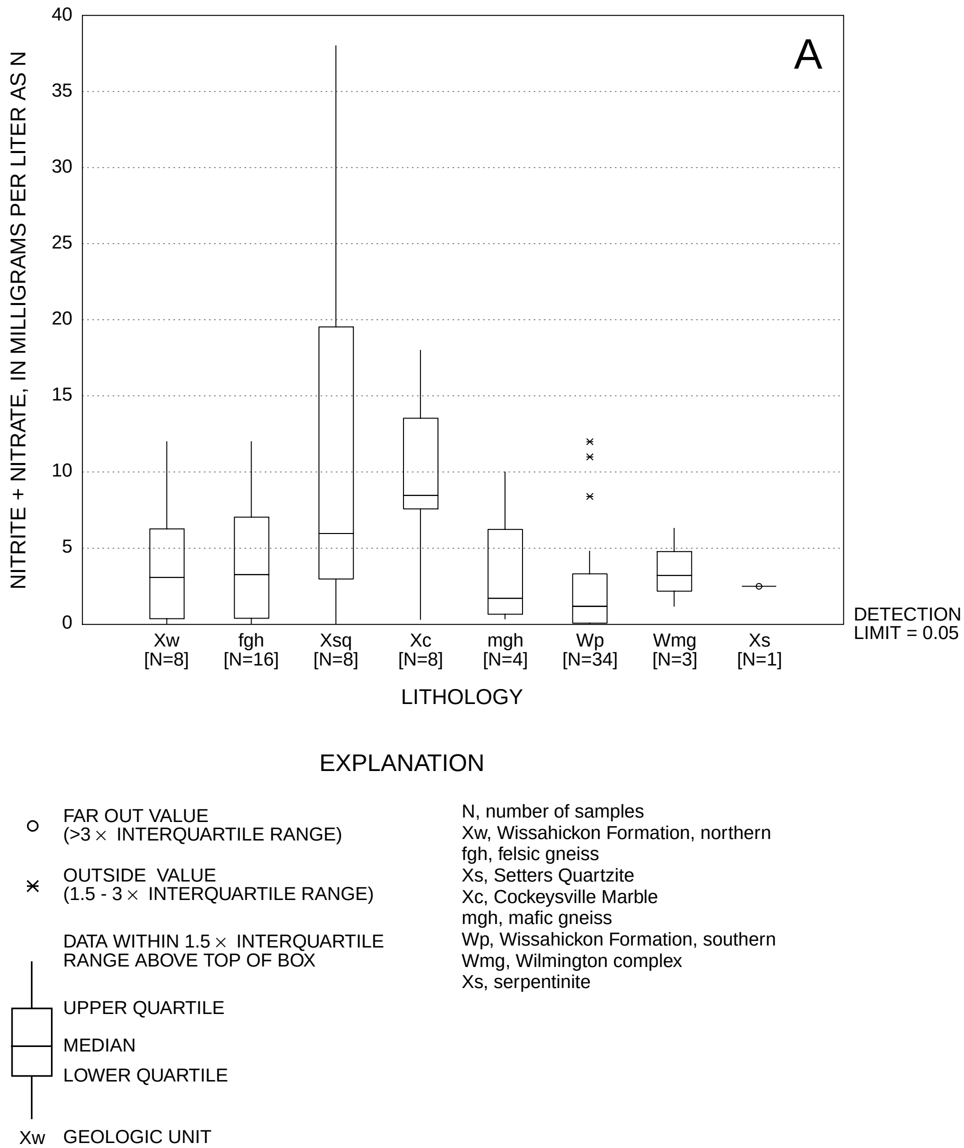

Figure 14. Distribution of (A) nitrate and (B) chloride concentrations in ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

dominated by a few ions and the milliequivalents generally are distributed more equally among the cation and anion groups, as can be seen from points that plot near the center of the Piper diagrams (fig. 15).

Depth to Water

The presence of contaminants from the land surface in ground water may be related to the depth to water in the formations. Recharge percolates through the unsaturated zone to reach the water table (which is the top of the saturated zone in an unconfined aquifer). Transport rates may be slower in the unsaturated zone than in

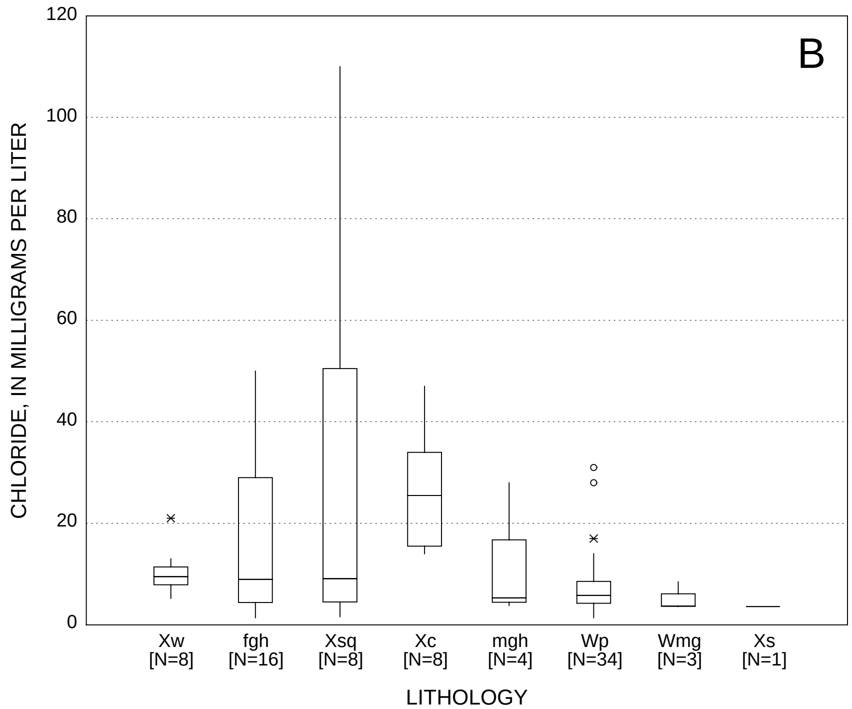

Figure 14. Distribution of (A) nitrate and (B) chloride concentrations in ground water from 82 wells in 8 lithologies, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware—Continued.

the saturated zone. Where the depth to the water table is small, ground water may be more susceptible to contamination than where that distance is great. In the Red Clay Creek Basin, depth to water ranged from about 1 to 60 ft below land surface. The median depth was 25.6 ft below land surface for 66 of 82 wells for which water levels were available in 1993. Although the median depth to water was least for the Cockeysville Marble (13 ft below land surface), differences in the median depth to water between lithologic groups were not statistically significant (as determined by nonparametric ANOVA). Depth to water correlated positively with well depth (r_s = 0.38, p-value 0.0021) and negatively with yield (r_s = -0.34, p-value 0.0095); these correlations are consistent with the observations in the Piedmont that wells on hilltops commonly are drilled deeper and have deeper water levels and lower yields than wells drilled on slopes and in valleys.

No statistically significant correlations (Spearman rho test, p-value <0.05)) were found between the depth to water and concentration of any chemical constituent, except radon-222, which correlated weakly and negatively with depth to water (r_s = -0.29, p-value 0.0201). This correlation may actually be due in part to an apparent relation between depth to water and radon-222 in a single lithologic group with a large number of samples; radon-222 does not correlate with depth to water within any lithologic group except the southern Wissahickon Formation in which radon-222 is inversely correlated with the depth to water (r_s = -0.43, p-value 0.0119, n=27). Because radon-222 is primarily controlled by the uranium distribution in aquifer materials and aquifer properties, a correlation between depth to water and radon-222 may reflect a relation between those factors in the southern Wissahickon Formation.

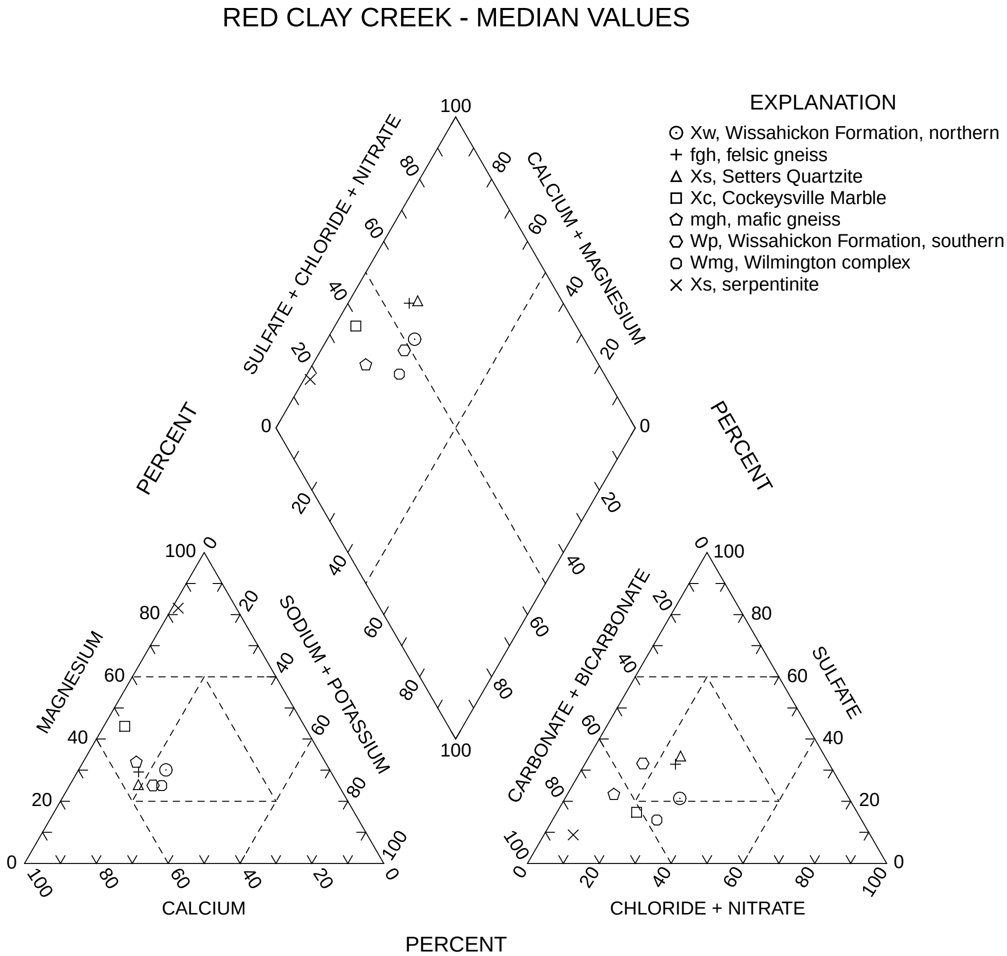

Figure 15. Relative median major ion concentrations for 8 lithologic groups in ground water from 82 wells sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

Depth to Bedrock and Well Depth

Thickness of the soils and saprolite can affect the rate and quantity of recharge from the land surface. Recharge (and water-borne contaminants from land surface) may travel more slowly through the pores in unconsolidated soils and saprolite than in the fractures of underlying bedrock. Some chemical constituents can be adsorbed on soil, clay, and mineral particles in unconsolidated material, which has greater porosity and surface area than the underlying bedrock. Therefore, contaminants from land surface may be transported into bedrock aquifers more readily in areas where bedrock is overlain by relatively thin covers of soil and saprolite than where covers are thick. Data on depth to bedrock are not available for many wells; however, the casing length can be used as a surrogate variable for depth to bedrock because casing commonly is set only a few feet into competent bedrock. For 63 of 82 wells sampled in 1993 (tables 18, 19), casing length ranged from 24 to 198 ft; the median casing length was 55 ft.

Because recharge reaches fractures in the upper part of the bedrock first and then travels through the bedrock in deeper parts of the fracture network to return to the surface as discharge, shallow fractures may be more likely to intercept contaminants from the land surface than deep fractures. However, each well may penetrate more than one fracture, and it is difficult to determine the contribution of water (and contaminants) from each fracture without isolating the fracture. Although deep wells may intersect only relatively deep water-bearing fractures, in some deep wells most water is produced from relatively shallow fractures. Well depth does necessarily indicate the fracture depth. However, for many of the wells sampled in the Red Clay Creek Basin, depth to water-bearing fractures is related to well depth (fig. 16). Well depth ranged from 50 to 575 ft; the median well depth was 175 ft for 78 wells sampled in 1993; 80 percent of the wells sampled were deeper than 80 ft but shallower than 360 ft.

Susceptibility to weathering, type of soil development, and depth of water-bearing fractures may depend on and differ by lithology. Statistical tests (nonparametric ANOVA) indicate that of the sampled wells, those drilled in the Cockeysville Marble tend to be shallower (median depth of 98 ft) than wells drilled in the other formations (medians ranging from 155 to 220 ft). No significant differences were detected between lithologic groups for casing length.

Relations between casing length and well depth and the concentration of chemical constituents were tested statistically with nonparametric Spearman rho correlations for wells sampled in 1993. Casing length and well depth correlations were statistically significant at the 95-percent confidence level with each other ($r_s = 0.40$, p-value = 0.0011) and with most of the same chemical constituents (table 14). Because casing length and well depth correlate with each other, it is difficult to determine whether one or both of those factors affect observed water quality. Negative correlations between both casing length and well depth and concentrations of dissolved oxygen and nitrate suggest that where the saprolite is thick and(or) water-bearing fractures are deep, ground water is not as rapidly recharged as where the saprolite is thin and(or) fractures are shallow. Both oxygen and nitrate can be consumed by biological and chemical processes that probably occur in the soils and saprolite. The consumption of dissolved oxygen and nitrate may result in a chemically reducing environment for iron and manganese, and thereby increase the solubility of those metals. Positive correlations between both casing length and well depth and dissolved manganese reflect a reducing geochemical environment (low oxygen and nitrate concentrations) that allows manganese reduction and dissolution.

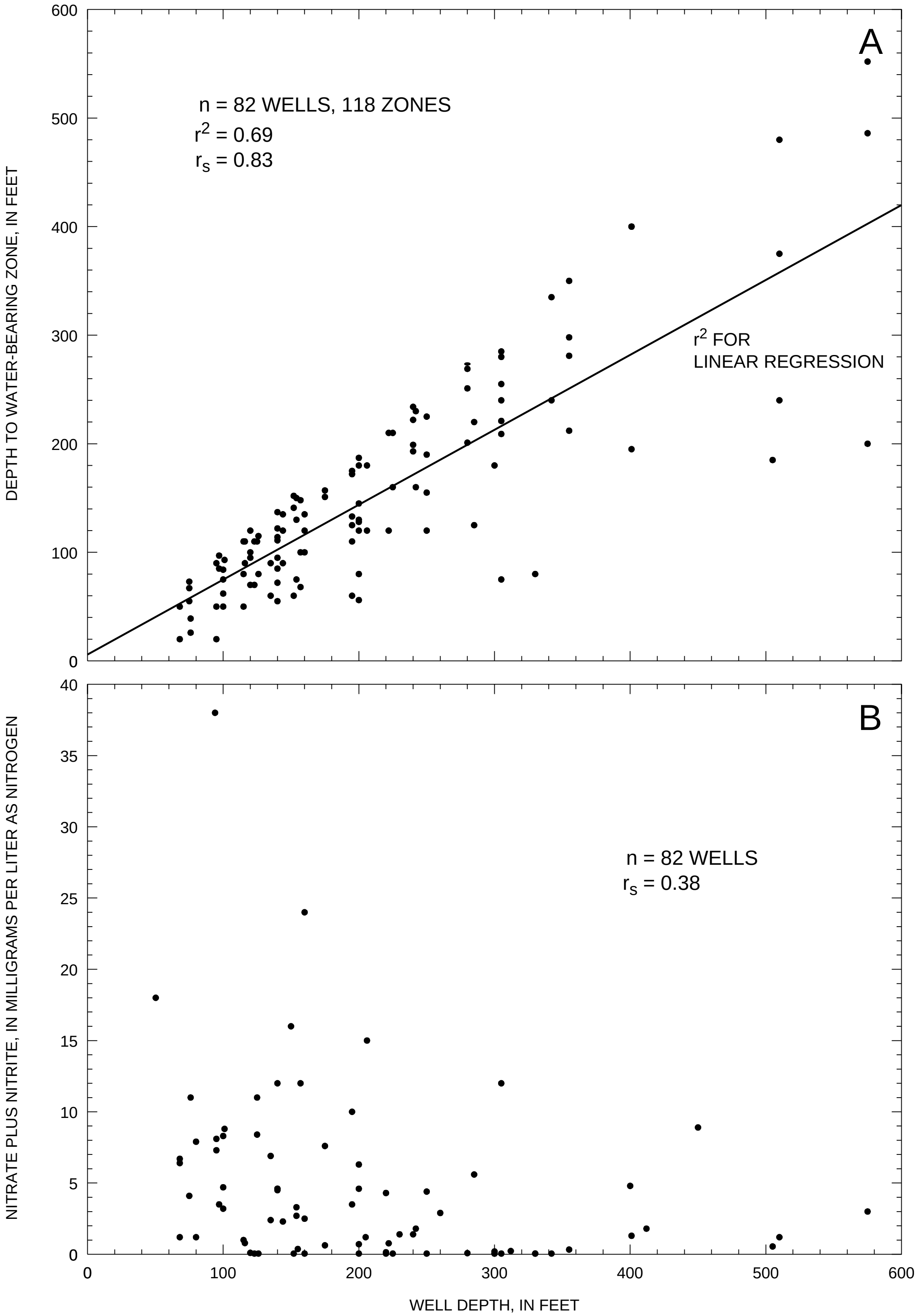

Figure 16. Relation between well depth and (a) depth of reported water-bearing zones and (b) nitrate concentrations for wells sampled in 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

Table 14. *Selected Spearman rho correlations significant at the 95-percent confidence interval between casing length, well depth, and specific capacity and concentration of chemical constituent for wells sampled July-November, 1993, Red Clay Creek Basin, Pennsylvania and Delaware*

[ft, feet; n, number of samples; (gal/min)/ft, gallons per minute per foot; r_s, Spearman rho correlation coefficient; p-value, probability of type I error; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picoCuries per liter; --, not significant at 95-percent confidence interval)

Chemical constituent	Casing length (ft) (n=63)		Well depth (ft) (n=78)		Specific capacity [(gal/min)/ft] (n=30)	
	r_s	(p-value)	r_s	(p-value)	r_s	(p-value)
Dissolved oxygen (mg/L)	-0.36	(0.0034)	-0.38	(0.007)	0.38	(0.0372)
Nitrite + nitrate (mg/L as N)	-.31	(.0133)	-.40	(.0003)	.41	(.0226)
Manganese (µg/L)	.31	(.0147)	.35	(.0018)	-.41	(.0236)
Phosphorus (mg/L as P)	--	--	-.26	(.0203)	.40	(.0266)

Specific Capacity

Specific capacity is in part dependent on the aquifer permeability. Contaminants may be transported more rapidly but are more likely to be diluted in aquifers with high permeability than low permeability. When pumping a high specific capacity well, water supplying the well may come from distances further from the well than the water that supplies a low specific capacity well. Thus, aquifer permeability can affect the rate and distance of contaminant transport in ground-water flow.

Correlations (Spearman rho test, p-value <0.05) were statistically significant between specific capacity and several chemical constituents (table 14). Among the strongest correlations, specific capacity was positively correlated with concentrations of dissolved oxygen, ammonia, nitrate, and phosphorus and negatively correlated with manganese. These correlations support the supposition that well oxygenated water carrying contaminants from the surface is transported to and in the ground-water system more rapidly in areas where aquifer permeability is relatively high than where it is relatively low.

RELATION OF GROUND-WATER QUALITY TO LAND USE

Human activities related to land use can contribute contaminants to the ground-water system. The association between current land use in the vicinity of a well and concentrations of chemical constituents in ground water was tested with nonparametric ANOVA. The association between land use and the frequency of pesticide or VOC detections in ground water was tested with the Krusal-Wallis test for ordered categorical responses (Helsel and Hirsch, 1992, p. 382-385). Samples from open or forested areas generally represent natural background ground-water quality; however, because samples were collected from domestic wells, these samples may be effected by some human activities.

Of the inorganic chemical constituents analyzed, differences in the median concentrations of nitrate, sodium, and chloride in ground water among the four land-use categories were statistically significant. Concentrations of chloride and nitrate in ground water were greater in agricultural and industrial and commercial areas than in residential and open and forested areas. Sodium concentrations in ground water were greater in agricultural areas than in industrial and commercial, residential, and open and forested areas. The distribution of nitrate, sodium, and chloride concentrations in ground water by land-use category is shown in figure 17; each of these constituents is associated with human activities. Nitrate is in fertilizers, manure and some compost, and effluent from septic systems. Sodium and chloride are in road salt and septic system effluent and may be associated with some agricultural activities; salt is sometimes used in mushroom growing operations and chloride is a component of some fertilizers.

Statistically significant differences in the concentrations of nitrate and chloride in ground water from agricultural areas compared to areas with other land uses have been determined in studies elsewhere. For example, nitrate concentrations in ground water were highest in agricultural areas and differed significantly from those in ground water in forested and urban areas in the Piedmont in Maryland (McFarland, 1994, p. 15). Hamilton and Helsel (1995) found nitrate, chloride, and other inorganic

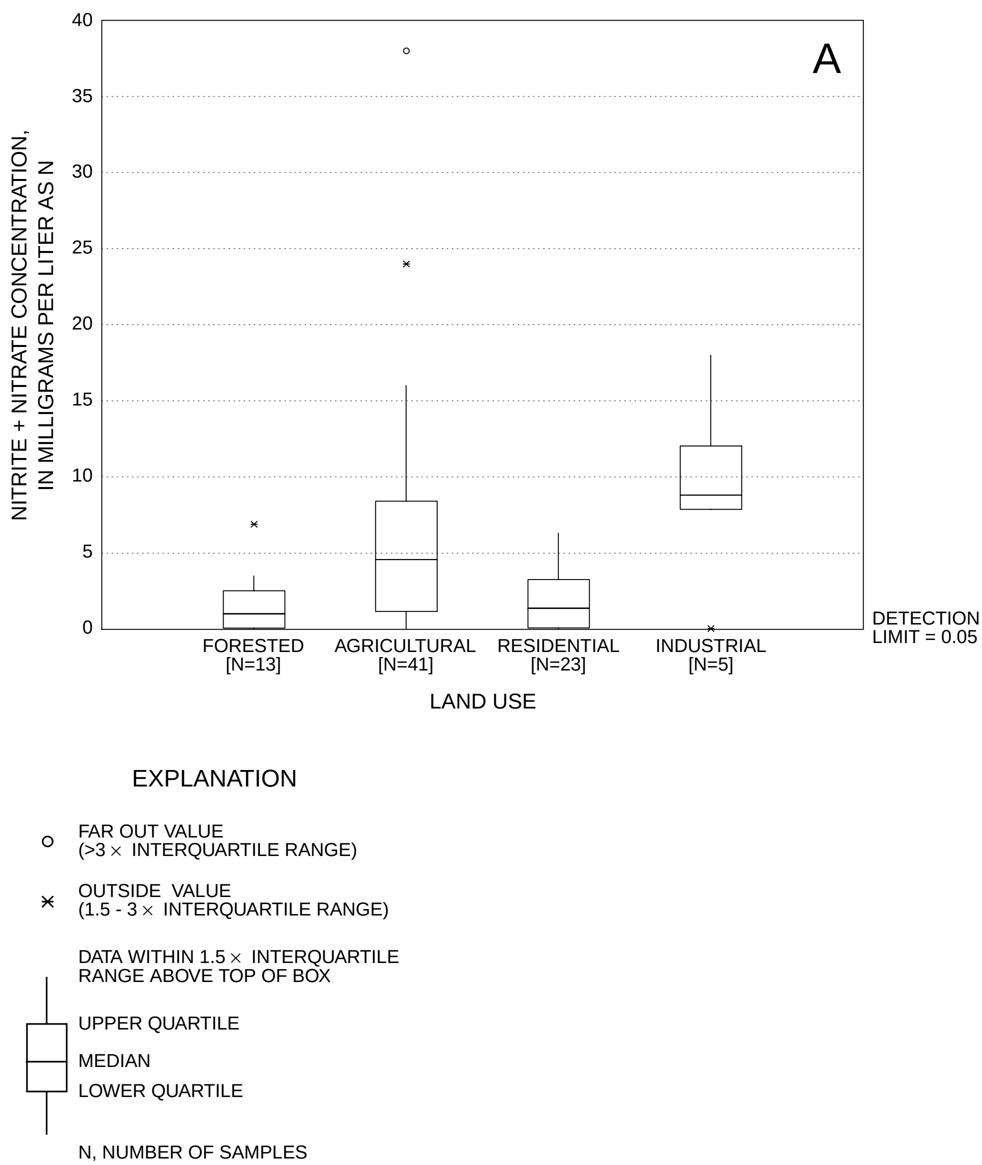

Figure 17. Distribution of (A) nitrate, (B) chloride, and (C) sodium concentrations in ground water from 82 wells in 4 land-use categories, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware.

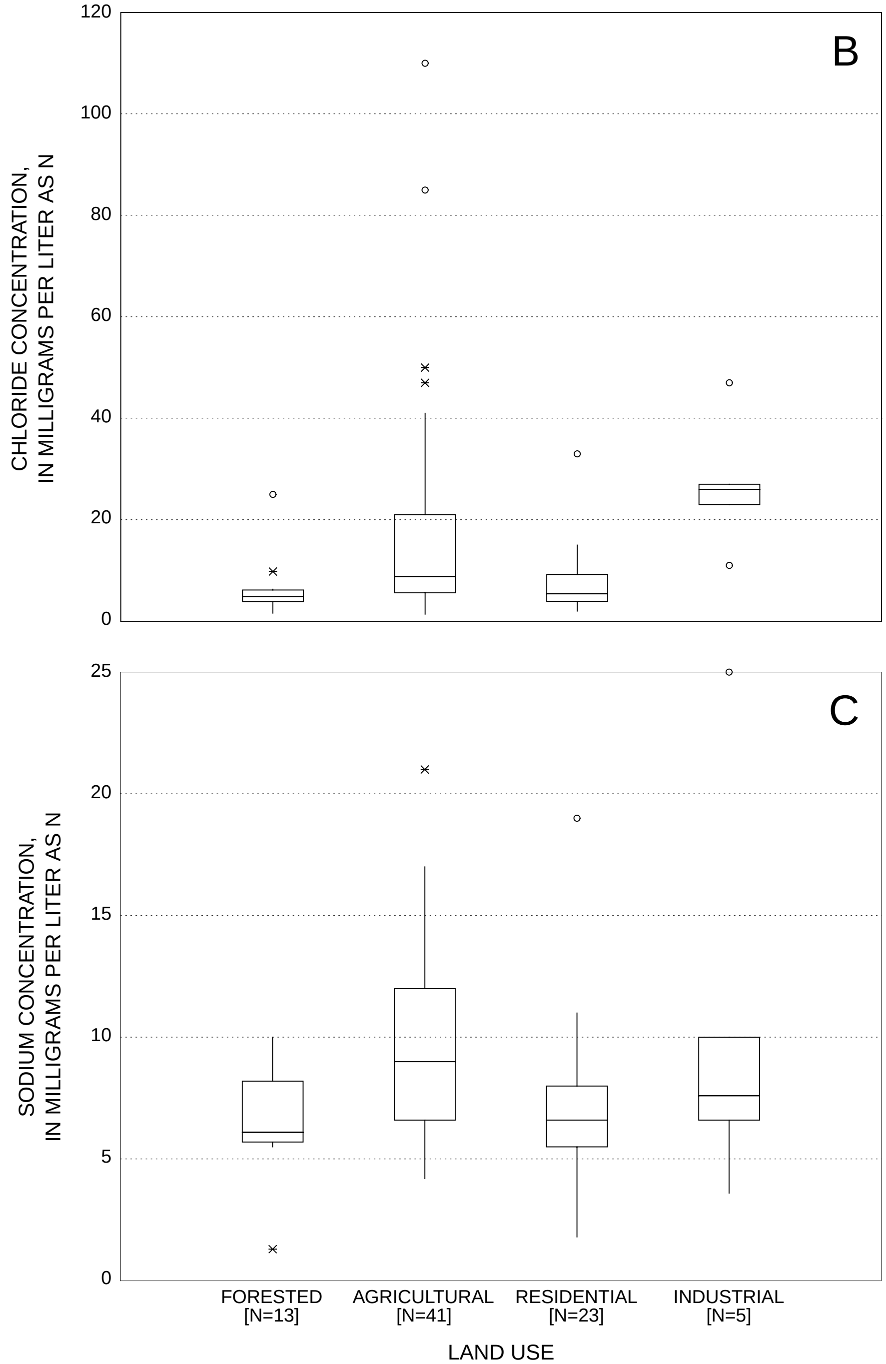

Figure 17. Distribution of (A) nitrate, (B) chloride, and (C) sodium concentrations in ground water from 82 wells in 4 land-use categories, sampled July-November 1993, Red Clay Creek Basin, Pennsylvania and Delaware—Continued.

constituents to be significantly elevated in ground water from agricultural areas in five regions of the United States; they attributed elevated chloride concentrations in ground water to the use of potash fertilizers (potassium chloride) in agricultural areas.

In recent studies of nitrate concentrations in ground water in the United States, it was found that nitrate concentrations were greatest in shallow ground water in areas with well drained soils and high nitrogen loads; in these areas the median nitrate concentration in ground water was about 5 mg/L as N and the nitrate concentration exceeded 10 mg/L as N in about 26 percent of the samples (Nolan and Ruddy, 1996). Soils in the Red Clay Creek Basin generally are well drained and nitrogen loads are highest in the agricultural areas. The median nitrate concentration of about 4.6 mg/L as N in ground-water samples from agricultural areas of the Red Clay Creek Basin (fig. 17) is very similar to that observed for other areas with well drained soils and high nitrogen loads in the United States as a whole. Nitrate concentrations were equal to or greater than 10 mg/L as N in 9 (22 percent) of 41 samples from agricultural areas in the Red Clay Creek Basin.

Most of the elevated nitrate concentrations were measured in the northern part of the basin, where agricultural land use is more prevalent than in the southern part of the basin (fig. 18). Elevated nitrate concentrations also were measured in some ground-water samples from industrial and commercial areas. Most industrial and commercial areas sampled were near Kennett Square and include land previously used for mushroom growing operations; therefore, elevated nitrate concentrations in ground water in these areas may be associated with past land use.

The concentrations of nitrate, chloride, and sodium generally were greater, although not statistically different, in ground water in residential areas than in forested areas. The denitrification process, which can occur in soils in forested areas, may partly account for the low nitrate concentrations in ground water in forested areas; however, denitrification may also occur in residential areas where organic carbon compounds also are present in septic effluent.

Of the herbicides analyzed, only the frequency of metolachlor detections differed significantly by land-use category (table 15). Metolachlor was detected more frequently in agricultural areas than in areas with other land uses. Although the frequency of atrazine and deethylatrazine detections did not appear to differ among the land-use categories, these compounds were detected more frequently in areas underlain by the Cockeysville Marble and Setters Quartzite than by other geologic units. Herbicides metolachlor and atrazine are commonly used to control weeds in corn, soybeans, and hay crops in Chester County; these compounds were most frequently detected in agricultural areas in the northern part of the Red Clay Creek Basin (fig. 18), which includes land underlain by the Cockeysville Marble and Setters Quartzite. Some reasons for the lack of statistically significant differences (determined by the Krusal-Wallis tests) in individual pesticide detections among land use categories may include (1) some land uses have changed (for example, agricultural land is being developed for residential use), which could result in a carry-over from the previous use; and (2) pesticide application in agricultural areas may result in airborne transport of pesticide to near-by areas with other land use; and (3) the small number of samples in some land-use and pesticide-detection categories. Despite the apparent lack of statistically significant differences in detections of most pesticides among land-use categories, ground-water samples from agricultural areas contained a greater number and type of pesticides than ground water from other land-use areas, especially when compared to forested areas. Some pesticides, however, have nonagricultural uses. For example, chlordane is used to control termites in and near residences and other buildings.

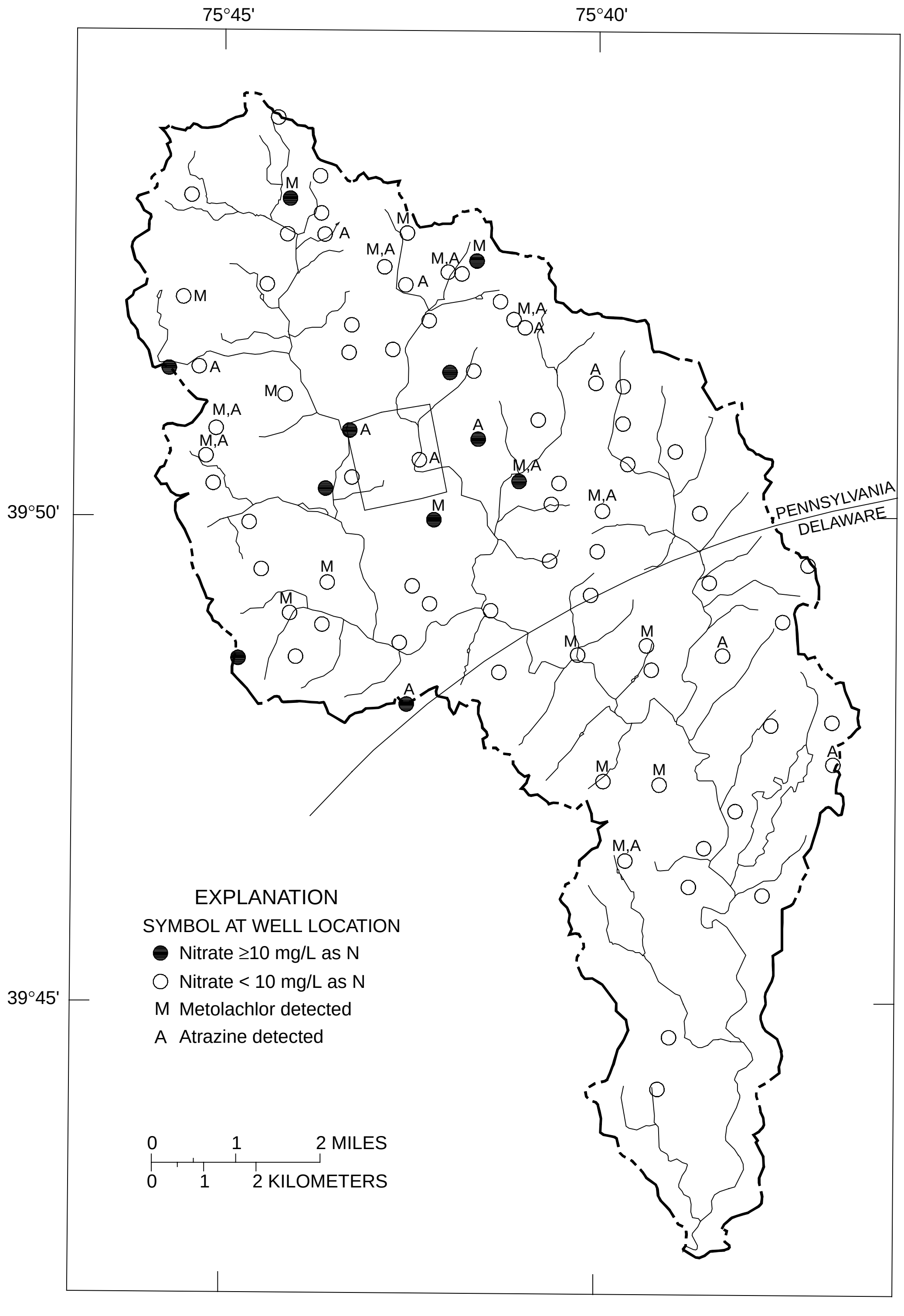

Figure 18. Location of wells yielding nitrate concentrations greater than 10 milligrams per liter as nitrogen and detectable concentrations of atrazine and metolachlor, Red Clay Creek Basin, Pennsylvania and Delaware, July-November 1993.

Table 15. *Number and percentage of well-water samples in which pesticides or volatile organic compounds were detected and land-use category for 82 wells sampled in 1993 in the Red Clay Creek Basin, Pennsylvania and Delaware*

Pesticide or volatile organic compound	Land use - number (percent) of samples with detections				
	Open/ forested (13 wells)	Agricultural (41 wells)	Residential (23 wells)	Commercial/ industrial (5 wells)	Total for all uses (82 wells)
Atrazine	1 (8)	13 (32)	3 (13)	1 (20)	18 (22)
Deethylatrazine	0	7 (17)	2 (9)	1 (20)	10 (12)
Alachlor	0	2 (5)	0	0	2 (2)
Chlordane	0	1 (2)	1 (4)	0	2 (2)
Diazinon	0	4 (10)	2 (9)	0	6 (7)
Dieldrin	0	1 (2)	2 (9)	0	3 (4)
Heptachlor epoxide	0	1 (2)	1 (4)	0	2 (2)
Lindane	0	2 (5)	0	0	2 (2)
Malathion	0	4 (10)	1 (4)	0	5 (6)
Metolachlor	2 (15)	16 (39)	2 (9)	0	20 (24)
Metribuzin	0	2 (5)	0	0	2 (2)
Prometon	0	2 (5)	0	1 (20)	3 (4)
Simazine	0	0	0	1 (20)	1 (1)
Carbon tetrachloride	0	0	2 (9)	0	2 (2)
Chloroform	0	2 (5)	3 (13)	1 (20)	6 (7)
1,1-Dichloroethane	0	0	1 (4)	0	1 (1)
Tetrachloroethylene	0	1 (2)	0	2 (40)	3 (4)
Toluene	0	0	2 (9)	0	2 (2)
1,1,1-Trichloroethane	0	2 (5)	1 (4)	0	3 (4)
Trichloroethylene	0	1 (2)	0	1 (20)	2 (2)
Xylene	0	0	2 (9)	0	2 (2)
MTBE	1 (8)	1 (2)	1 (4)	2 (40)	5 (6)

Of the VOC’s analyzed, only the detection of PCE differed significantly among the land-use categories; PCE was most frequently detected in commercial and industrial areas. The total number of VOC detections was small, which may limit the ability to distinguish between groups. The relative order of the frequency of VOC detection is, by land-use category: greatest in ground water in industrial and commercial areas; residential; agricultural; and least in forested areas. This distribution of VOC detections is related to the use of those compounds. In a recent assessment of ground-water quality in the Lower Susquehanna River Basin in Pennsylvania and Maryland to the west of the basin, low concentrations (less than 3 µg/L) of VOC’s were detected in about 30 percent of wells in rural areas, but higher concentrations were detected in up to 80 percent of wells in urban areas (Daly and Lindsey, 1996). Chloroform, the most frequently detected VOC in the Red Clay Creek Basin, may be generated when water wells are chlorinated for disinfection purposes or when chlorine is introduced into the ground-water system by septic systems. Septic system discharge also may be the source of VOC’s detected in ground water in the residential and agricultural areas of the basin.

RELATION OF GROUND-WATER QUALITY TO SURFACE-WATER QUALITY

Ground-water discharge to streams is the source of base flow. Solutes in the ground water can be transported to streams in ground-water discharge, and the composition of base flow reflects the mixture of ground water that discharges to the streams. However, the chemistry of the water entering the streams from the ground-water system can be altered by chemical processes in the interface between ground water and surface water. Chemical processes active in this interface may include plant uptake of nutrients, bacterial decomposition, adsorption, oxidation and reduction, and precipitation.

The relation between the composition of ground water and surface water in the Red Clay Creek Basin can be seen by examining (1) the control of aquifer mineralogy on ground-water and surface-water composition, and (2) the concentrations of anthropogenic solutes that are transported relatively conservatively in ground water, such as chloride and nitrate. Conservative solutes are chemically stable and not readily sorbed or precipitated, and therefore tend to remain in solution. Alkalinity is relatively conservative and is generated primarily by mineral weathering; for example, alkalinity in ground water in the Cockeysville Marble (high) differs from ground water in the Wissahickon Formation (moderate to low). Chloride, once in the ground-water system, is not readily adsorbed, precipitated, or altered chemically. Nitrate in ground water can be transported conservatively unless reduced by chemical or bacterial processes to less soluble nitrogen forms, such as ammonia, or denitrified to nitrogen gas. In the near-stream interface between ground water and surface water, however, nitrate, unlike chloride, is more likely to be taken up by plants or altered chemically. Dissolved constituents other than chloride or nitrate in ground water also may be discharged to streams. For example, the herbicides atrazine, promotone, prometryne, propazine, and simazine have been detected in base flow in nearby Lancaster County, Pa. (Lietman and others, 1983, p. 31-32).

The concentration of conservative solutes in base flow is a volume-weighted average of the concentrations in ground water that discharges to the stream. Alkalinity and the concentrations of chloride and nitrate in base flow have been measured by the USGS in autumn at two sites on the Red Clay Creek since 1972; one site (station number 01479680) is on the West Branch Red Clay Creek at Kennett Square and the other (station number 01479800) is on the East Branch Red Clay Creek near Five Point (pl. 1). The drainage areas above these sites include several different lithologies and land uses. Assuming that the ground-water samples collected in 1993 in the Red Clay Creek Basin are distributed evenly in the discharge area above each stream-sampling site, the average concentration in ground-water samples is an estimate of the volume-weighted average concentration in base flow. The results of the 1993 and 1994 surface-water analyses at the two stream sites (U.S. Geological Survey, 1994-95) and ground-water analyses for the drainage area above the sites are shown in table 16. Both alkalinity and the concentration of chloride, calculated by averaging ground-water concentrations, is similar to that observed in base flow at the two sites. The concentration of nitrate, calculated by averaging ground-water concentrations, however, is about 2 to 3 mg/L as N greater than the concentration observed in base flow. Chemical processes in the stream or near the interface between surface water and ground water may account for the apparent loss of nitrate in base flow. In addition, the relation between ground-water and surface-water composition is affected by the traveltime for solutes generated by mineral weathering or applied on the land surface in the basin to reach the stream. For example, if traveltimes are on the order of 1 year or less, then nitrate reaching the ground water in a recharge area will discharge to the stream within 1 year. Nevertheless, the data indicate that base-flow concentrations of chloride and nitrate can at least be estimated from ground-water concentrations of those constituents.

Table 16. *Concentrations of nitrate, chloride, sulfate, and alkalinity in ground water from wells sampled summer-autumn 1993 in drainage areas above sites and in surface water (base flow) sampled autumn 1993 and 1994 at sites on the West Branch Red Clay Creek near Kennett Square and East Branch Red Clay Creek, Pennsylvania*

[mg/L, milligrams per liter; N, nitrogen; $CaCO_3$, calcium carbonate]

Stream site or well number	Date of sample	Nitrate (mg/L as N)	Chloride (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L as $CaCO_3$)
Ground water - wells in drainage area above West Branch Red Clay Creek at Kennett Square					
CH-3506	07-08-93	5.6	8.8	7.7	67
CH-3504	07-20-93	4.4	7.0	2.7	26
CH-4414	08-04-93	12.0	13	8.6	20
CH-4343	09-23-93	<.05	5.2	17	33
CH-4410	07-21-93	.08	9.2	31	42
CH-3383	09-08-93	.71	9.8	28	70
CH-2513	08-03-93	4.6	8.2	14	54
CH-3495	07-22-93	.08	1.4	.8	43
CH-3516	08-02-93	16.0	41	46	250
CH-2067	08-02-93	7.6	12	33	149
CH-3543	09-01-93	4.1	33	29	22
CH-3482	07-27-93	3.5	25	26	47
CH-3484	08-03-93	8.3	47	31	27
CH-3532	11-16-93	8.9	50	110	64
CH-2593	09-09-93	15	16	67	33
CH-3533	11-22-93	6.7	7.0	25	36
CH-4552	08-30-93	7.9	26	50	212
CH-3488	09-09-93	<.05	11	30	51
CH-71	08-30-93	18	27	110	161
Average (n= 19)		6.5	18.8	35	74
Surface water - West Branch Red Clay Creek at Kennett Square					
01479680	11-22-93	5.0	25	27	102
01479680	11-08-94	4.6	19	--	96
Ground water - wells in drainage area above East Branch Red Clay Creek at Five Points					
CH-3392	09-08-93	1.8	21	15	68
CH-4731	09-10-93	5.2	10	47	82
CH-770	07-22-93	38	110	130	58
CH-4729	09-02-93	8.1	14	16	144
CH-4344	09-27-93	7.3	25	21	41
CH-4728	09-01-93	.33	15	31	119
CH-2342	07-29-93	<.05	4.3	40	37
CH-3384	09-08-93	1.2	36	74	37
CH-3382	09-10-93	4.5	3.8	29	22
CH-3398	07-29-93	<.05	3.9	50	35
CH-3396	07-27-93	1.4	5.3	13	62
CH-4415	08-05-93	12	23	25	41
CH-4418	08-25-93	<.05	11	24	71
CH-4417	08-24-93	<.05	1.6	42	53
CH-4730	09-07-93	24	85	160	146
CH-3210	08-10-93	8.9	49	73	258
CH-3426	09-01-93	11	16	110	258
CH-26	08-17-93	.37	5.1	20	69
CH-3432	09-08-93	1.0	3.6	14	58

Table 16. *Concentrations of nitrate, chloride, sulfate, and alkalinity in ground water from wells sampled summer-autumn 1993 in drainage areas above sites and in surface water (base flow) sampled autumn 1993 and 1994 at sites on the West Branch Red Clay Creek near Kennett Square and East Branch Red Clay Creek, Pennsylvania—Continued*

[mg/L, milligrams per liter; N, nitrogen; $CaCO_3$, calcium carbonate]

Stream site or well number	Date of sample	Nitrate (mg/L as N)	Chloride (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L as $CaCO_3$)
Ground water - wells in drainage area above East Branch Red Clay Creek at Five Points—Continued					
CH-2596	08-11-93	10	28	63	65
CH-4361	08-26-93	.77	1.4	7.5	13
CH-4727	08-31-93	4.6	3.8	27	22
Average (n=22)		6.4	22	47	80
Surface water - East Branch Red Clay Creek at Five Points					
01479800	11-22-93	3.6	20	37	136
01479800	11-08-94	2.7	25	--	85

Base-flow samples in the headwaters of the West Branch Red Clay Creek (pl. 1) were collected in July 1994 to investigate the relation between land use and ground-water and surface-water quality. Stream discharge measured at the time of sampling (table 26 at the end of the report) indicate that the intervals between sampling sites on the mainstem were gaining reaches. Samples were collected for nutrient and chloride analysis (table 17; table 26) on the main stem and on tributaries that drained areas covered predominantly by one land use—either residential or agricultural. Nitrate concentrations measured in 1993 were higher in ground water in the agricultural areas than in ground water in residential areas. Chloride concentrations measured in 1993 were similar or slightly higher in ground water in the agricultural areas than in ground water in residential areas. Concentrations of chloride and nitrate in the base-flow samples generally reflected the concentrations of those constituents in ground water in areas drained by the streams (table 17; pl. 1).

Nonpoint-source contaminants can affect both ground water and base flow of streams. Long-term trends in solute concentrations in streams may reflect trends in application rates of those solutes and subsequent ground-water infiltration. The chloride and nitrate data for the period of record (1970-95) (Moore, 1989; U.S. Geological Survey, 1982-95) plotted as a function of time (fig. 19) suggest that concentrations of chloride and nitrate in base flow increased in the West Branch Red Clay Creek; and chloride, but not nitrate, concentrations increased in base flow in the East Branch Red Clay Creek. The nonparametric statistical seasonal Kendall tau (Hirsch and others, 1982) was used to test for significance of apparent trends. For 26 years of data at the West Branch Red Clay Creek, the seasonal Kendall tau was significant at the 95-percent confidence interval for increasing trends in dissolved chloride (tau =.42, 2-sided p-value = 0.002468) and total nitrate (tau = 0.57, 2-sided p-value = 0.000041). Because chloride, but not nitrate, is significantly correlated with discharge, the seasonal Kendall tau also was calculated for chloride normalized (divided) by discharge, and the results indicate that the increasing trend is still significant (tau = 0.39, 2-sided p-value = 0.04776). Seasonal Kendall tests for the same period of record for East Branch Red Clay Creek indicate that the increasing trend in chloride concentrations was significant (tau = 0.38, p-value = 0.007), and the trend in nitrate concentrations was not significant (fig 19).

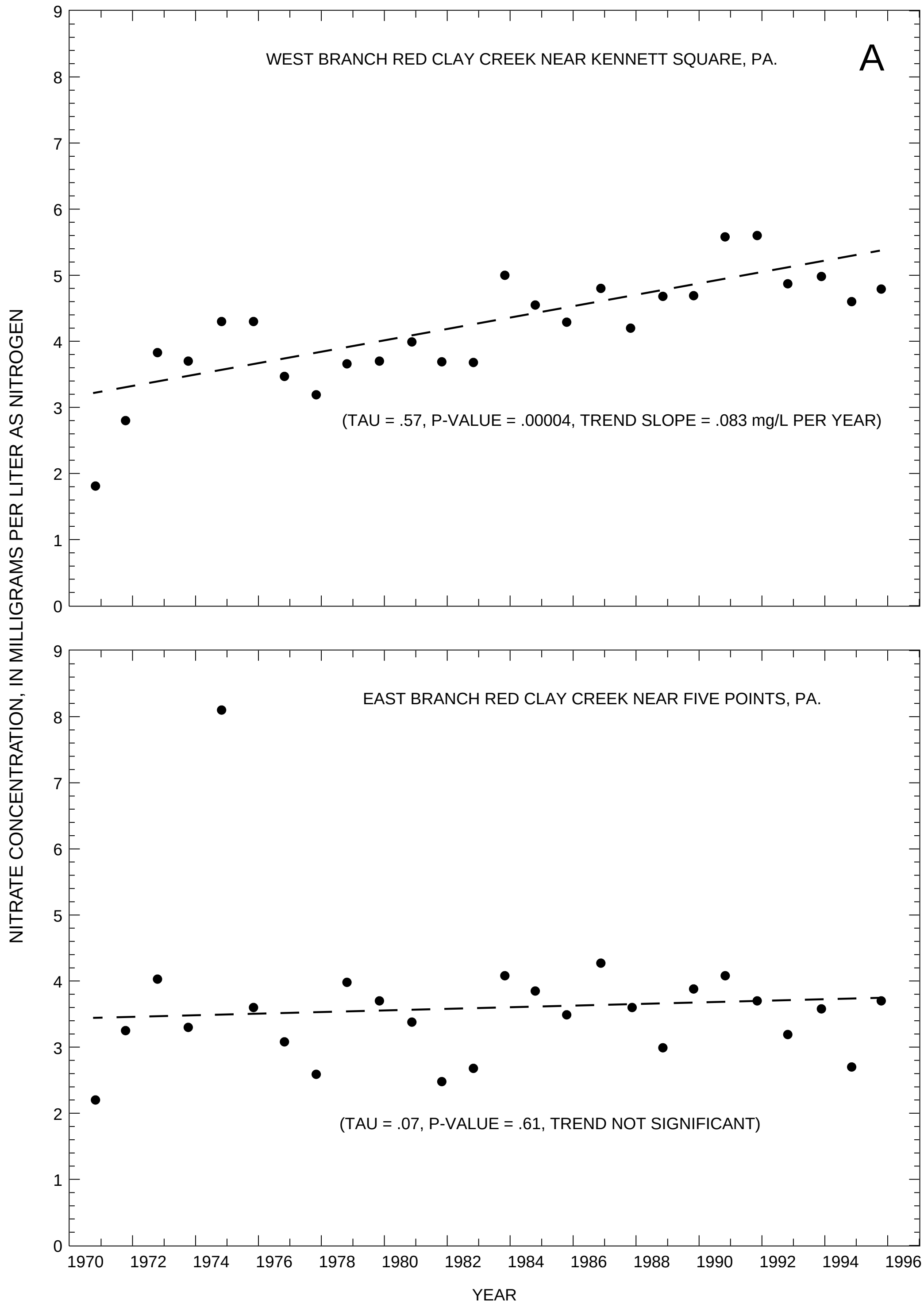

Figure 19. (A) Nitrate and (B) chloride concentrations as a function of time in base flow of the West Branch Red Clay Creek near Kennett Square and East Branch Red Clay Creek near Five Points, Pennsylvania, 1970-95.

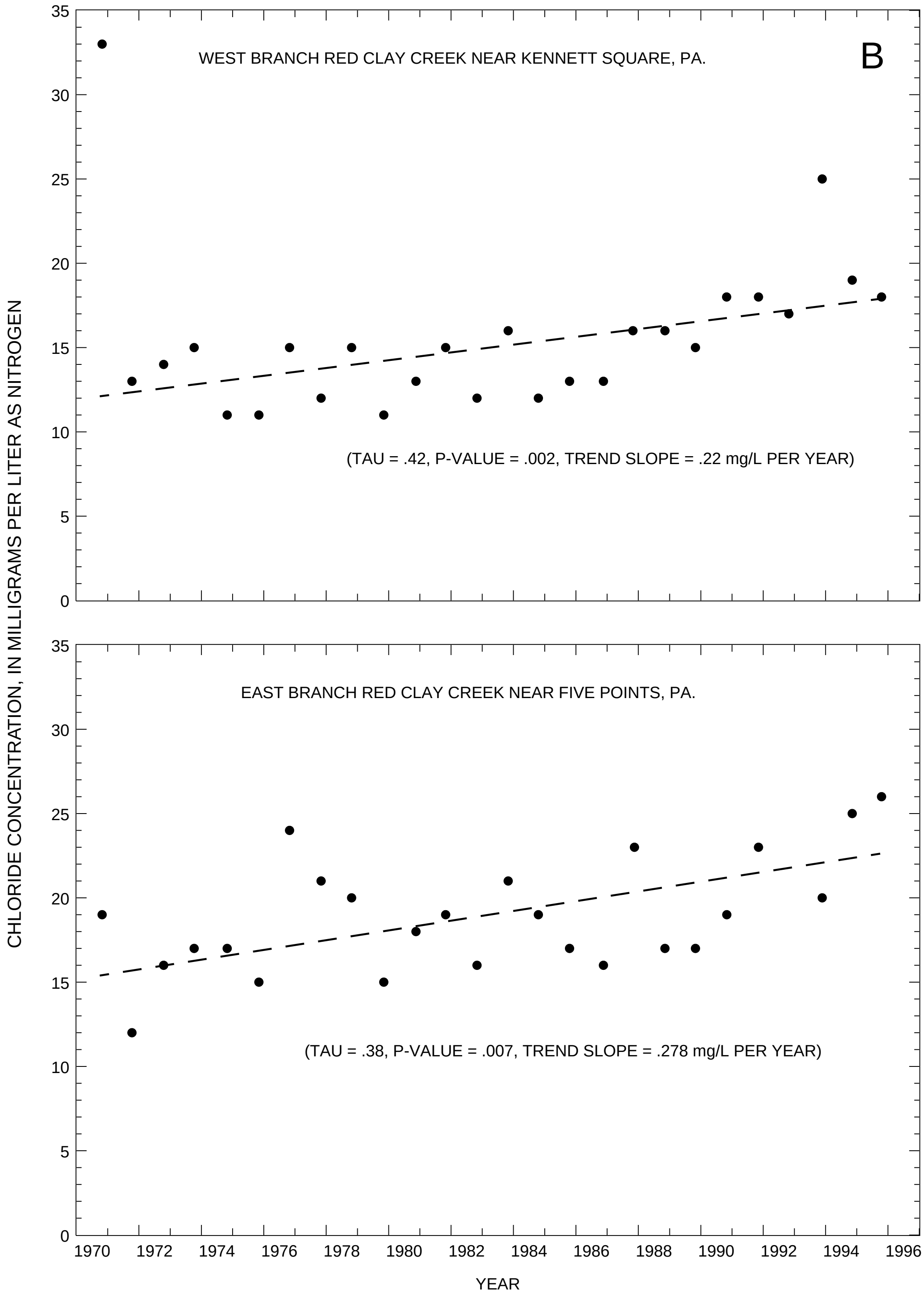

Figure 19. (A) Nitrate and (B) chloride concentrations as a function of time in base flow of the West Branch Red Clay Creek near Kennett Square and East Branch Red Clay Creek near Five Points, Pennsylvania, 1970-95—Continued.

Table 17. *Concentrations of nitrate and chloride in ground water from wells sampled summer 1993 in drainage area above stream sites and in surface water sampled summer 1994 at stream sites in the headwaters of West Branch Red Clay Creek, Pennsylvania*

[Sites listed in downstream order; locations of wells and stream sites shown on plate 1; mg/L, milligrams per liter; N, nitrogen; --, no data]

USGS local well number for well(s) near stream site	Predominant land use near well	Nitrate (mg/L as N)	Chloride (mg/L)	West Branch Red Clay Creek sampling site on main stem or (tributary)	Nitrate (mg/L as N)	Chloride (mg/L)
Ground water				Surface water		
CH-3506	Agricultural	5.6	8.8	H, at Mill Rd.	3.7	11
DER-02[1]	Agricultural	12.9	25	(G, tributary at Mill Rd.)	4.3	16
CH--3504	Agricultural	4.4	7.0	(F, tributary at Poplar Rd.)	3.2	18
CH-21	Forested	6.9	9.8			
Average (n=4)		7.5	13	E, at Walker Rd.	4.6	13
CH-4343	Residential	<.05	5.2			
CH-4414	Agricultural	12.0	13			
CH-4410	Residential	.08	9.2			
Average (n=3)		4.0	9.1	(D, tributary at Walker Rd.)	3.3	17
CH-3383	Residential	.71	9.8	(C, tributary at Walker Rd.)	1.6	31
--		--	--	(B, tributary at Walker Rd.)	5.0	6.9
CH-2513	Agricultural	4.6	8.2			
Average (n= 9)		5.2	11	A, at Route 926	3.8	13

[1] Well sampled by the Pennsylvania Department of Environmental Protection, 1992; data from Scott Lookingbill, Pennsylvania Department of Environmental Protection, written commun., 1993.

SUMMARY

The Red Clay Creek Basin in the Piedmont Province of Pennsylvania and Delaware is a 54-square-mile area underlain by a structurally complex assemblage of fractured metamorphosed sedimentary and igneous rocks that form a water-table aquifer. Ground-water-flow systems generally are local, and ground water discharges to streams. Because ground water and surface water in the basin are used for drinking-water supplies, degradation of these resources is of concern. A study to assess ground-water quality and evaluate the relation between ground-water quality and land-use and hydrogeologic factors, and surface-water quality in the basin was begun in 1992 by the U.S. Geological Survey in cooperation with the Red Clay Valley Association and Chester County Water Resources Authority. These data can provide a baseline for continuing assessment of ground-water quality in the basin.

Ground-water quality and the relation between ground-water quality and hydrogeologic and land-use factors was assessed using samples collected in 1993 from bedrock aquifers in the basin. A total of 82 wells were sampled during July-November 1993, based on a stratified random sampling scheme that included 8 hydrogeologic and 4 land-use categories to distribute the samples evenly over the basin area. The eight hydrogeologic units were determined by formation or lithology and were northern Wissahickon Formation, felsic gneiss, Setters Quartzite, Cockeysville Marble, mafic gneiss, southern Wissahickon Formation, Wilmington Complex, and serpentinite. The land-use categories were forested or open/undeveloped, agricultural, residential, and industrial/commercial. Well-water samples were analyzed for major and minor ions, nutrients, VOC's, pesticides, PCB's, and radon-222. Differences between ground-water quality in the lithologic and land-use categories were tested statistically with nonparametric analysis of variance (Krusal-Wallis test).

Concentrations of some constituents in the ground-water samples exceeded MCL's or SMCL's established by the USEPA for drinking water. Nitrate concentrations were greater than the MCL of 10 mg/L as N in water from 11 (13 percent) of 82 wells sampled. Nitrate concentrations as high as 38 mg/L as N were measured. Of the VOC's and pesticides analyzed, water from only 1 of 82 wells sampled contained compounds that exceeded a MCL; water from that well contained 3 µg/L chlordane (MCL of 2 µg/L) and 1 µg/L of PCB's (MCL of 0.5 µg/L). Iron concentrations were greater than the SMCL of 300 mg/L in water from 12 (15 percent) of 82 wells sampled; manganese concentrations were greater than the SMCL of 50 µg/L in water from 28 (34 percent) of the 82 wells sampled. Half of the 82 well-water samples had pH values that exceeded the SMCL range of 6.5-8.5; most waters were slightly acidic. Water from 68 (83 percent) of 82 wells sampled was corrosive as measured by Langlier index values. Water from two wells contained total dissolved solids greater than the SMCL of 500 mg/L. Water from 70 (85 percent) of the 82 wells sampled contained radon-222 activities in excess of the proposed MCL of 300 pCi/L.

Differences in concentrations of selected major and minor ion and radon-222 were statistically significant between some lithologies and are related to differences in mineralogy. Water samples from wells in the Cockeysville Marble generally had higher pH and alkalinity; higher concentrations of calcium, magnesium, and sulfate; and lower concentrations of iron and silica than water from other lithologic units. Water from a well completed in serpentinite contained the highest concentrations of magnesium and silica. Lithium concentrations generally were greatest in water from the northern Wissahickon Formation, and barium concentrations generally were greatest in water from the Setters Quartzite. Water from the northern Wissahickon Formation and felsic gneiss generally contained higher radon-222 activities than the other lithologies; activities as high as 10,000 pCi/L were measured in a water sample from the felsic gneiss. Aquifer materials in these lithologies probably have a higher uranium content than the other lithologies.

Differences in the median concentrations of nitrate, sodium, and chloride and the frequency of pesticide detections were statistically significant between water from wells in some land-use categories and are related to differences in human activities in those areas. Nitrate concentrations generally were greatest in agricultural and in industrial and commercial areas and can be attributed to fertilizer use on the land surface and other agricultural activities such as composting. The median nitrate concentration of about 4.6 mg/L as N in ground-water samples from agricultural areas of the Red Clay Creek Basin (fig. 17) is very similar to that observed for other areas with well drained soils and high nitrogen loads in the United States as a whole. Nitrate concentrations were equal to or greater than 10 mg/L as N in 9 (22 percent) of 41 samples from agricultural areas in the basin. Much of the industrial and commercial land use is in areas previously used for or related to mushroom production. Chloride concentrations were greatest in water from wells in agricultural and industrial and commercial areas, probably because of fertilizer use and road salt. Differences in median concentrations of nitrate, chloride, and sodium in water samples from wells in forested and residential land use were not statistically significant. The herbicides metolachlor and atrazine, the most frequently detected pesticides, were detected more frequently in agricultural areas than in areas with other land uses. Their presence is related to their use in crop production. Statistically significant differences were determined for the frequency of metolachlor detections in ground water in agricultural areas compared to ground water in areas with other land uses. VOC’s were detected infrequently and only in residential and industrial and commercial areas.

In 1994, 10 wells that had previously yielded water containing pesticides, VOC’s, or PCB’s were resampled to confirm the presence of those compounds. In all wells containing triazine herbicides, similar concentrations were measured in both 1993 and 1994 samples, suggesting that the compounds are persistent and(or) that similar application rates were in effect those 2 years. Differences in the detection of organophosphorus insecticides in the samples from 1993 and 1994 were observed, perhaps reflecting the shorter half-life or persistence of these compounds compared to the herbicides. Chloroform was measured at about the same concentration in both 1993 and 1994 samples from a well in a residential area. Chlordane and PCB’s also were measured at about the same concentration in both 1993 and 1994 samples from a well.

Because ground water discharges to streams, the chemical composition of base flow is related to ground-water quality. Similar concentrations of nitrate and chloride were measured in base-flow and ground-water samples collected in headwaters of the West Branch Red Clay Creek. In addition, the average chloride and nitrate concentrations determined in 1993 in ground water in areas above two long-term stream monitoring stations on the East Branch and West Branch Red Clay Creek were similar to the observed concentrations of chloride and nitrate in base flow at those sites in autumn of 1993-94. An observed increase from 1970 to 1995 in nitrate concentration in base flow at the long-term monitoring station on the West Branch Red Clay Creek may be due to increases in nitrate concentrations in ground water. Changes in land use may result in changes in loads to the ground-water system and ultimately in changes in base-flow water quality.

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Table 18. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Pennsylvania*

USGS well number: Well number assigned by the U.S. Geological Survey.

Latitude and longitude: DDDMMSS, degrees, minutes, and seconds.

Township or borough: Name refers to borough unless noted as T or Twp for township.

Driller license number: 0110, Brown Bros. Drilling, Inc.; 0154, Leroy Myers; 0176, R. Walter Slauch & Sons; 0248, Thomas G. Keyes; 0308, Petersheim Bros.; 0319, Myers Bros.; 0543, Walton Corp.;0909, Calvin E. Powell; 0938, Constantine DiFilippo, Jr.; 0950, J. Norman Connell; 1083, Kenneth L. Madron; 1290, B.L. Myers; 1333, Leonard R. Mayberry; 1457, Bonnie J. Myers; 1583, J. Ernest Brewer; 1609, Edward Powell Well Drilling; 1628, B.L. Myers Bros. Inc.

Use of site: W, withdrawal; U, unused.

Use of water: C, commercial; H, domestic; I, irrigation; N, industrial; U, unused.

Topographic setting codes: F, flat; H, hilltop; S, slope; V, valley; W, draw.

Hydrogeologic unit codes: 000MFCGH, mafic gneiss, amphibolite facies; 300CCKV, Cockeysville Marble; 300STRS, Setters Quartzite; 300WSCKO, Wissahickon Formation; 400 FLCGH, felsic gneiss, amphibolite facies.

Land use codes: A, agricultural; I, industrial; O, open, undeveloped or forested; R, residential.

Other abbreviations: Elevation of land surface is estimated from topographic maps; datum is sea level; gal/min, gallons per minute; gal/min/ft, gallons per minute per foot of drawdown.

Table 18. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Pennsylvania*

USGS local well number	Latitude (DDMMSS)	Longitude (DDMMSS)	Township or borough	Owner	Driller license number	Year drilled	Use of site	Use of water	Elevation of land surface (feet)	Topo-graphic setting	Geologic unit
Ch-21	395254	0754410	E Marlborough Twp	Walker, J	0154	1954	U	H	400	S	300WSCKO
26	395021	0755220	Kennett Twp	Weiner, Helen	--	1972	U	U	577	S	000MFCGH
71	395011	0754348	New Garden Twp	Cordivano, Bernard	--	--	W	H	275	V	300CCKV
770	395238	0754138	E Marlborough Twp	Steele, Wilmer	0176	1932	W	H	390	S	300STRS
2021	394933	0754038	Kennett Twp	Shade, E	0176	1970	W	H	315	S	300WSCKO
2067	395132	0754520	E Marlborough Twp	University Of Penna.	0248	1967	W	H	397	S	400FLCGH[1]
2071	395058	0753940	Kennett Twp	Yovanovich, G	0938	1973	W	H	360	S	300STRS
2342	395213	0754119	E Marlborough Twp	Longwood Gardens	0248	1974	W	H	450	S	400FLCGH
2513	395223	0754426	E Marlborough Twp	Cauffman	0909	1976	W	H	372	H	300STRS
2593	395053	0754319	Kennett Twp	Riale, Cathleen	1083	1980	W	H	315	S	300STRS
2596	394958	0754211	Kennett Square	Phillips, D	0308	1978	W	H	372	S	000MFCGH
3210	395035	0754223	Kennett Square	Mushroom Coop. Co	0110	1976	W	N	294	V	300CCKV
3382	395202	0754108	E Marlborough Twp	Booker	1609	1985	W	H	440	W	400FLCGH
3383	395254	0754340	E Marlborough Twp	Garris, Charles	1628	1985	W	H	390	S	300WSCKO
3384	395201	0754216	E Marlborough Twp	Roberts, Robert E.	--	1978	W	H	353	H	400FLCGH
3392	395255	0754234	E Marlborough Twp	Preston, Robert	0909	1989	W	H	425	W	300WSCKO
3396	395143	0754745	E Marlborough Twp	Devitto, Gabriel	0909	1978	W	H	381	S	400FLCGH
3398	395157	0754059	E Marlborough Twp	Graf, Fred	0543	1983	W	H	410	S	400FLCGH
3405	395041	0753858	Kennett Twp	Stover, Robert M	1457	1978	W	H	361	S	000MFCGH
3426	395022	0754103	Kennett Twp	Kolb, Phillip	1083	1988	W	H	265	F	300WSCKO[2]
3430	395123	0754002	Kennett Twp	Choby, Alex	1609	1988	W	H	405	S	400FLCGH
3432	395008	0754037	Kennett Twp	Miller	0950	1966	W	H	345	S	300WSCKO
3434	395004	0753956	Kennett Twp	Massau, J. L.	--	1972	W	H	325	S	300WSCKO
3441	394853	0754340	New Garden Twp	Le Pore, Cheryl	0543	1988	W	H	332	S	300WSCKO
3444	395033	0753936	Kennett Twp	Stat	--	1975	W	H	315	S	000MFCGH
3445	394833	0754401	New Garden Twp	Tavoni, Leslie	1083	1988	W	H	411	H	300WSCKO
3447	394939	0754000	Kennett Twp	Borkovich, George	1083	1987	W	H	430	H	300WSCKO[3]
3448	394900	0754406	New Garden Twp	Haga, Joseph	0319	1978	W	H	315	S	300WSCKO
3482	395115	0754411	E Marlborough Twp	Irwin, Mark	0909	1976	W	H	365	S	400FLCGH
3484	395054	0754506	New Garden Twp	Cummings, J.	1583	1987	W	H	445	S	400FLCGH
3485	394927	0754429	New Garden Twp	Pratt, Kenneth	1083	1978	W	H	425	H	300WSCKO
3487	395121	0753940	Kennett Twp	Beech, Martin	0909	1986	W	H	395	S	400FLCGH
3488	394956	0754439	New Garden Twp	Di Fabio, Anthony	1083	1987	W	H	310	W	300WSCKO
3495	395215	0754533	W Marlborough Twp	Codichini, Ruth	1333	1976	W	H	428	H	400FLCGH
3504	395406	0754418	E Marlborough Twp	Pape, William	0319	1988	W	H	475	W	300WSCKO
3506	395318	0754527	E Marlborough Twp	Jordan, Judith & Brian	1628	1985	W	H	468	S	300WSCKO
3513	394832	0754447	New Garden Twp	Bonifacino, Judy	1240	1977	W	H	430	H	300WSCKO
3516	395131	0754544	W Marlborough Twp	University of Penna.	0950	1966	W	H	383	V	300CCKV
3532	395037	0754514	New Garden Twp	Modern Mushroom	0248	1989	W	C	370	W	400FLCGH
3533	395020	0754508	New Garden Twp	Dibello, William	--	1958	W	H	385	S	300STRS
3543	395141	0754320	E Marlborough Twp	Doughenty, Patricia	0319	1986	W	H	382	W	400FLCGH
3558	394902	0754125	Kennett Twp	Haggard, Homer H.	0543	1982	W	H	300	S	300WSCKO
3573	394804	0754232	Kennett Twp	Muhlenberg, Henry	0176	1949	W	H	403	H	300WSCKO
3580	394912	0754005	Kennett Twp	Carter, James	1083	1983	W	H	315	W	300WSCKO
4343	395330	0754344	E Marlborough Twp	Mcdonnell, Jim	0248	1976	W	H	451	S	300WSCKO

Table 18. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Pennsylvania*

Depth of well (feet)	Casing depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Depth to water level (feet)	Date of water level	Reported yield (gal/min)	Measured specific capacity [(gal/min)/ft]	Discharge (gal/min)	Pumping period (hours)	Land use	USGS local well number
135	27	6	--	24.20	11-22-55	--	--	--	--	O	Ch-21
155	--	--	--	.00	04-20-72	--	--	--	--	A	26
50	50	6	--	8.67	03-15-57	--	--	--	--	I	71
94	60	6	--	3.00	01-01-32	--	--	--	--	A	770
97	61	6	85/97	5.00	09-17-70	--	2.0	30	2.0	A	2021
175	70	6	151/157	65.00	10-03-74	30	--	--	--	A	2067
230	198	6	--	25.00	05-25-73	--	.33	15	3.0	R	2071
152	51	6	60/141/152	55.00	05-06-74	--	1.0	100	--	A	2342
200	25	6	130/187	24.30	08-04-83	--	10	20	--	A	2513
206	40	6	120/180	21.70	09-27-83	5	--	--	--	A	2593
195	50	6	60/110/125/175	34.40	09-28-83	--	.80	20	--	A	2596
101	38	8	93	22.00	09-01-87	--	200	200	8	I	3210
140	39	6	55/72/85/122	23.00	06-26-89	--	.58	35	3.5	R	3382
200	50	6	145/180	5.50	06-27-89	4	--	--	--	R	3383
80	--	--	--	11.90	06-28-89	--	--	--	--	A	3384
412	--	--	--	27.90	06-29-89	12	--	--	--	A	3392
240	78	6	193/199/222/234	55.00	06-30-89	--	.04	6	1	R	3396
200	40	6	56/80/120/128	29.20	07-03-89	--	.05	8	4	R	3398
135	24	6	60/90	31.80	07-10-89	5	--	--	--	R	3405
125	105	6	110	16.00	07-17-89	50	--	--	--	A	3426
575	55	6	200/486/552	41.70	07-18-89	--	.01	5	3.5	R	3430
115	30	6	50/80/110	50.10	07-18-89	17	--	--	--	O	3432
125	--	--	--	14.80	07-18-89	25	--	--	--	A	3434
120	60	6	70/5/100/1	25.80	07-20-89	--	.22	14	4.0	O	3441
--	--	--	--	19.40	07-20-89	--	--	--	--	O	3444
225	100	6	160/210	25.80	07-21-89	10	--	--	--	A	3445
510	70	6	240/375/480	60.70	07-21-89	6	--	--	--	O	3447
300	26	6	180	17.10	07-21-89	--	--	--	--	A	3448
195	40	6	133/172	19.50	08-04-89	--	.04	6	1.0	O	3482
100	35	6	50/75	14.10	08-04-89	--	.75	30	1.25	A	3484
154	53	6	75/130/150	17.90	08-07-89	10	--	--	--	A	3485
305	54	6	209/221/240/255	23.40	07-25-89	--	.04	8	1.0	O	3487
126	60	6	80/115	8.33	08-07-89	25	--	--	--	A	3488
116	80	6	90/110	19.70	08-07-89	--	2.2	22	1.0	A	3495
250	80	6	120/155/190/225	25.10	08-08-89	30	--	--	--	A	3504
285	53	6	125/220	22.10	08-10-89	5	--	--	--	A	3506
76	36	5	26/39	7.00	08-23-89	--	.18	7	3.0	A	3513
150	27	6	--	17.20	08-16-89	12	--	--	--	A	3516
450	80	4	--	3.28	09-05-89	80	--	--	--	A	3532
68	--	--	--	7.06	09-05-89	--	--	--	--	A	3533
75	45	6	55/67/73	7.70	09-05-89	30	--	--	--	R	3543
401	55	6	195/400	76.00	08-11-89	1	--	--	--	O	3558
140	--	--	--	34.10	09-12-89	6	--	--	--	A	3573
144	70	6	90/120/135	6.91	09-27-89	120	--	--	--	R	3580
160	85	6	100	55.50	12-30-92	4	--	--	1	R	4343

Table 18. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Pennsylvania—Continued*

USGS local well number	Latitude (DDMMSS)	Longitude (DDMMSS)	Township or borough	Owner	Driller license number	Year drilled	Use of site	Use of water	Elevation of land surface (feet)	Topo-graphic setting	Geologic unit
4344	395231	0754201	E Marlborough Twp	Simpers, Paul	0308	1963	W	H	365	V	300CCKV[4]
4345	394842	0754238	Kennett Twp	Clark, Stephen	0909	1976	W	H	280	S	300WSCKO
4361	394917	0754228	Kennett Twp	Closs, Norma	1083	1988	W	H	375	H	300WSCKO
4362	395003	0753838	Kennett Twp	Duggins, Ray	--	1959	W	H	300	H	300WSCKO
4410	395307	0754343	E Marlborough Twp	Carlino, Heather	0909	1984	W	H	420	S	300WSCKO
4412	395158	0754318	E Marlborough Twp	Schenarts, Thomas	0176	1983	W	H	472	S	400FLCGH
4414	395316	0754408	E Marlborough Twp	Sellers, Kenneth	0950	1967	W	H	435	H	300WSCKO
4415	395129	0754159	E Marlborough Twp	Kristman, Charles	1290	1987	W	H	469	S	400FLCGH
4416	394919	0754336	New Garden Twp	Jasienski, John	1083	1991	W	H	360	H	300WSCKO
4417	395100	0754048	Kennett Twp	Maisano, Daniel	1083	1992	W	H	355	S	300STRS
4418	395130	0754140	E Marlborough Twp	Malik Industries Inc	1083	1990	W	H	380	S	400FLCGH
4552	395024	0754317	Kennett Twp	Kaolin Mushroom	--	--	W	C	263	S	300CCKV
4727	394906	0754214	Kennett Twp	Baldwin, Frazier	0909	1980	W	H	340	S	300WSCKO
4728	395230	0754150	E Marlborough Twp	Holton, George Jr	0909	1987	W	H	372	S	300CCKV
4729	395223	0754235	E Marlborough Twp	Edgar, Clifton	--	1974	W	H	370	F	300CCKV
4730	395048	0754136	Kennett Twp	Gold Star Nursery	0248	1988	W	I	332	S	300STRS[1]
4731	395234	0754252	E Marlborough Twp	Landhope Corporation	--	--	W	H	395	S	300STRS

[1] Near contact with 300CCKV.
[2] Well probably completed in 300CCKV.
[3] Near contact with 000PGMT.
[4] Near contact with 300STRS.

Table 18. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Pennsylvania—Continued*

Depth of well (feet)	Casing depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Depth to water level (feet)	Date of water level	Reported yield (gal/min)	Measured specific capacity [(gal/min)/ft]	Discharge (gal/min)	Pumping period (hours)	Land use	USGS local well number
95	54	6	20/50/90	--	03-31-93	142	--	--	--	A	4344
100	24	6	62/84	27.00	08-19-93	--	0.5	15	1.0	R	4345
222	75	6	120/210	20.30	08-26-93	8	--	--	--	A	4361
154	--	--	--	--	--	--	--	--	--	R	4362
280	80	6	201/251/269/275	29.70	07-21-93	--	.09	10	1	R	4410
68	34	6	20/50	17.50	07-28-93	--	1.0	25	2	A	4412
157	--	--	68/100/148	43.00	08-04-93	15	--	--	--	A	4414
305	70	6	75/280/285	52.40	08-05-93	1	--	--	--	I	4415
242	84	6	160/230	49.60	08-18-93	5	--	--	--	A	4416
123	60	6	70/110	21.20	08-24-93	25	--	--	--	O	4417
342	120	6	240/335	5.37	08-25-93	12	--	--	--	I	4418
80	--	--	--	--	--	200	--	--	--	I	4552
140	35	6	95/111/114/137	34.00	08-31-93	--	.50	20	1	R	4727
355	62	6	212/281/298/350	6.82	09-01-93	--	.08	12	1.0	R	4728
95	--	--	--	--	--	--	--	--	--	A	4729
160	61	6	135	11.80	09-07-93	30	--	--	2	A	4730
--	--	--	--	--	--	--	--	--	--	A	4731

Table 19. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Delaware*

DGS well number: Well number assigned by the Delaware Geological Survey.

Latitude and longitude: DDDMMSS, degrees, minutes, and seconds.

Use of site: W, withdrawal.

Use of water: C, commercial; H, domestic; I, irrigation.

Topographic setting codes: H, hilltop; S, slope; W, draw.

Hydrogeologic unit codes: 000SRPN, serpentinite; 300CCKV, Cockeysville Marble; 300WSCK, Wissahickon Formation; 300WLMG, Wilmington complex.

Land use codes: A, agricultural; O, open, undeveloped or forested; R, residential.

Other abbreviations: Elevation of land surface is estimated from topographic maps; datum is sea level; gal/min, gallons per minute; gal/min/ft, gallons per minute per foot of drawdown.

Table 19. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Delaware*

DGS local well number	Latitude (DDMMSS)	Longitude (DDMMSS)	Quadrangle map	Owner	Driller	Year drilled	Use of site	Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
Bb24-15	394824	0754118	Kennett Square	Donahue, John	Walton	--	W	H	345	S	300WSCK
Bb25-28	394835	0754015	Kennett Square	Verbeck, Arthur	Walton	1985	W	H	230	H	300WSCK
Bc12-03	394920	0753830	Kennett Square	Kelly, Paul	Walton	1983	W	H	245	S	300WSCK
Bc13-19	394931	0753711	Wilmington North	Witsil, Pamela	Walton	1989	W	H	421	H	300WSCK
Bc21-07	394826	0753916	Kennett Square	DuPont, Eugenie	Walton	1976	W	H	225	W	300WSCK
Bc21-09	394841	0753920	Kennett Square	Cripps, Harry	Powell	1989	W	H	272	S	300WSCK
Bc22-10	394835	0753819	Kennett Square	Frederick, Richard	--	1960	W	H	325	S	300WSCK
Bc23-22	394856	0753731	Kennett Square	Greenville Country Club	Powell	1961	W	C	365	S	300WSCK
Bc31-08	394715	0753909	Kennett Square	DuPont-Copeland, Lamont	Walton	1980	W	H	315	W	300WSCK
Bc31-10	394717	0753954	Kennett Square	Vague, Lisa	Powell	1988	W	H	310	S	300WSCK
Bc33-09	394752	0753740	Kennett Square	Rollins, John W.	Walton	1985	W	I	300	S	000SRPN
Bc34-14	394754	0753651	Wilmington North	Brevort, F.	Walton	1963	W	H	321	H	300WSCK
Bc34-16	394628	0753650	Wilmington North	Minker, Mat	Walton	1980	W	H	330	S	300WSCK
Bc41-13	394628	0753936	Kennett Square	Florick, Alfred	Walton	--	W	H	335	S	300WSCK
Bc42-16	394636	0753833	Kennett Square	Spencer, Thaddeus	--	1970	W	H	150	S	300WSCK
Bc42-22	394612	0753845	Kennett Square	Miller, Robert	Walton	1960	W	H	237	W	300WSCK
Bc42-28	394659	0753808	Kennett Square	Popel, George	Powell	1992	W	H	242	S	300WSCK
Bc43-15	394607	0753746	Kennett Square	Krespan, Carl	Powell	1979	W	H	262	H	300WLMG
Cc11-16	394407	0753909	Newark East	Campbell, William	--	1949	W	H	140	S	300WLMG
Cc12-02	394439	0753900	Newark East	Comoletti, Donald	--	1950	W	H	162	S	300WLMG

Table 19. *Record of wells sampled in 1993 in the Red Clay Creek Basin, Delaware*

Depth of well (feet)	Casing depth (feet)	Diameter (inches)	Depth to water bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Discharge (gal/min)	Pumping period (hours)	Land use	DGS local well number
220	40	6	--	31.0	09-12-89	--	--	--	--	R	Bb24-15
220	40	6	--	70.3	09-21-89	--	0.04	7	4	R	Bb25-28
250	--	--	--	36.2	08-02-89	25	--	--	--	A	Bc12-03
300	109	6	--	27.5	03-07-90	--	.02	5	4	R	Bc13-19
205	95	--	--	7.7	08-01-89	25	--	--	--	A	Bc21-07
260	54	6.25	--	2.6	08-01-89	11	--	--	--	O	Bc21-09
--	--	--	--	34.7	07-19-89	--	--	--	--	A	Bc22-10
--	--	--	--	10.7	07-27-89	--	--	--	--	A	Bc23-22
330	92	8	--	39.0	09-20-89	--	.30	48	24	O	Bc31-08
220	28	6	--	24.1	07-26-89	--	.01	.5	3	A	Bc31-10
160	120	6	120	--	--	--	.36	25	4	A	Bc33-09
312	42	6	--	33.8	08-23-89	--	.11	20	8	R	Bc34-14
330	65	--	80	38.4	08-23-89	3.25	--	--	--	A	Bc34-16
300	--	--	--	42.5	09-29-89	--	--	--	--	A	Bc41-13
400	--	--	--	38.3	08-14-89	20	--	--	--	R	Bc42-16
175	64	6	--	19.6	07-25-89	--	.06	6	4	R	Bc42-22
505	185	6	185	62	01-22-92	--	.32	25	1	O	Bc42-28
200	33	6	--	41.4	08-21-89	--	.08	8	1	R	Bc43-15
100	--	--	--	5.7	10-03-89	30	--	--	--	R	Cc11-16
68	--	--	--	11.5	10-03-89	7	--	--	--	R	Cc12-02

Table 20. *Field measurements of physical properties and constituents and results of chemical analyses for major ions, nutrients, radon-222, and total dissolved solids for water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ft bls, feet below land surface; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picoCuries per liter]

USGS local well number	Geologic unit	Date of sample	Depth to water (ft bls)	Water temperature (degrees Celsius)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	pH (standard units)	Alkalinity, incremental titration (mg/L as $CaCO_3$)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)
Pennsylvania											
CH-21	300WSCKO	07-21-93	27.79	14.0	160	12.1	6.2	13	13	6.3	6.1
26	000MFCGH	08-17-93	1.11	17.5	218	.7	8.0	69	27	5.0	6.7
71	300CCKV	08-30-93	--	14.0	680	3.8	7.6	161	78	41	3.6
770	300STRS	07-22-93	--	14.0	1,010	.4	5.8	58	120	33	17
2021	300WSCKO	09-07-93	3.11	14.5	164	8.6	6.3	18	15	4.9	6.1
2067	[1]400FLCGH	08-02-93	59.50	13.0	442	3.6	7.5	149	47	21	7.4
2071	300STRS	08-09-93	28.78	13.5	43	8.5	6.0	5	.81	2.0	1.8
2342	400FLCGH	07-29-93	44.25	14.0	179	<.1	6.6	37	10	5.3	5.7
2513	300STRS	08-03-93	25.30	14.0	208	6.9	6.5	54	19	7.5	6.6
2593	300STRS	09-09-93	22.50	14.0	392	10.2	6.4	33	35	13	15
2596	000MFCGH	08-11-93	45.96	14.0	428	9.3	6.4	65	39	17	9.2
3210	300CCKV	08-10-93	--	15.0	848	2.4	7.3	258	79	41	25
3382	400FLCGH	09-10-93	25.46	13.0	164	9.6	6.0	22	14	4.3	7.0
3383	300WSCKO	09-08-93	9.95	13.5	240	1.1	7.1	70	24	8.6	8.2
3384	400FLCGH	09-08-93	18.88	14.0	360	9.2	6.3	37	32	11	15
	400FLCGH	07-13-94	18.95	14.5	428	10.4	6.0	39	42	12	15
3392	300WSCKO	09-08-93	33.08	13.5	252	.4	7.4	68	29	6.8	9.9
3396	400FLCGH	07-27-93	42.25	14.0	191	3.8	6.7	62	20	5.5	6.6
3398	400FLCGH	07-29-93	31.89	14.0	212	0	6.9	35	20	5.1	6.6
3405	000MFCGH	08-09-93	32.53	13.0	172	9.3	6.4	49	15	8.1	5.1
3426	[1]300WSCKO	09-01-93	20.70	14.5	805	.4	7.6	258	86	50	9.2
3430	400FLCGH	08-04-93	36.91	13.5	252	6.1	6.5	40	28	6.4	5.2
	400FLCGH	07-12-94	39.80	13.5	251	4.1	6.2	43	23	6.4	5.3
3432	300WSCKO	09-08-93	--	13.0	167	.8	7.1	58	15	5.9	8.3
3434	300WSCKO	08-31-93	19.87	13.5	228	9.9	6.3	26	19	8.2	7.1
3441	300WSCKO	09-09-93	31.24	12.5	159	.2	7.1	51	17	3.6	6.0
3444	000MFCGH	08-10-93	25.75	13.0	213	5.4	7.7	69	21	9.0	5.9
3445	300WSCKO	08-19-93	24.47	15.0	160	.3	6.3	37	19	2.7	5.2
	300WSCKO	07-12-94	23.55	14.5	158	.3	6.9	39	18	2.7	4.7
3447	[2]300WSCKO	08-12-93	--	14.5	267	4.4	6.4	[3]100	31	8.6	8.2
3448	300WSCKO	09-09-93	--	14.0	215	4.8	6.7	41	18	7.0	11
3482	400FLCGH	07-27-93	19.54	13.5	269	5.8	6.3	47	28	7.1	10
3482	400FLCGH	07-13-94	--	12.0	308	5.3	6.4	72	39	8.1	9.2
3484	400FLCGH	08-03-93	17.42	14.0	360	6.5	5.7	27	27	14	11
	400FLCGH	07-13-94	17.00	12.5	360	6.2	5.7	18	29	14	11
3485	300WSCKO	08-12-93	24.06	14.0	144	7.9	6.0	15	9.9	3.6	7.6
3487	400FLCGH	07-28-93	26.82	12.5	193	.1	6.6	46	17	7.0	5.6
3488	300WSCKO	09-02-93	13.18	14.0	208	.4	6.3	51	12	3.5	21
3495	400FLCGH	07-22-93	23.02	14.0	92	9.2	6.4	43	9.4	1.5	5.2

Table 20. *Field measurements of physical properties and constituents and results of chemical analyses for major ions, nutrients, radon-222, and total dissolved solids for water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ft bls, feet below land surface; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picoCuries per liter]

USGS local well number	Date of sample	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L as SiO_2)	Ammonia (mg/L as N)	Nitrite (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Ortho-phosphate (mg/L as P)	Radon-222 (pCi/L)	Total dissolved solids (mg/L)
Pennsylvania												
CH-21	07-21-93	1.8	9.8	19	<0.10	17	<0.01	<0.01	6.90	<0.01	1,300	110
26	08-17-93	3.0	5.1	20	.20	18	.02	.01	.370	<.01	210	129
71	08-30-93	3.1	27	110	<.10	14	.03	.03	18.0	.01	990	--
770	07-22-93	5.6	110	130	<.10	30	.05	.02	38.0	.01	1,200	773
2021	09-07-93	1.4	4.9	29	.10	26	.02	<.01	3.50	.02	2,400	121
2067	08-02-93	7.4	12	33	<.10	14	.02	<.01	7.60	<.01	850	265
2071	08-09-93	1.6	2.0	.20	<.10	12	.01	<.01	1.40	<.01	930	31
2342	07-29-93	3.6	4.3	40	.10	28	.01	<.01	<.05	<.01	2,500	110
2513	08-03-93	1.3	8.2	14	<.10	23	.01	<.01	4.60	.02	5,000	122
2593	09-09-93	3.6	16	67	.30	22	.02	<.01	15.0	.02	540	255
2596	08-11-93	2.4	28	63	<.10	27	.02	<.01	10.0	<.01	520	265
3210	08-10-93	5.9	47	75	<.10	18	.01	<.01	8.80	.08	290	486
3382	09-10-93	1.3	3.8	29	.10	25	.02	<.01	4.50	.03	2,700	111
3383	09-08-93	2.7	9.8	28	<.10	17	.02	<.01	.71	<.01	1,300	144
3384	09-08-93	<.10	36	74	.10	24	.02	.02	1.20	<.01	1,700	219
	07-13-94	--	57	64	<.10	24	.03	.02	.82	.01	890	--
3392	09-08-93	1.3	21	15	.10	18	<.01	.17	1.80	<.01	2,000	144
3396	07-27-93	3.7	5.3	13	<.10	23	.02	<.01	1.40	<.01	1,100	123
3398	07-29-93	3.3	3.9	50	.10	29	.02	<.01	<.05	<.01	2,200	142
3405	08-09-93	1.4	5.5	16	<.10	30	.01	<.01	2.40	.03	330	119
3426	09-01-93	2.9	16	110	.20	17	.12	<.01	11.0	.02	490	470
3430	08-04-93	<.10	6.9	36	<.10	21	.03	<.01	3.00	<.01	1,200	152
	07-12-94	--	6.3	36	.10	21	<.01	<.01	3.60	<.01	1,500	--
3432	09-08-93	2.6	3.6	14	<.10	22	<.01	<.01	1.00	.02	670	105
3434	08-31-93	1.4	8.1	29	.10	25	.02	<.01	8.40	.04	520	154
3441	09-09-93	2.0	5.2	18	.10	28	.01	<.01	.10	<.01	1,500	95
3444	08-10-93	4.4	3.8	24	<.10	20	.01	<.01	.99	<.01	790	132
3445	08-19-93	1.9	3.9	28	.10	32	.02	<.01	<.05	<.01	1,000	115
	07-12-94	--	3.5	26	.20	32	<.01	<.01	<.05	<.01	980	--
3447	08-12-93	3.4	6.3	24	<.10	24	.02	<.01	1.20	<.01	1,200	170
3448	09-09-93	3.4	8.3	42	.10	30	<.01	<.01	<.05	<.01	400	143
3482	07-27-93	3.5	25	26	<.10	20	.02	<.01	3.50	<.01	2,400	156
	07-13-94	--	28	27	<.10	21	.02	<.01	1.90	<.01	2,200	--
3484	08-03-93	3.0	47	31	<.10	24	.02	<.01	8.30	<.01	9,000	236
	07-13-94	--	50	27	<.10	24	.01	<.01	7.00	<.01	9,000	--
3485	08-12-93	3.2	7.9	21	.10	23	.01	<.01	2.70	.02	460	96
3487	07-28-93	3.1	4.5	26	.10	26	.03	<.01	<.05	<.01	540	124
3488	09-02-93	2.9	11	30	.20	22	.09	<.01	<.05	.04	650	131
3495	07-22-93	.50	1.4	.80	<.10	25	<.01	<.01	.790	<.01	10,000	69

***Table 20.** Field measurements of physical properties and constituents and results of chemical analyses for major ions, nutrients, radon-222, and total dissolved solids for water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ft bls, feet below land surface; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picoCuries per liter]

USGS local well number	Geologic unit	Date of sample	Depth to water (ft bls)	Water temperature (degrees Celsius)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	pH (standard units)	Alkalinity, incremental titration (mg/L as $CaCO_3$)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)
3504	300WSCKO	07-20-93	26.76	14.5	110	6.2	E6.3	26	7.2	3.5	8.1
3506	300WSCKO	07-08-93	24.88	13.0	140	7.9	6.2	67	10	3.9	7.7
3513	300WSCKO	09-02-93	12.20	13.5	260	5.2	6.2	34	21	7.6	12
3516	300CCKV	08-02-93	20.77	13.5	830	7.3	7.2	250	87	51	9.0
	300CCKV	07-13-94	20.87	13.5	855	7.1	7.0	292	82	49	9.2
3532	400FLCGH	11-16-93	--	13.0	595	3.3	6.1	64	71	16	15
3533	300STRS	11-22-93	7.00	14.0	210	9.8	6.4	36	24	4.3	4.9
3543	400FLCGH	09-01-93	9.87	15.0	273	6.9	5.7	22	23	9.4	9.8
3558	300WSCKO	08-30-93	--	13.5	295	.2	7.9	96	45	5.1	5.7
3573	300WSCKO	09-09-93	39.44	15.0	248	9.0	6.3	28	19	8.0	11
3580	300WSCKO	08-26-93	10.06	14.0	177	7.7	6.5	45	17	4.1	6.9
4343	300WSCKO	12-30-92	54.50	12.5	174	<.1	6.9	28	4.0	4.5	8.3
	300WSCKO	04-01-93	23.44	12.5	122	<.1	6.8	64	3.9	4.3	8.2
	300WSCKO	06-10-93	27.48	13.5	119	<.1	6.8	21	4.1	4.7	8.2
	300WSCKO	09-23-93	33.93	13.5	128	<.1	6.8	33	4.0	4.3	8.4
4344	[4]300CCKV	03-31-93	.0	12.5	254	4.9	6.3	35	21	9.4	10
	[4]300CCKV	06-16-93	1.50	12.5	248	7.0	6.1	51	25	7.3	11
	[4]300CCKV	09-27-93	3.61	13.0	266	5.3	6.0	41	24	6.8	11
	[4]300CCKV	07-07-94	2.09	11.5	273	5.0	5.9	53	25	7.4	11
4345	300WSCKO	08-19-93	26.99	14.0	120	10.0	6.0	18	9.8	3.0	5.1
	300WSCKO	07-11-94	27.16	13.5	107	9.0	6.1	22	8.2	2.6	4.7
4361	300WSCKO	08-26-93	20.27	13.5	58	9.5	6.6	13	3.2	.75	4.2
4362	300WSCKO	08-30-93	--	13.5	149	7.3	6.2	27	11	4.8	6.5
4410	300WSCKO	07-21-93	29.69	13.5	201	.4	7.2	42	16	8.6	11
4412	400FLCGH	07-28-93	17.55	13.0	243	7.5	6.0	[3]32	20	9.4	7.4
4414	300WSCKO	08-04-93	43.03	14.0	229	5.3	6.3	22	16	5.8	14
4415	400FLCGH	08-05-93	52.40	16.0	330	4.0	6.3	41	32	9.7	10
4416	300WSCKO	08-18-93	49.58	13.5	228	.3	6.4	28	21	5.5	10
4417	300STRS	08-24-93	21.23	13.5	217	.4	7.4	53	24	5.6	5.5
4418	400FLCGH	08-25-93	5.37	14.0	235	.4	6.3	71	25	7.9	6.6
4552	300CCKV	08-30-93	--	15.0	600	3.8	7.6	212	68	36	7.6
4727	300WSCKO	08-31-93	33.97	15.0	162	10.0	6.4	22	15	3.7	6.2
4728	300CCKV	09-01-93	6.82	13.5	333	.2	8.0	119	37	16	4.7
4729	300CCKV	09-02-93	--	16.5	430	6.0	7.8	144	58	15	4.5
4730	[1]300STRS	09-07-93	11.80	13.5	1,010	.7	7.0	146	150	31	12
	[1]300STRS	07-11-94	--	13.0	1,100	.5	6.7	145	150	32	12
4731	300STRS	09-10-93	--	15.0	340	6.6	6.7	82	33	8.9	21

Table 20. *Field measurements of physical properties and constituents and results of chemical analyses for major ions, nutrients, radon-222, and total dissolved solids for water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ft bls, feet below land surface; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picoCuries per liter]

USGS local well number	Date of sample	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L as SiO_2)	Ammonia (mg/L as N)	Nitrite (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Ortho-phosphate (mg/L as P)	Radon-222 (pCi/L)	Total dissolved solids (mg/L)
3504	07-20-93	2.3	7.0	2.7	<0.10	29	<0.01	<0.01	4.40	0.04	3,600	84
3506	07-08-93	2.0	8.8	7.7	<.10	22	.02	<.01	5.60	.03	2,300	--
3513	09-02-93	2.9	9.6	24	<.10	32	.02	<.01	11.0	.03	1,800	184
3516	08-02-93	2.2	41	46	<.10	14	.02	<.01	16.0	<.01	1,900	450
	07-13-94	--	44	42	<.10	14	.02	<.01	17.0	<.01	1,900	--
3532	11-16-93	3.8	50	110	<.10	26	.02	<.01	8.90	.02	4,200	374
3533	11-22-93	3.1	7.0	25	<.10	16	.01	<.01	6.70	.02	3,800	127
3543	09-01-93	2.0	33	29	<.10	25	.02	<.01	4.10	.02	2,600	186
3558	08-30-93	4.0	6.0	32	.10	16	.02	.350	1.30	<.01	2,000	172
3573	09-09-93	3.0	4.9	35	<.10	17	<.01	<.01	12.0	.03	1,800	158
3580	08-26-93	2.2	4.8	26	.10	26	.01	<.01	2.30	.02	1,900	118
4343	12-30-92	1.7	4.9	16	.10	26	.03	.03	<.05	<.01	2,000	71
	04-01-93	1.7	5.2	2.2	<.10	26	.03	<.01	<.05	<.01	2,000	76
	06-10-93	1.7	5.5	17	.10	24	<.01	<.01	<.05	.01	2,100	87
	09-23-93	1.7	5.2	17	.20	26	.02	<.01	<.05	<.01	2,200	84
4344	03-31-93	1.8	30	24	<.10	18	.01	<.01	7.00	.04	3,100	204
	06-16-93	2.1	24	22	<.10	29	<.01	<.01	6.90	.05	3,400	200
	09-27-93	2.0	25	21	<.10	30	.02	<.01	7.30	.04	3,400	191
	07-07-94	--	26	22	.10	30	<.01	<.01	7.00	.04	3,100	--
4345	08-19-93	1.7	7.5	2.6	.10	19	.01	<.01	4.70	.03	380	79
	07-11-94	--	5.8	2.8	.10	19	<.01	<.01	3.70	.02	420	--
4361	08-26-93	1.5	1.4	7.5	<.10	21	.01	<.01	.770	.05	320	51
4362	08-30-93	2.2	4.4	20	.10	22	.01	<.01	3.30	.03	320	97
4410	07-21-93	2.5	9.2	31	.10	25	.05	<.01	.076	<.01	2,900	131
4412	07-28-93	2.7	5.6	46	<.10	16	.01	<.01	6.40	.01	5,800	136
4414	08-04-93	2.4	13	8.6	<.10	30	.02	<.01	12.0	<.01	2,200	166
4415	08-05-93	3.2	23	25	<.10	25	.02	<.01	12.0	<.01	1,700	216
4416	08-18-93	2.0	31	15	.10	22	.02	.33	1.80	<.01	360	132
4417	08-24-93	4.4	1.6	42	.10	24	.02	<.01	<.05	<.01	2,100	134
4418	08-25-93	3.6	11	24	.10	21	.02	<.01	<.05	<.01	510	145
4552	08-30-93	2.9	26	50	<.10	18	.03	.03	7.90	.05	440	--
4727	08-31-93	2.2	3.8	27	.10	23	.02	<.01	4.60	.04	310	107
4728	09-01-93	3.1	15	31	.10	10	.02	.16	.33	<.01	2,600	184
4729	09-02-93	<.10	14	16	<.10	15	.02	<.01	8.10	.01	330	239
4730	09-07-93	8.7	85	160	<.10	15	.04	1.90	24.0	<.01	2,000	664
	07-11-94	--	82	150	.10	19	.02	.94	34.0	<.01	2,100	--
4731	09-10-93	5.5	10	47	<.10	22	.08	.06	5.20	.06	1,600	211

Table 20. *Field measurements of physical properties and constituents and results of chemical analyses for major ions, nutrients, radon-222, and total dissolved solids for water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ft bls, feet below land surface; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picoCuries per liter]

USGS local well number	Geologic unit	Date of sample	Depth to water (ft bls)	Water temperature (degrees Celsius)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	pH (standard units)	Alkalinity, incremental titration (mg/L as $CaCO_3$)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)
Delaware											
Bb24-15	300WSCK	10-13-93	28.63	13.0	195	0.2	7.4	69	23	4.6	5.8
Bb25-28	300WSCK	09-22-93	--	13.0	286	.4	7.0	76	34	7.2	7.8
Bc12-03	300WSCK	10-13-93	41.30	13.0	143	.2	7.8	47	17	2.8	7.0
Bc13-19	300WSCK	10-06-93	36.47	14.0	187	.2	7.0	58	13	7.0	10
Bc21-07	300WSCK	09-22-93	5.81	14.5	168	3.0	8.2	55	22	2.1	5.2
Bc21-09	300WSCK	09-30-93	4.62	13.0	274	3.8	7.0	93	37	8.6	6.9
Bc22-10	300WSCK	10-07-93	44.93	16.0	143	6.0	6.1	23	12	3.0	6.1
Bc23-22	300WSCK	10-18-93	--	13.5	339	1.3	7.1	54	31	9.6	12
Bc31-08	300WSCK	10-05-93	10.80	13.0	163	.2	6.6	35	14	3.5	9.3
Bc31-10	300WSCK	10-04-93	32.04	13.0	100	9.1	5.7	15	7.3	2.1	4.4
Bc 33-09	000SRPN	11-09-93	--	11.5	358	8.1	8.1	150	13	40	1.3
Bc34-14	300WSCK	09-20-93	28.90	13.5	344	.4	6.1	76	42	3.4	17
Bc34-16	300WSCK	10-05-93	--	13.0	600	.1	6.6	82	55	16	19
Bc41-13	300WSCK	09-30-93	28.06	13.0	145	.6	7.0	39	14	2.4	8.2
Bc42-16	300WSCK	10-14-93	36.85	13.5	251	6.0	6.6	48	19	5.5	16
	300WSCK	09-08-94	41.43	13.5	261	4.9	6.5	52	20	5.7	18
Bc42-22	300WSCK	09-28-93	25.53	13.0	184	1.6	6.0	25	16	3.9	7.1
Bc42-28	300WSCK	10-19-93	58.50	13.5	162	3.0	8.6	43	14	5.0	6.9
Bc43-15	300WLMG	10-07-93	51.02	14.0	159	8.4	5.8	26	15	3.1	6.3
Cc11-16	300WLMG	09-29-93	12.35	14.0	184	5.2	6.4	50	13	9.4	6.0
Cc12-02	300WLMG	10-21-93	--	17.5	96	7.6	6.2	34	5.2	4.0	4.6

[1] Near contact with 300CCKV.
[2] Near contact with 000PGMT.
[3] Done by fixed endpoint in laboratory.
[4] Near contact with 300STRS.

***Table 20.** Field measurements of physical properties and constituents and results of chemical analyses for major ions, nutrients, radon-222, and total dissolved solids for water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ft bls, feet below land surface; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picoCuries per liter]

USGS local well number	Date of sample	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L as SiO_2)	Ammonia (mg/L as N)	Nitrite (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Ortho-phosphate (mg/L as P)	Radon-222 (pCi/L)	Total dissolved solids (mg/L)
Delaware												
Bb24-15	10-13-93	2.9	3.9	28	<0.10	25	0.05	<0.01	<0.05	<0.01	1,300	128
Bb25-28	09-22-93	2.5	8.8	46	<.10	21	.02	<.01	.140	<.01	550	183
Bc12-03	10-13-93	1.7	1.8	16	<.10	22	.02	<.01	<.05	.02	200	94
Bc13-19	10-06-93	2.0	14	13	.10	22	.01	<.01	<.05	<.01	250	105
Bc21-07	09-22-93	1.5	4.3	13	<.10	18	.02	.01	1.20	.01	1,100	110
Bc21-09	09-30-93	2.7	5.7	26	.10	27	.02	<.01	2.90	<.01	150	177
Bc22-10	10-07-93	3.5	6.4	22	.20	19	<.01	<.01	1.90	<.01	--	93
Bc23-22	10-18-93	5.4	17	58	<.10	24	.02	<.01	2.20	.01	470	195
Bc31-08	10-05-93	2.0	3.9	31	.10	33	.01	<.01	<.05	<.01	170	118
Bc31-10	10-04-93	2.2	2.9	12	<.10	16	.01	<.01	4.30	<.01	310	65
Bc33-09	11-09-93	.30	3.6	16	<.10	43	<.01	<.01	2.50	.03	530	216
Bc34-14	09-20-93	2.6	28	40	.10	23	.09	<.01	.23	.04	410	208
Bc34-16	10-05-93	4.5	--	21	.30	27	.04	<.01	<.05	<.01	220	--
Bc41-13	09-30-93	3.0	5.9	15	.20	20	.02	<.01	.20	<.01	<80	91
Bc42-16	10-14-93	4.5	5.6	42	.10	19	<.01	<.01	4.80	.03	120	156
	09-08-94		5.9	41	<.10	20	.02	.02	4.50	.03	170	--
Bc42-22	09-28-93	3.7	13	33	.10	23	.02	<.01	.63	<.01	160	124
Bc42-28	10-19-93	2.9	4.2	20	<.10	16	<.01	<.01	.55	.03	100	91
Bc43-15	10-07-93	2.8	3.6	16	.20	23	<.01	<.01	6.30	.02	320	109
Cc11-16	09-29-93	3.1	8.5	8.4	<.10	30	.02	<.01	3.20	.03	1,000	112
Cc12-02	10-21-93	1.4	3.7	2.4	.10	30	<.01	<.01	1.20	.03	1,300	68

Table 21. *Results of chemical analyses for selected trace constituents in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Arsenic (µg/L)	Barium (µg/L)	Beryllium (µg/L)	Boron (µg/L)	Cadmium (µg/L)	Chromium (µg/L	Cobalt (µg/L)	Copper (µg/L)	Iron (µg/L)
Pennsylvania											
CH-21	300WSCKO	07-21-93	--	15	<0.5	--	<1.0	<5	<3	40	15
26	000MFCGH	08-17-93	--	24	<.5	--	2.0	<5	<3	<10	9
71	300CCKV	08-30-93	--	39	<.5	--	<1.0	<5	<3	<10	3
770	300STRS	07-22-93	--	170	<.5	--	1.0	<5	<3	<10	25
2021	300WSCKO	09-07-93	--	85	<.5	--	<1.0	<5	<3	40	31
2067	[1]400FLCGH	08-02-93	--	58	<.5	--	<1.0	<5	<3	<10	4
2071	300STRS	08-09-93	--	27	<.5	--	<1.0	<5	<3	<10	39
2342	400FLCGH	07-29-93	--	78	<.5	--	<1.0	<5	5	<10	7,500
2513	300STRS	08-03-93	--	40	<.5	--	<1.0	<5	<3	<10	26
2593	300STRS	09-09-93	--	76	<.5	--	<1.0	<5	<3	<10	16
2593	300STRS	09-09-93	--	76	<.5	--	<1.0	<5	<3	<10	17
2596	000MFCGH	08-11-93	--	17	<.5	--	<1.0	<5	<3	10	<3
3210	300CCKV	08-10-93	--	41	<.5	--	<1.0	<5	<3	<10	6
3382	400FLCGH	09-10-93	--	75	<.5	--	<1.0	<5	<3	40	4
3383	300WSCKO	09-08-93	--	6	<.5	--	<1.0	<5	<3	<10	20
3384	400FLCGH	09-08-93	--	75	<.5	--	<1.0	<5	20	<10	5,000
		07-13-94	<1	--	--	10	--	--	--	--	4,600
3392	300WSCKO	09-08-93	--	37	<.5	--	<1.0	<5	<3	<10	4
3396	400FLCGH	07-27-93	--	30	<.5	--	<1.0	<5	<3	<10	19
3398	400FLCGH	07-29-93	--	50	<.5	--	<1.0	<5	<3	<10	5,500
3405	000MFCGH	08-09-93	--	19	<.5	--	<1.0	5	<3	<10	<3
3426	[1]300WSCKO	09-01-93	--	94	<.5	--	<1.0	<5	<3	<10	6
3430	400FLCGH	08-04-93	--	91	<.5	--	<1.0	<5	<3	10	9
		07-12-94	<1	--	--	<10	--	--	--	--	53
3432	300WSCKO	09-08-93	--	16	<.5	--	<1.0	<5	<3	30	<3
3434	300WSCKO	08-31-93	--	48	<.5	--	1.0	<5	<3	20	8
3441	300WSCKO	09-09-93	--	5	<.5	--	<1.0	<5	<3	<10	910
3444	000MFCGH	08-10-93	--	8	<.5	--	<1.0	<5	<3	<10	<3
3445	300WSCKO	08-19-93	--	<2	<.5	--	<1.0	<5	<3	<10	570
		07-12-94	<1	--	--	<10	--	--	--	--	620
3447	[2]300WSCKO	08-12-93	--	32	<.5	--	1.0	<5	<3	20	4
3448	300WSCKO	09-09-93	--	37	<.5	--	<1.0	<5	<3	<10	38
3482	400FLCGH	07-27-93	--	60	<.5	--	<1.0	<5	<3	<10	27
		07-13-94	<1	--	--	<10	--	--	--	--	<3
3484	400FLCGH	08-03-93	--	58	<.5	--	<1.0	<5	<3	<10	17
		07-13-94	<1	--	--	<10	--	--	--	--	13
3485	300WSCKO	08-12-93	--	29	<.5	--	<1.0	<5	<3	50	27
3487	400FLCGH	07-28-93	--	48	<.5	--	<1.0	<5	<3	<10	1,700
3488	300WSCKO	09-02-93	--	27	<.5	--	<1.0	<5	<3	<10	17

__Table 21.__ Results of chemical analyses for selected trace constituents in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Date of sample	Lead (µg/L)	Lithium (µg/L)	Manganese (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Silver (µg/L)	Strontium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)
Pennsylvania										
CH-21	07-21-93	<10	5	4	<10	<10	<1.0	120	<6	26
26	08-17-93	<10	<4	220	<10	<10	<1.0	170	<6	540
71	08-30-93	<10	5	1	<10	<10	<1.0	49	<6	100
770	07-22-93	<10	6	54	<10	50	<1.0	900	<6	32
2021	09-07-93	10	<4	4	<10	<10	<1.0	96	<6	8
2067	08-02-93	<10	<4	<1	<10	<10	<1.0	66	<6	<3
2071	08-09-93	<10	<4	11	<10	<10	<1.0	6	<6	19
2342	07-29-93	<10	<4	200	<10	<10	<1.0	66	<6	7
2513	08-03-93	<10	<4	3	<10	<10	<1.0	68	<6	<3
2593	09-09-93	<10	<4	3	<10	<10	<1.0	140	<6	8
2596	08-11-93	<10	8	<1	<10	<10	<1.0	130	<6	<3
3210	08-10-93	<10	<4	<1	10	<10	<1.0	71	<6	97
3382	09-10-93	<10	<4	<1	<10	<10	<1.0	130	<6	<3
3383	09-08-93	<10	9	23	<10	<10	<1.0	110	<6	<3
3384	09-08-93	<10	<4	160	<10	<10	<1.0	110	<6	75
	07-13-94	--	--	200	--	--	--	--	--	--
3392	09-08-93	<10	6	30	<10	<10	<1.0	190	<6	<3
3396	07-27-93	<10	<4	5	<10	<10	<1.0	44	<6	<3
3398	07-29-93	<10	<4	270	<10	<10	<1.0	74	<6	<3
3405	08-09-93	<10	<4	<1	<10	<10	<1.0	44	<6	<3
3426	09-01-93	<10	<4	240	<10	<10	<1.0	94	<6	<3
3430	08-04-93	<10	<4	45	<10	<10	<1.0	130	<6	10
	07-12-94	--	--	44	--	--	--	--	--	--
3432	09-08-93	<10	<4	31	<10	<10	<1.0	80	<6	<3
3434	08-31-93	<10	<4	<1	<10	<10	1.0	88	<6	<3
3441	09-09-93	<10	<4	160	<10	<10	<1.0	100	<6	<3
3444	08-10-93	<10	7	<1	<10	<10	<1.0	56	<6	<3
3445	08-19-93	<10	<4	69	<10	<10	<1.0	76	<6	<3
	07-12-94	--	--	66	--	--	--	--	--	--
3447	08-12-93	<10	<4	4	<10	<10	<1.0	130	<6	6
3448	09-09-93	<10	9	130	<10	<10	<1.0	120	<6	5
3482	07-27-93	<10	<4	23	<10	<10	<1.0	99	<6	10
3484	08-03-93	<10	13	9	<10	<10	<1.0	170	<6	7
	07-13-94	--	--	9	--	--	--	--	--	--
3485	08-12-93	<10	5	9	<10	<10	<1.0	120	<6	7
3487	07-28-93	<10	<4	60	<10	<10	<1.0	54	<6	5
3488	09-02-93	<10	<4	92	<10	<10	<1.0	96	<6	<3

Table 21. *Results of chemical analyses for selected trace constituents in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Arsenic (µg/L)	Barium (µg/L)	Beryllium (µg/L)	Boron (µg/L)	Cadmium (µg/L)	Chromium (µg/L	Cobalt (µg/L)	Copper (µg/L)	Iron (µg/L)
3495	400FLCGH	07-22-93	--	21	<0.5	--	1.0	<5	<3	870	<3
3504	300WSCKO	07-20-93	--	16	<.5	--	<1.0	<5	<3	50	<3
3506	300WSCKO	07-08-93	--	15	<.5	--	<1.0	<5	<3	10	18
3513	300WSCKO	09-02-93	--	46	<.5	--	<1.0	<5	<3	20	20
3516	300CCKV	08-02-93	--	25	<.5	--	<1.0	5	<3	<10	<3
		07-13-94	<1	--	--	20	--	--	--	--	<3
3532	400FLCGH	11-16-93	--	84	<.5	--	<1.0	<5	<3	<10	8
3533	300STRS	11-22-93	--	65	<.5	--	<1.0	<5	<3	20	13
3543	400FLCGH	09-01-93	--	92	<.5	--	<1.0	<5	<3	30	7
3558	300WSCKO	08-30-93	--	14	<.5	--	<1.0	<5	<3	<10	<3
3573	300WSCKO	09-09-93	--	66	<.5	--	<1.0	<5	<3	60	31
3580	300WSCKO	08-26-93	--	44	<.5	--	<1.0	<5	<3	<10	4
4343	300WSCKO	12-30-92	--	--	--	--	--	--	--	--	5,600
		04-01-93	--	--	--	--	--	--	--	--	5,700
		06-10-93	--	--	--	--	--	--	--	--	5,200
		09-23-93	--	5	<.5	--	<1.0	<5	20	<10	5,300
4344	[3]300CCKV	03-31-93	--	--	--	--	--	--	--	--	6
		06-16-93	--	--	--	--	--	--	--	--	<10
		09-27-93	--	210	<.5	--	<1.0	<5	<3	<10	<3
		07-07-94	<1	--	--	20	--	--	--	--	<3
4345	300WSCKO	08-19-93		12	<.5	--	<1.0	<5	<3	10	8
		07-11-94	<1	--	--	20	--	--	--	--	13
4361	300WSCKO	08-26-93	--	5	<.5	--	<1.0	<5	<3	<10	69
4362	300WSCKO	08-30-93	--	24	<.5	--	<1.0	<5	<3	<10	5
4410	300WSCKO	07-21-93	--	16	<.5	--	<1.0	<5	<3	<10	740
4412	400FLCGH	07-28-93	--	40	<.5	--	<1.0	<5	<3	<10	<3
4414	300WSCKO	08-04-93	--	24	<.5	--	<1.0	<5	<3	<10	250
4415	400FLCGH	08-05-93	--	380	<.5	--	<1.0	<5	<3	10	22
4416	300WSCKO	08-18-93	--	43	<.5	--	<1.0	<5	<3	<10	8
4417	300STRS	08-24-93	--	70	<.5	--	<1.0	<5	<3	<10	630
4418	400FLCGH	08-25-93	--	35	<.5	--	1.0	<5	<3	<10	65
4552	300CCKV	08-30-93	--	71	<.5	--	<1.0	<5	<3	<10	<3
4727	300WSCKO	08-31-93	--	14	<.5	--	<1.0	<5	<3	90	6
4728	300CCKV	09-01-93	--	15	<.5	--	<1.0	<5	<3	<10	<3
4729	300CCKV	09-02-93	--	23	<.5	--	<1.0	<5	<3	<10	<3
4730	[1]300STRS	09-07-93	--	130	<.5	--	<1.0	<5	<3	<10	84
		07-11-94	<1	--	--	10	--	--	--	--	27
4731	300STRS	09-10-93	--	73	<.5	--	<1.0	<5	<3	10	3

***Table 21.** Results of chemical analyses for selected trace constituents in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Date of sample	Lead (µg/L)	Lithium (µg/L)	Manganese (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Silver (µg/L)	Strontium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)
3495	07-22-93	<10	<4	19	<10	<10	<1.0	60	<6	31
3504	07-20-93	<10	10	15	<10	<10	<1.0	68	<6	<3
3506	07-08-93	<10	9	15	<10	<10	1.0	120	<6	25
3513	09-02-93	<10	16	4	<10	<10	<1.0	240	<6	21
3516	08-02-93	<10	5	<1	<10	<10	<1.0	68	<6	<3
	07-13-94	--	--	<1	--	--	--	--	--	--
3532	11-16-93	<10	6	4	<10	<10	1.0	300	<6	14
3533	11-22-93	<10	<4	2	<10	<10	2.0	76	<6	13
3543	09-01-93	<10	4	3	<10	<10	<1.0	160	<6	9
3558	08-30-93	<10	5	15	<10	<10	<1.0	100	<6	350
3573	09-09-93	<10	<4	6	<10	<10	<1.0	110	<6	390
3580	08-26-93	<10	<4	2	<10	<10	<1.0	74	<6	<3
4343	12-30-92	--	--	100	--	--	--	--	--	--
	04-01-93	--	--	90	--	--	--	--	--	--
	06-10-93	--	--	80	--	--	--	--	--	--
	09-23-93	<10	10	96	<10	<10	<1.0	50	<6	<3
4344	03-31-93	--	--	3	--	--	--	--	--	--
	06-16-93	--	--	<10	--	--	--	--	--	--
	09-27-93	<10	<4	1	<10	<10	<1.0	330	<6	5
	07-07-94	--	--	<1	--	--	--	--	--	--
4345	08-19-93	<10	<4	2	<10	<10	<1.0	75	<6	<3
	07-11-94	--	--	2	--	--	--	--	--	--
4361	08-26-93	<10	<4	16	<10	<10	2.0	36	<6	<3
4362	08-30-93	10	<4	3	<10	<10	2.0	98	<6	26
4410	07-21-93	<10	11	140	<10	<10	<1.0	140	<6	<3
4412	07-28-93	<10	<4	<1	<10	<10	<1.0	90	<6	7
4414	08-04-93	<10	12	63	<10	<10	<1.0	250	<6	31
4415	08-05-93	<10	<4	12	<10	<10	<1.0	200	<6	<3
4416	08-18-93	<10	5	130	<10	<10	<1.0	99	<6	<3
4417	08-24-93	<10	<4	81	<10	<10	1.0	53	<6	<3
4418	08-25-93	<10	4	88	<10	<10	<1.0	140	<6	<3
4552	08-30-93	<10	6	<1	<10	<10	<1.0	57	<6	4
4727	08-31-93	<10	<4	<1	10	<10	<1.0	120	<6	8
CH-4728	09-01-93	<10	5	11	<10	<10	<1.0	79	<6	<3
4729	09-02-93	<10	<4	2	<10	<10	<1.0	64	<6	54
4730	09-07-93	<10	11	170	<10	<10	<1.0	390	<6	5
	07-11-94	--	--	210	--	--	--	--	--	--
4731	09-10-93	<10	<4	44	<10	<10	<1.0	220	<6	4

***Table 21.** Results of chemical analyses for selected trace constituents in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Arsenic (µg/L)	Barium (µg/L)	Beryllium (µg/L)	Boron (µg/L)	Cadmium (µg/L)	Chromium (µg/L	Cobalt (µg/L)	Copper (µg/L)	Iron (µg/L)
Delaware											
Bb24-15	300WSCK	10-13-93	--	17	<0.5	--	<1.0	<5	<3	<10	280
Bb25-28	300WSCK	09-22-93	--	23	<.5	--	<1.0	<5	<3	<10	160
Bc12-03	300WSCK	10-13-93	--	2	<.5	--	<1.0	<5	<3	<10	46
Bc13-19	300WSCK	10-06-93	--	17	<.5	--	<1.0	<5	<3	<10	1,100
Bc21-07	300WSCK	09-22-93	--	<2	<.5	--	<1.0	<5	<3	<10	12
Bc21-09	300WSCK	09-30-93	--	14	<.5	--	<1.0	<5	<3	<10	67
Bc22-10	300WSCK	10-07-93	--	18	<.5	--	<1.0	<5	<3	50	30
Bc23-22	300WSCK	10-18-93	--	17	<.5	--	<1.0	<5	<3	<10	<3
Bc31-08	300WSCK	10-05-93	--	17	<.5	--	<1.0	<5	<3	<10	1,900
Bc31-10	300WSCK	10-04-93	--	9	<.5	--	<1.0	<5	<3	50	12
Bc33-09	000SRPN	11-09-93	--	9	<.5	--	<1.0	7	<3	<10	7
Bc34-14	300WSCK	09-20-93	--	7	<.5	--	<1.0	<5	<3	<10	30
Bc34-16	300WSCK	10-05-93	--	120	<.5	--	<1.0	<5	9	<10	6,200
Bc34-16	300WSCK	10-05-93	--	120	<.5	--	<1.0	<5	9	<10	6,200
Bc41-13	300WSCK	09-30-93	--	16	<.5	--	<1.0	<5	<3	<10	250
Bc42-16	300WSCK	10-14-93	--	10	<.5	--	<1.0	<5	<3	20	<3
		09-08-94	<1	--	--	--	--	--	--	--	<3
Bc42-22	300WSCK	09-28-93	--	40	<.5	--	1.0	<5	<3	<10	150
Bc42-28	300WSCK	10-19-93	--	<2	<.5	--	<1.0	<5	<3	<10	<3
Bc43-15	300WLMG	10-07-93	--	13	<.5	--	<1.0	<5	<3	40	9
Cc11-16	300WLMG	09-29-93	--	53	<.5	--	<1.0	9	<3	50	10
Cc12-02	300WLMG	10-21-93	--	26	<.5	--	<1.0	9	<3	60	6

[1] Near contact with 300CCKV.
[2] Near contact with 000PGMT.
[3] Near contact with 300STRS.

Table 21. *Results of chemical analyses for selected trace constituents in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1992-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Date of sample	Lead (µg/L)	Lithium (µg/L)	Manganese (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Silver (µg/L)	Strontium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)
Delaware										
Bb24-15	10-13-93	<10	<4	120	<10	<10	<1.0	70	<6	<3
Bb25-28	09-22-93	<10	<4	86	<10	<10	<1.0	140	<6	<3
Bc12-03	10-13-93	<10	<4	92	<10	<10	2.0	62	<6	<3
Bc13-19	10-06-93	10	<4	58	<10	<10	<1.0	88	<6	4
Bc21-07	09-22-93	<10	<4	2	<10	<10	<1.0	74	<6	<3
Bc21-09	09-30-93	<10	<4	28	<10	<10	<1.0	130	<6	9
Bc22-10	10-07-93	10	<4	71	<10	<10	<1.0	120	<6	500
Bc23-22	10-18-93	<10	<4	37	<10	<10	<1.0	170	<6	91
Bc31-08	10-05-93	<10	11	100	<10	<10	<1.0	84	<6	170
Bc31-10	10-04-93	10	<4	2	<10	<10	<1.0	70	<6	<3
Bc33-09	11-09-93	<10	<4	3	<10	<10	<1.0	24	<6	30
Bc34-14	09-20-93	<10	<4	85	<10	<10	<1.0	320	<6	<3
Bc34-16	10-05-93	<10	4	910	<10	<10	<1.0	340	<6	8
Bc34-16	10-05-93	<10	4	910	<10	<10	<1.0	340	<6	8
Bc41-13	09-30-93	<10	<4	66	<10	<10	<1.0	100	<6	<3
Bc42-16	10-14-93	<10	8	10	<10	<10	<1.0	190	<6	18
	09-08-94	--	--	9	--	--	--	--	--	--
Bc42-22	09-28-93	<10	<4	63	<10	<10	<1.0	110	<6	<3
Bc42-28	10-19-93	<10	<4	<1	<10	<10	<1.0	63	<6	<3
Bc43-15	10-07-93	10	<4	2	<10	<10	2.0	110	<6	13
Cc11-16	09-29-93	<10	<4	2	<10	<10	<1.0	45	<6	11
Cc12-02	10-21-93	<10	<4	2	<10	<10	<1.0	28	<6	9

Table 22. *Results of chemical analyses for organochlorine insecticides and polychlorobiphenyl compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; μg/L, micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Aldrin, total (μg/L)	alpha BHC, dissolved (μg/L)	Chlordane, total (μg/L)	DDD, total (μg/L)	DDE, total (μg/L)	DDT, total (μg/L)	Dieldrin, total (μg/L)	Dieldrin, dissolved (μg/L)	Endosulfan, total (μg/L)	Endrin total (μg/L)
Pennsylvania												
CH-21	300WSCKO	07-21-93	<0.01	<0.007	<0.1	<0.01	<0.01	<0.01	<0.01	<0.020	<0.01	<0.01
26	000MFCGH	08-17-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
71	300CCKV	08-30-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
770	300STRS	07-22-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2021	300WSCKO	09-07-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2067	[1]400FLCGH	08-02-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2071	300STRS	08-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2342	400FLCGH	07-29-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2513	300STRS	08-03-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2593	300STRS	09-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
2596	000MFCGH	08-11-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3210	300CCKV	08-10-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3382	400FLCGH	09-10-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3383	300WSCKO	09-08-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3384	400FLCGH	09-08-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	.022	<.01	<.01
3392	300WSCKO	09-08-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3396	400FLCGH	07-27-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3398	400FLCGH	07-29-93	--	<.007	--	--	--	--	--	<.020	--	--
3405	000MFCGH	08-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3426	[1]300WSCKO	09-01-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3430	400FLCGH	08-04-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3432	300WSCKO	09-08-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3434	300WSCKO	08-31-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3441	300WSCKO	09-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3444	000MFCGH	08-10-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3445	300WSCKO	08-19-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3447	[2]300WSCKO	08-12-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3448	300WSCKO	09-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3482	400FLCGH	07-27-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3484	400FLCGH	08-03-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3485	300WSCKO	08-12-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3487	400FLCGH	07-28-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3488	300WSCKO	09-02-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3495	400FLCGH	07-22-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3504	300WSCKO	07-20-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3506	300WSCKO	07-08-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3513	300WSCKO	09-02-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3516	300CCKV	08-02-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3532	400FLCGH	11-16-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3533	300STRS	11-22-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3543	400FLCGH	09-01-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3558	300WSCKO	08-30-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3573	300WSCKO	09-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
3580	300WSCKO	08-26-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01

***Table 22.** Results of chemical analyses for organochlorine insecticides and polychlorobiphenyl compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ug/L, micrograms per liter]

USGS local well number	Date of sample	Hep-tachlor total (µg/L)	Hep-tachlor epoxide total (µg/L)	Lindane, total (µg/L)	Lindane, dissolved (µg/L)	Methoxy-chlor, total (µg/L)	Mirex, total (µg/L)	P,P' DDE, dissolved (µg/L)	PCB's, total (µg/L)	PCN's, total (µg/L)	Perthane, total (µg/L)	Tox-aphene, total (µg/L)	HCH alpha D surrogate, total, percent recovery
Pennsylvania													
CH-21	07-21-93	<0.01	<0.01	<0.01	<0.011	<0.01	<0.01	<0.02	<0.1	<0.1	<0.1	<1	95.0
26	08-17-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	85.0
71	08-30-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	77.0
770	07-22-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	110.0
2021	09-07-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	85.0
2067	08-02-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	80.0
2071	08-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	78.0
2342	07-29-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	78.0
2513	08-03-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	90.0
2593	09-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	86.0
2596	08-11-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	80.0
3210	08-10-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	84.0
3382	09-10-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	86.0
3383	09-08-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	76.0
3384	09-08-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	85.0
3392	09-08-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	87.0
3396	07-27-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	82.0
3398	07-29-93	--	--	--	<.011	--	--	<.02	--	--	--	--	79.0
3405	08-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	75.0
3426	09-01-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	71.0
3430	08-04-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	74.0
3432	09-08-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	87.0
3434	08-31-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	80.0
3441	09-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	86.0
3444	08-10-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	82.0
3445	08-19-93	<.01	<.01	.04	.035	<.01	<.01	<.02	<.1	<.1	<.1	<1	75.0
3447	08-12-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	80.0
3448	09-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	79.0
3482	07-27-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	86.0
3484	08-03-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	87.0
3485	08-12-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	76.0
3487	07-28-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	86.0
3488	09-02-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	69.0
3495	07-22-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	93.0
3504	07-20-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	81.0
3506	07-08-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	100.0
3513	09-02-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	65.0
3516	08-02-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	76.0
3532	11-16-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	92.0
3533	11-22-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	81.0
3543	09-01-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	69.0
3558	08-30-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	75.0
3573	09-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	93.0
3580	08-26-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	91.0

Table 22. *Results of chemical analyses for organochlorine insecticides and polychlorobiphenyl compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; µg/L, micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Aldrin, total (µg/L)	alpha BHC, dissolved (µg/L)	Chlordane, total (µg/L)	DDD, total (µg/L)	DDE, total (µg/L)	DDT, total (µg/L)	Dieldrin, total (µg/L)	Dieldrin, dissolved (µg/L)	Endosulfan, total (µg/L)	Endrin total (µg/L)
4343	300WSCKO	09-23-93	<0.01	<0.007	<0.1	<0.01	<0.01	<0.01	<0.01	<0.020	<0.01	<0.01
4344	[3]300CCKV	09-27-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4345	300WSCKO	08-19-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4361	300WSCKO	08-26-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4362	300WSCKO	08-30-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4410	300WSCKO	07-21-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4412	400FLCGH	07-28-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4414	300WSCKO	08-04-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4415	400FLCGH	08-05-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4416	300WSCKO	08-18-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4417	300STRS	08-24-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4418	400FLCGH	08-25-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4552	300CCKV	08-30-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4727	300WSCKO	08-31-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4728	300CCKV	09-01-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4729	300CCKV	09-02-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4730	[1]300STRS	09-07-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
4731	300STRS	09-10-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Delaware												
Bb24-15	300WSCK	10-13-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bb25-28	300WSCK	09-22-93	<.01	<.007	<.1	<.01	<.01	<.01	.40	.370	<.01	<.01
Bc12-03	300WSCK	10-13-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc13-19	300WSCK	10-06-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc21-07	300WSCK	09-22-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc21-09	300WSCK	09-30-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc22-10	300WSCK	10-07-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc23-22	300WSCK	10-18-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc31-08	300WSCK	10-05-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc31-10	300WSCK	10-04-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc33-09	0SRPN	11-09-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc34-14	300WSCK	09-20-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc34-16	300WSCK	10-05-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc41-13	300WSCK	09-30-93	--	<.007	--	--	--	--	--	<.020	--	--
Bc42-16	300WSCK	10-14-93	<.01	<.007	3.0	<.01	<.01	<.01	<.01	<.020	<.01	<.01
		09-08-94	<.01	--	2.0	<.01	<.01	<.01	<.01	--	<.01	<.01
Bc42-22	300WSCK	09-28-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc42-28	300WSCK	10-19-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Bc43-15	300WLMG	10-07-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01
Cc11-16	300WLMG	09-29-93	<.01	<.007	.1	<.01	<.01	<.01	.08	.072	<.01	<.01
Cc12-02	300WLMG	10-21-93	<.01	<.007	<.1	<.01	<.01	<.01	<.01	<.020	<.01	<.01

[1] Near contact with 300CCKV.
[2] Near contact with 000PGMT.
[3] Near contact with 300STRS.

Table 22. *Results of chemical analyses for organochlorine insecticides and polychlorobiphenyl compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; ug/L, micrograms per liter]

USGS local well number	Date of sample	Hep-tachlor total (μg/L)	Hep-tachlor epoxide total (μg/L)	Lindane, total (μg/L)	Lindane, dissolved (μg/L)	Methoxy-chlor, total (μg/L)	Mirex, total (μg/L)	P,P' DDE, dissolved (μg/L)	PCB's, total (μg/L)	PCN's, total (μg/L)	Perthane, total (μg/L)	Tox-aphene, total (μg/L)	HCH alpha D surrogate, total, percent recovery
4343	09-23-93	<0.01	<0.01	<0.01	<0.011	<0.01	<0.01	<0.01	<0.1	<0.1	<0.1	<1	83.0
4344	09-27-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	91.0
4345	08-19-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	76.0
4361	08-26-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	77.0
4362	08-30-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	79.0
4410	07-21-93	<.01	--	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	110.00
4412	07-28-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	85.0
4414	08-04-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	66.0
4415	08-05-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	70.0
4416	08-18-93	<.01	<.01	.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	74.0
4417	08-24-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	84.0
4418	08-25-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	82.0
4552	08-30-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	79.0
4727	08-31-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	74.0
4728	09-01-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	69.0
4729	09-02-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	72.0
4730	09-07-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	92.0
4731	09-10-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	97.0
Delaware													
Bb24-15	10-13-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	69.0
Bb25-28	09-22-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	88.0
Bc12-03	10-13-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	62.0
Bc13-19	10-06-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	84.0
Bc21-07	09-22-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	80.0
Bc21-09	09-30-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	80.0
Bc22-10	10-07-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	87.0
Bc23-22	10-18-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	73.0
Bc31-08	10-05-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	88.0
Bc31-10	10-04-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	90.0
Bc33-09	11-09-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	74.0
Bc34-14	09-20-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	93.0
Bc34-16	10-05-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	87.0
Bc41-13	09-30-93	--	--	--	<.011	--	--	<.01	--	--	--	--	83.0
Bc42-16	10-14-93	<.01	.04	<.01	<.011	<.01	<.01	<.02	1.0	<.1	<.1	<1	71.0
	09-08-94	<.01	.04	<.01	--	<.01	<.01	--	1.0	<.1	<.1	<1	--
Bc42-22	09-28-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	87.0
Bc42-28	10-19-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	92.0
Bc43-15	10-07-93	<.01	<.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	88.0
Cc11-16	09-29-93	<.01	.01	<.01	<.011	<.01	<.01	<.01	<.1	<.1	<.1	<1	89.0
Cc12-02	10-21-93	<.01	<.01	<.01	<.011	<.01	<.01	<.02	<.1	<.1	<.1	<1	73.0

Table 23. *Results of chemical analyses for organophosphorus insecticides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT; μg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Geologic unit	Date of sample	Chlorpyrifos, dissolved (μg/L)	Diazinon, dissolved (μg/L)	Dimethoate, dissolved (μg/L)	Disulfoton, dissolved (μg/L)	Ethoprop, dissolved (μg/L)	Fonofos, dissolved (μg/L)
Pennsylvania								
CH-21	300WSCKO	07-21-93	<0.005	<0.008	<0.024	<0.020	<0.012	<0.008
26	000MFCGH	08-17-93	<.005	<.008	<.024	<.020	<.012	<.008
71	300CCKV	08-30-93	<.005	<.008	<.024	<.020	<.012	<.008
770	300STRS	07-22-93	<.005	<.008	<.024	<.020	<.012	<.008
2021	300WSCKO	09-07-93	<.005	<.008	<.024	<.020	<.012	<.008
2067	[1]400FLCGH	08-02-93	<.005	<.008	<.024	<.020	<.012	<.008
2071	300STRS	08-09-93	<.005	<.008	<.024	<.020	<.012	<.008
2342	400FLCGH	07-29-93	<.005	<.008	<.024	<.020	<.012	<.008
2513	300STRS	08-03-93	<.005	<.008	<.024	<.020	<.012	<.008
2593	300STRS	09-09-93	<.005	<.008	<.024	<.020	<.012	<.008
2596	000MFCGH	08-11-93	<.005	<.008	<.024	<.020	<.012	<.008
3210	300CCKV	08-10-93	<.005	<.008	<.024	<.020	<.012	<.008
3382	400FLCGH	09-10-93	<.005	<.008	<.024	<.020	<.012	<.008
3383	300WSCKO	09-08-93	<.005	<.008	<.024	<.020	<.012	<.008
3384	400FLCGH	09-08-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-13-94	<.008	<.008	<.024	<.060	<.012	<.008
3392	300WSCKO	09-08-93	<.005	<.008	<.024	<.020	<.012	<.008
3396	400FLCGH	07-27-93	<.005	<.008	<.024	<.020	<.012	<.008
3398	400FLCGH	07-29-93	<.005	<.008	<.024	<.020	<.012	<.008
3405	000MFCGH	08-09-93	<.005	<.008	<.024	<.020	<.012	<.008
3426	[1]300WSCKO	09-01-93	<.005	<.008	<.024	<.020	<.012	<.008
3430	400FLCGH	08-04-93	<.005	.018	<.024	<.020	<.012	<.008
		07-12-94	<.008	<.008	<.024	<.060	<.012	<.008
3432	300WSCKO	09-08-93	<.005	<.008	<.024	<.020	<.012	<.008
3434	300WSCKO	08-31-93	<.005	<.008	<.024	<.020	<.012	<.008
3441	300WSCKO	09-09-93	<.005	<.008	<.024	<.020	<.012	<.008
3444	000MFCGH	08-10-93	<.005	<.008	<.024	<.020	<.012	<.008
3445	300WSCKO	08-19-93	<.005	.057	<.024	<.020	<.012	<.008
		07-12-94	<.008	<.008	<.024	<.060	<.012	<.008
3447	[2]300WSCKO	08-12-93	<.005	<.008	<.024	<.020	<.012	<.008
3448	300WSCKO	09-09-93	<.005	<.008	<.024	<.020	<.012	<.008
3482	400FLCGH	07-27-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-13-94	<.008	<.008	<.024	<.060	<.012	<.008
3484	400FLCGH	08-03-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-13-94	<.008	<.008	<.024	<.060	<.012	<.008
3485	300WSCKO	08-12-93	<.005	<.008	<.024	<.020	<.012	<.008
3487	400FLCGH	07-28-93	<.005	<.008	<.024	<.020	<.012	<.008
3488	300WSCKO	09-02-93	<.005	<.008	<.024	<.020	<.012	<.008
3495	400FLCGH	07-22-93	<.005	<.008	<.024	<.020	<.012	<.008
3504	300WSCKO	07-20-93	<.005	.015	<.024	<.020	<.012	<.008
3506	300WSCKO	07-08-93	<.005	<.008	<.024	<.020	<.012	<.008
3513	300WSCKO	09-02-93	<.005	<.008	<.024	<.020	<.012	<.008
3516	300CCKV	08-02-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-13-94	<.005	<.008	<.024	<.060	<.012	<.008
3532	400FLCGH	11-16-93	<.005	<.008	<.024	<.020	<.012	<.008
3533	300STRS	11-22-93	<.005	<.008	<.024	<.020	<.012	<.008
3543	400FLCGH	09-01-93	<.005	<.008	<.024	<.020	<.012	<.008
3558	300WSCKO	08-30-93	<.005	<.008	<.024	<.020	<.012	<.008
3573	300WSCKO	09-09-93	<.005	<.008	<.024	<.020	<.012	<.008

Table 23. *Results of chemical analyses for organophosphorous insecticides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation, in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT;ug/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	Malathion, dissolved (µg/L)	Methyl-azinphos, dissolved (µg/L)	Methyl parathion, dissolved (µg/L)	Parathion, dissolved (µg/L)	Phorate, dissolved (µg/L)	Terbufos, dissolved (µg/L)	Diazinon D10 surrogate, percent recovery
Pennsylvania								
CH-21	07-21-93	<0.010	<0.038	<0.035	<0.022	<0.020	<0.012	75.0
26	08-17-93	<.014	<.080	<.035	<.022	<.020	<.012	76.3
71	08-30-93	<.014	<.080	<.035	<.022	<.020	<.012	92.9
770	07-22-93	<.010	<.038	<.035	<.022	<.020	<.012	101.0
2021	09-07-93	<.010	<.038	<.035	<.022	<.020	<.012	73.0
2067	08-02-93	<.014	<.080	<.035	<.022	<.020	<.012	80.5
2071	08-09-93	<.014	<.080	<.035	<.022	<.020	<.012	66.5
2342	07-29-93	<.014	<.080	<.035	<.022	<.020	<.012	79.1
2513	08-03-93	<.014	<.080	<.035	<.022	<.020	<.012	80.4
2593	09-09-93	<.010	<.038	<.035	<.022	<.020	<.012	74.3
2596	08-11-93	<.014	<.080	<.035	<.022	<.020	<.012	77.4
3210	08-10-93	<.014	<.080	<.035	<.022	<.020	<.012	87.5
3382	09-10-93	<.010	<.038	<.035	<.022	<.020	<.012	74.9
3383	09-08-93	<.010	<.038	<.035	<.022	<.020	<.012	65.3
3384	09-08-93	<.010	<.038	<.035	<.022	<.020	<.012	83.3
	07-13-94	<.014	<.005	<.035	<.022	<.011	<.012	102.0
3392	09-08-93	.003e	<.038	<.035	<.022	<.020	<.012	73.6
3396	07-27-93	<.014	<.080	<.035	<.022	<.020	<.012	88.0
3398	07-29-93	<.014	<.080	<.035	<.022	<.020	<.012	80.1
3405	08-09-93	<.014	<.080	<.035	<.022	<.020	<.012	77.0
3426	09-01-93	<.014	<.080	<.035	<.022	<.020	<.012	77.0
3430	08-04-93	<.014	<.080	<.035	<.022	<.020	<.012	81.9
	07-12-94	<.014	<.005	<.035	<.022	<.011	<.012	92.0
3432	09-08-93	<.010	<.038	<.035	<.022	<.020	<.012	76.1
3434	08-31-93	<.014	<.080	<.035	<.022	<.020	<.012	83.0
3441	09-09-93	<.010	<.038	<.035	<.022	<.020	<.012	69.3
3444	08-10-93	<.014	<.080	<.035	<.022	<.020	<.012	80.2
3445	08-19-93	.047	<.080	<.035	<.022	<.020	<.012	71.2
	07-12-94	<.014	<.005	<.035	<.022	<.011	<.012	85.3
3447	08-12-93	<.014	<.080	<.035	<.022	<.020	<.012	80.8
3448	09-09-93	<.010	<.038	<.035	<.022	<.020	<.012	76.7
3482	07-27-93	<.014	<.080	<.035	<.022	<.020	<.012	82.6
	07-13-94	<.014	<.080	<.035	<.022	<.011	<.012	101.0
3484	08-03-93	<.014	<.080	<.035	<.022	<.020	<.012	89.4
	07-13-94	<.014	<.005	<.035	<.022	<.011	<.012	101.0
3485	08-12-93	<.014	<.080	<.035	<.022	<.020	<.012	75.8
3487	07-28-93	<.014	<.080	<.035	<.022	<.020	<.012	87.3
3488	09-02-93	<.014	<.080	<.035	<.022	<.020	<.012	65.3
3495	07-22-93	<.010	<.038	<.035	<.022	<.020	<.012	77.8
3504	07-20-93	<.014	<.038	<.035	<.022	<.020	<.012	77.3
3506	07-08-93	<.014	<.038	<.035	<.022	<.020	<.012	100.0
3513	09-02-93	<.014	<.080	<.035	<.022	<.020	<.012	63.7
3516	08-02-93	<.014	<.080	<.035	<.022	<.020	<.012	64.7
	07-13-94	<.014	<.005	<.035	<.022	<.011	<.012	94.4
3532	11-16-93	<.010	<.038	<.035	<.022	<.020	<.012	93.7
3533	11-22-93	<.010	<.038	<.035	<.022	<.020	<.012	92.0
3543	09-01-93	<.014	<.080	<.035	<.022	<.020	<.012	80.3
3558	08-30-93	<.014	<.080	<.035	<.022	<.020	<.012	85.9
3573	09-09-93	<.010	<.038	<.035	<.022	<.020	<.012	96.2

Table 23. *Results of chemical analyses for organophosphorus insecticides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT; µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Geologic unit	Date of sample	Chlorpyrifos, dissolved (µg/L)	Diazinon, dissolved (µg/L)	Dimethoate, dissolved (µg/L)	Disulfoton, dissolved (µg/L)	Ethoprop, dissolved (µg/L)	Fonofos, dissolved (µg/L)
3580	300WSCKO	08-26-93	<0.005	<0.008	<0.024	<0.020	<0.012	<0.008
4343	300WSCKO	09-23-93	<.005	<.008	<.024	<.020	<.012	<.008
4344	[3]300CCKV	09-27-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-07-94	<.008	<.008	<.024	<.060	<.012	<.008
4345	300WSCKO	08-19-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-11-94	<.008	<.008	<.024	<.060	<.012	<.008
4361	300WSCKO	08-26-93	<.005	<.008	<.024	<.020	<.012	<.008
4362	300WSCKO	08-30-93	<.005	<.008	<.024	<.020	<.012	<.008
4410	300WSCKO	07-21-93	<.005	<.008	<.024	<.020	<.012	<.008
4412	400FLCGH	07-28-93	<.005	<.008	<.024	<.020	<.012	<.008
4414	300WSCKO	08-04-93	<.005	<.008	<.024	<.020	<.012	<.008
4415	400FLCGH	08-05-93	<.005	<.008	<.024	<.020	<.012	<.008
4416	300WSCKO	08-18-93	<.005	<.008	<.024	<.020	<.012	<.008
4417	300STRS	08-24-93	<.005	<.008	<.024	<.020	<.012	<.008
4418	400FLCGH	08-25-93	<.005	<.008	<.024	<.020	<.012	<.008
4552	300CCKV	08-30-93	<.005	<.008	<.024	<.020	<.012	<.008
4727	300WSCKO	08-31-93	<.005	<.008	<.024	<.020	<.012	<.008
4728	300CCKV	09-01-93	<.005	<.008	<.024	<.020	<.012	<.008
4729	300CCKV	09-02-93	<.005	<.008	<.024	<.020	<.012	<.008
4730	[1]300STRS	09-07-93	<.005	<.008	<.024	<.020	<.012	<.008
		07-11-94	<.008	5.00	<.024	<.060	<.012	<.008
4731	300STRS	09-10-93	<.005	<.008	<.024	<.020	<.012	<.008
Delaware								
Bb24-15	300WSCK	10-13-93	<.005	<.008	<.024	<.020	<.012	<.008
Bb25-28	300WSCK	09-22-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc12-03	300WSCK	10-13-93	<.005	.012	<.024	<.020	<.012	<.008
Bc13-19	300WSCK	10-06-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc21-07	300WSCK	09-22-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc21-09	300WSCK	09-30-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc22-10	300WSCK	10-07-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc23-22	300WSCK	10-18-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc31-08	300WSCK	10-05-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc31-10	300WSCK	10-04-93	<.005	.003e	<.024	<.020	<.012	<.008
Bc33-09	000SRPN	11-09-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc34-14	300WSCK	09-20-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc34-16	300WSCK	10-05-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc34-16	300WSCK	10-05-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc41-13	300WSCK	09-30-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc42-16	300WSCK	10-14-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc42-22	300WSCK	09-28-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc42-28	300WSCK	10-19-93	<.005	<.008	<.024	<.020	<.012	<.008
Bc43-15	300WLMG	10-07-93	<.005	.003e	<.024	<.020	<.012	<.008
Cc11-16	300WLMG	09-29-93	<.005	<.008	<.024	<.020	<.012	<.008
Cc12-02	300WLMG	10-21-93	<.005	<.008	<.024	<.020	<.012	<.008

[1] Near contact with 300CCKV.
[2] Near contact with 000PGMT.
[3] Near contact with 300STRS.

Table 23. *Results of chemical analyses for organophosphorous insecticides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation, in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT;ug/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	Malathion, dissolved (µg/L)	Methyl-azinphos, dissolved (µg/L)	Methyl parathion, dissolved (µg/L)	Parathion, dissolved (µg/L)	Phorate, dissolved (µg/L)	Terbufos, dissolved (µg/L)	Diazinon D10 surrogate, percent recovery
3580	08-26-93	<0.014	<0.080	<0.035	<0.022	<0.020	<0.012	86.0
4343	09-23-93	<.010	<.038	<.035	<.022	<.020	<.012	70.6
4344	09-27-93	<.010	<.038	<.035	<.022	<.020	<.012	86.9
	07-07-94	<.014	<.005	<.035	<.022	<.011	<.012	116.0
4345	08-19-93	<.014	<.080	<.035	<.022	<.020	<.012	77.9
4361	08-26-93	<.014	<.080	<.035	<.022	<.020	<.012	74.3
4362	08-30-93	<.014	<.080	<.035	<.022	<.020	<.012	83.3
4410	07-21-93	<.010	<.038	<.035	<.022	<.020	<.012	87.6
4412	07-28-93	<.014	<.080	<.035	<.022	<.020	<.012	83.3
4414	08-04-93	<.014	<.080	<.035	<.022	<.020	<.012	77.6
4415	08-05-93	<.014	<.080	<.035	<.022	<.020	<.012	98.3
4416	08-18-93	<.014	<.080	<.035	<.022	<.020	<.012	69.2
4417	08-24-93	<.014	<.080	<.035	<.022	<.020	<.012	99.9
4418	08-25-93	<.014	<.080	<.035	<.022	<.020	<.012	108.0
4552	08-30-93	<.014	<.080	<.035	<.022	<.020	<.012	86.6
4727	08-31-93	<.014	<.080	<.035	<.022	<.020	<.012	84.3
4728	09-01-93	<.014	<.080	<.035	<.022	<.020	<.012	67.8
4729	09-02-93	<.014	<.080	<.035	<.022	<.020	<.012	74.8
4730	09-07-93	<.010	<.038	<.035	<.022	<.020	<.012	77.1
	07-11-94	.880	<.005	<.035	<.022	<.011	<.012	98.9
4731	09-10-93	<.010	<.038	<.035	<.022	<.020	<.012	82.0
Delaware								
Bb24-15	10-13-93	<.014	<.080	<.035	<.022	<.020	<.012	75.6
Bb25-28	09-22-93	<.010	<.038	<.035	<.022	<.020	<.012	72.9
Bc12-03	10-13-93	<.014	<.080	<.035	<.022	<.020	<.012	71.8
Bc13-19	10-06-93	<.010	<.038	<.035	<.022	<.020	<.012	77.0
Bc21-07	09-22-93	<.010	<.038	<.035	<.022	<.020	<.012	59.0
Bc21-09	09-30-93	<.010	<.038	<.035	<.022	<.020	<.012	64.1
Bc22-10	10-07-93	<.010	<.038	<.035	<.022	<.020	<.012	75.3
Bc23-22	10-18-93	<.014	<.080	<.035	<.022	<.020	<.012	88.9
Bc31-08	10-05-93	<.010	<.038	<.035	<.022	<.020	<.012	69.0
Bc31-10	10-04-93	.003e	<.038	<.035	<.022	<.020	<.012	76.0
Bc33-09	11-09-93	<.014	<.080	<.035	<.022	<.020	<.012	83.5
Bc34-14	09-20-93	.003e	<.038	<.035	<.022	<.020	<.012	65.0
Bc34-16	10-05-93	<.010	<.038	<.035	<.022	<.020	<.012	70.5
Bc34-16	10-05-93	<.010	<.038	<.035	<.022	<.020	<.012	70.5
Bc41-13	09-30-93	<.010	<.038	<.035	<.022	<.020	<.012	67.1
Bc42-16	10-14-93	<.014	<.080	<.035	<.022	<.020	<.012	87.7
Bc42-22	09-28-93	<.010	<.038	<.035	<.022	<.020	<.012	87.3
Bc42-28	10-19-93	<.014	<.080	<.035	<.022	<.020	<.012	88.7
Bc43-15	10-07-93	.039	<.038	<.035	<.022	<.020	<.012	86.8
Cc11-16	09-29-93	<.010	<.038	<.035	<.022	<.020	<.012	63.3
Cc12-02	10-21-93	<.014	<.080	<.035	<.022	<.020	<.012	77.1

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Geologic unit	Date of sample	Alachlor, dissolved (µg/L)	Atrazine, dissolved (µg/L)	Benfluralin, dissolved (µg/L)	Butylate, dissolved (µg/L)	Cyanazine, dissolved (µg/L)e	DCPA, dissolved (µg/L)	Deethyl-atrazine, dissolved (µg/L)
Pennsylvania									
CH-21	300WSCKO	07-21-93	<0.009	<0.017	<0.013	<0.008	<0.013	<0.004	<0.020
26	000MFCGH	08-17-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
71	300CCKV	08-30-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
770	300STRS	07-22-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
2021	300WSCKO	09-07-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
2067	[1]400FLCGH	08-02-93	<.009	.110	<.009	<.008	<.013	<.005	.100
2071	300STRS	08-09-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
2342	400FLCGH	07-29-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
2513	300STRS	08-03-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
2593	300STRS	09-09-93	<.009	.005e	<.013	<.008	<.013	<.004	<.020
2596	000MFCGH	08-11-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3210	300CCKV	08-10-93	<.009	.047	<.009	<.008	<.013	<.005	.028
3382	400FLCGH	09-10-93	<.009	.002e	<.013	<.008	<.013	<.004	.031
3383	300WSCKO	09-08-93	<.009	.002e	<.013	<.008	<.013	<.004	<.020
3384	400FLCGH	09-08-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
		07-13-94	<.009	<.017	<.013	<.008	<.013	<.004	<.005
3392	300WSCKO	09-08-93	<.009	<.017	<.013	<.008	<.013	<.002	<.020
3396	400FLCGH	07-27-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3398	400FLCGH	07-29-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3405	000MFCGH	08-09-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3426	[1]300WSCKO	09-01-93	<.009	.019	<.009	<.008	<.013	<.005	<.020
3430	400FLCGH	08-04-93	<.009	.082	<.009	<.008	<.013	<.005	.250
3430	400FLCGH	07-12-94	<.009	.100	<.013	<.008	<.013	<.004	.170
3432	300WSCKO	09-08-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
3434	300WSCKO	08-31-93	<.009	<.006	<.009	<.008	<.013	<.005	.210
3441	300WSCKO	09-09-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
3444	000MFCGH	08-10-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3445	300WSCKO	08-19-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
		07-12-94	<.009	<.017	<.013	<.008	<.013	<.004	<.005
3447	[2]300WSCKO	08-12-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3448	300WSCKO	09-09-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
3482	400FLCGH	07-27-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
		07-13-94	<.009	<.017	<.013	<.008	<.013	<.004	.009e
3484	400FLCGH	08-03-93	<.009	.016	<.009	<.008	<.013	<.005	.100
		07-13-94	<.009	.018	<.013	<.008	<.013	<.004	.096
3485	300WSCKO	08-12-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3487	400FLCGH	07-28-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3488	300WSCKO	09-02-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3495	400FLCGH	07-22-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
3504	300WSCKO	07-20-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3506	300WSCKO	07-08-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3513	300WSCKO	09-02-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3516	300CCKV	08-02-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
		07-13-94	<.009	<.017	<.013	<.008	<.013	<.004	.003e
3532	400FLCGH	11-16-93	<.009	.053	<.013	<.008	<.013	<.004	.062
3533	300STRS	11-22-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
3543	400FLCGH	09-01-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3558	300WSCKO	08-30-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
3573	300WSCKO	09-09-93	<.009	.002e	<.013	<.008	<.013	<.004	<.020

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	EPTC, dissolved (µg/L)	Ethalfluralin, dissolved (µg/L)	Linuron, dissolved (µg/L)	Metolachlor, dissolved (µg/L)	Metribuzin, dissolved (µg/L)	Molinate, dissolved (µg/L)	Napropamide, dissolved (µg/L)
Pennsylvania								
CH-21	07-21-93	<0.005	<0.013	<0.039	<0.009	<0.012	<0.007	<0.010
26	08-17-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
71	08-30-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
770	07-22-93	<.005	<.013	<.039	.006e	<.012	<.007	<.010
2021	09-07-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
2067	08-02-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
2071	08-09-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
2342	07-29-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
2513	08-03-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
2593	09-09-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
2596	08-11-93	<.010	<.013	<.039	.014	<.012	<.007	<.010
3210	08-10-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3382	09-10-93	<.005	<.013	<.039	.001e	<.012	<.007	<.010
3383	09-08-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3384	09-08-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
	07-13-94	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3392	09-08-93	<.005	<.013	<.039	.002e	.004e	<.007	<.010
3396	07-27-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3398	07-29-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3405	08-09-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3426	09-01-93	<.010	<.013	<.039	.002e	<.012	<.007	<.010
3430	08-04-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
	07-12-94	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3432	09-08-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3434	08-31-93	<.010	<.013	<.039	.007e	<.012	<.007	<.010
3441	09-09-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3444	08-10-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3445	08-19-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
	07-12-94	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3447	08-12-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3448	09-09-93	<.005	<.013	<.039	.002e	<.012	<.007	<.010
3482	07-27-93	<.010	<.013	<.039	.008e	<.012	<.007	<.010
	07-13-94	<.005	<.013	<.039	.009	<.012	<.007	<.010
3484	08-03-93	<.010	<.013	<.039	.006e	<.012	<.007	<.010
	07-13-94	<.005	<.013	<.039	.010	<.012	<.007	<.010
3485	08-12-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3487	07-28-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3488	09-02-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3495	07-22-93	<.005	<.013	<.039	.002e	<.012	<.007	<.010
3504	07-20-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3506	07-08-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3513	09-02-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3516	08-02-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
	07-13-94	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3532	11-16-93	<.005	<.013	<.039	.008e	<.012	<.007	<.010
3533	11-22-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
3543	09-01-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3558	08-30-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
3573	09-09-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	Pebulate, dissolved (µg/L)	Pendimethalin, dissolved (µg/L)	Prometon, dissolved (µg/L)	Pronamide, dissolved (µg/L)	Propachlor, dissolved (µg/L)	Propanil, dissolved (µg/L)	Propargite, dissolved (µg/L)
Pennsylvania								
CH-21	07-21-93	<0.009	<0.018	<0.008	<0.009	<0.015	<0.016	<0.010
26	08-17-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
71	08-30-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
770	07-22-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2021	09-07-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2067	08-02-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2071	08-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2342	07-29-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2513	08-03-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2593	09-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
2596	08-11-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3210	08-10-93	<.009	<.018	.360	<.009	<.015	<.016	<.010
3382	09-10-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3383	09-08-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3384	09-08-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-13-94	<.009	<.018	<.008	<.009	<.015	<.016	<.008
3392	09-08-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3396	07-27-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3398	07-29-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3405	08-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3426	09-01-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3430	08-04-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-12-94	<.009	<.018	<.008	<.009	<.015	<.016	<.008
3432	09-08-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3434	08-31-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3441	09-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3444	08-10-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3445	08-19-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-12-94	<.009	<.018	<.008	<.009	<.015	<.016	<.008
3447	08-12-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3448	09-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3482	07-27-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-13-94	<.009	<.018	<.008	<.009	<.015	<.016	<.008
3484	08-03-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-13-94	<.009	<.018	<.008	<.009	<.015	<.016	<.008
3485	08-12-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3487	07-28-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3488	09-02-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3495	07-22-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3504	07-20-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3506	07-08-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3513	09-02-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3516	08-02-93	<.009	<.018	.043	<.009	<.015	<.016	<.010
	07-13-94	<.009	<.018	.040	<.009	<.015	<.016	<.008
3532	11-16-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3533	11-22-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3543	09-01-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3558	08-30-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
3573	09-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010

***Table 24.** Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	Simazine, dissolved (µg/L)	Tebuthiuron, dissolved (µg/L)	Terbacil, dissolved (µg/L)	Thibencarb, dissolved (µg/L)	Triallate, dissolved (µg/L)	Trifluralin, dissolved (µg/L)	Terbuthylazine, surrogate, dissolved percent recovery
Pennsylvania								
CH-21	07-21-93	<0.010	<0.015	<0.030	<0.008	<0.008	<0.012	91.9
26	08-17-93	<.010	<.015	<.030	<.008	<.004	<.012	96.2
71	08-30-93	<.010	<.015	<.030	<.008	<.004	<.012	85.9
770	07-22-93	<.010	<.015	<.030	<.008	<.008	<.012	103.0
2021	09-07-93	<.010	<.015	<.030	<.008	<.008	<.012	79.8
2067	08-02-93	<.010	<.015	<.030	<.008	<.004	<.012	98.9
2071	08-09-93	<.010	<.015	<.030	<.008	<.004	<.012	100.0
2342	07-29-93	<.010	<.015	<.030	<.008	<.004	<.012	96.1
2513	08-03-93	<.010	<.015	<.030	<.008	<.004	<.012	118.0
2593	09-09-93	<.010	<.015	<.030	<.008	<.008	<.012	70.0
2596	08-11-93	<.010	<.015	<.030	<.008	<.004	<.012	91.4
3210	08-10-93	.023	<.015	<.030	<.008	<.004	<.012	116.0
3382	09-10-93	<.010	<.015	<.030	<.008	<.008	<.012	109.0
3383	09-08-93	<.010	<.015	<.030	<.008	<.008	<.012	70.8
3384	09-08-93	<.010	<.015	<.030	<.008	<.008	<.012	82.3
	07-13-94	<.008	<.015	<.030	<.008	<.008	<.012	93.5
3392	09-08-93	<.010	<.015	<.030	<.008	<.008	<.012	89.1
3396	07-27-93	<.010	<.015	<.030	<.008	<.004	<.012	99.9
3398	07-29-93	<.010	<.015	<.030	<.008	<.004	<.012	109.0
3405	08-09-93	<.010	<.015	<.030	<.008	<.004	<.012	109.0
3426	09-01-93	<.010	<.015	<.030	<.008	<.004	<.012	76.5
3430	08-04-93	<.010	<.015	<.030	<.008	<.004	<.012	107.0
	07-12-94	<.008	<.015	<.030	<.008	<.008	<.012	93.6
3432	09-08-93	<.010	<.015	<.030	<.008	<.008	<.012	83.8
3434	08-31-93	<.010	<.015	<.030	<.008	<.004	<.012	82.0
3441	09-09-93	<.010	<.015	<.030	<.008	<.008	<.012	80.2
3444	08-10-93	<.010	<.015	<.030	<.008	<.004	<.012	101.0
3445	08-19-93	<.010	<.015	<.030	<.008	<.004	<.012	77.7
	07-12-94	<.008	<.015	<.030	<.008	<.008	<.012	87.3
3447	08-12-93	<.010	<.015	<.030	<.008	<.004	<.012	91.1
3448	09-09-93	<.010	<.015	<.030	<.008	<.008	<.012	78.5
3482	07-27-93	<.010	<.015	<.030	<.008	<.004	<.012	107.0
	07-13-94	<.008	<.015	<.030	<.008	<.008	<.012	95.4
3484	08-03-93	<.010	<.015	<.030	<.008	<.004	<.012	125.0
	07-13-94	<.008	<.015	<.030	<.008	<.008	<.012	93.1
3485	08-12-93	<.010	<.015	<.030	<.008	<.004	<.012	97.2
3487	07-28-93	<.010	<.015	<.030	<.008	<.004	<.012	98.6
3488	09-02-93	<.010	<.015	<.030	<.008	<.004	<.012	79.7
3495	07-22-93	<.010	<.015	<.030	<.008	<.008	<.012	96.1
3504	07-20-93	<.010	<.015	<.030	<.008	<.004	<.012	93.0
3506	07-08-93	<.010	<.015	<.030	<.008	<.004	<.012	100.0
3513	09-02-93	<.010	<.015	<.030	<.008	<.004	<.012	69.3
3516	08-02-93	<.010	<.015	<.030	<.008	<.004	<.012	104.0
	07-13-94	<.008	<.015	<.030	<.008	<.008	<.012	86.1
3532	11-16-93	<.010	<.015	<.030	<.008	<.008	<.012	104.0
3533	11-22-93	<.010	<.015	<.030	<.008	<.008	<.012	94.8
3543	09-01-93	<.010	<.015	<.030	<.008	<.004	<.012	74.9
3558	08-30-93	<.010	<.015	<.030	<.008	<.004	<.012	82.3
3573	09-09-93	<.010	<.015	<.030	<.008	<.008	<.012	111.0

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Geologic unit	Date of sample	Alachlor, dissolved (µg/L)	Atrazine, dissolved (µg/L)	Benfluralin, dissolved (µg/L)	Butylate, dissolved (µg/L)	Cyanazine, dissolved (µg/L)e	DCPA, dissolved (µg/L)	Deethyl-atrazine, dissolved (µg/L)
3580	300WSCKO	08-26-93	<0.009	<0.006	<0.009	<0.008	<0.013	<0.005	<0.020
4343	300WSCKO	09-23-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
4344	[1]300CCKV	09-27-93	.460	.001e	<.013	<.008	<.013	<.004	.028
		07-07-94	.520	<.017	<.013	<.008	<.013	<.004	.034
4345	300WSCKO	08-19-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4361	300WSCKO	08-26-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4362	300WSCKO	08-30-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4410	300WSCKO	07-21-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
4412	400FLCGH	07-28-93	<.009	.100	<.009	<.008	<.013	<.005	.037
4414	300WSCKO	08-04-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4415	400FLCGH	08-05-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4416	300WSCKO	08-18-93	.024	<.006	<.009	<.008	<.013	<.005	<.020
4417	300STRS	08-24-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4418	400FLCGH	08-25-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4552	300CCKV	08-30-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4727	300WSCKO	08-31-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4728	300CCKV	09-01-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
4729	300CCKV	09-02-93	<.009	.011	<.009	<.008	<.013	<.005	.046
4730	[1]300STRS	09-07-93	<.009	.002e	<.013	<.008	<.013	<.004	<.020
		07-11-94	<.009	.003e	<.013	<.008	<.013	<.004	.003e
4731	300STRS	09-10-93	<.009	.009	<.013	<.008	<.013	<.004	<.020
Delaware									
Bb24-15	300WSCK	10-13-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
Bb25-28	300WSCK	09-22-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc12-03	300WSCK	10-13-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
Bc13-19	300WSCK	10-06-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc21-07	300WSCK	09-22-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc21-09	300WSCK	09-30-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc22-10	300WSCK	10-07-93	<.009	.001e	<.013	<.008	<.013	<.004	<.020
Bc23-22	300WSCK	10-18-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
Bc31-08	300WSCK	10-05-93	<.009	.001e	<.013	<.008	<.013	<.004	<.020
Bc31-10	300WSCK	10-04-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc33-09	000SRPN	11-09-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
Bc34-14	300WSCK	09-20-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc34-16	300WSCK	10-05-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc41-13	300WSCK	09-30-93	<.009	.001e	<.013	<.008	<.013	<.004	<.020
Bc42-16	300WSCK	10-14-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
Bc42-22	300WSCK	09-28-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020
Bc42-28	300WSCK	10-19-93	<.009	<.006	<.009	<.008	<.013	<.005	<.020
Bc43-15	300WLMG	10-07-93	<.009	<.017	<.013	<.008	<.013	<.004	<.020

[1] Near contact with 300CCKV.

[2] Near contact with 000PGMT.

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	EPTC, dissolved (µg/L)	Ethalfluralin, dissolved (µg/L)	Linuron, dissolved (µg/L)	Metolachlor, dissolved (µg/L)	Metribuzin, dissolved (µg/L)	Molinate, dissolved (µg/L)	Napropamide, dissolved (µg/L)
3580	08-26-93	<0.010	<0.013	<0.039	<0.009	<0.012	<0.007	<0.010
4343	09-23-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
4344	09-27-93	<.005	<.013	<.039	.017	.011	<.007	<.010
	07-07-94	<.005	<.013	<.039	.014	.016	<.007	<.010
4345	08-19-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4361	08-26-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4362	08-30-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4410	07-21-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
4412	07-28-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4414	08-04-93	<.010	<.013	<.039	.002e	<.012	<.007	<.010
4415	08-05-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4416	08-18-93	<.010	<.013	<.039	.004e	<.012	<.007	<.010
4417	08-24-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4418	08-25-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4552	08-30-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4727	08-31-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4728	09-01-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4729	09-02-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
4730	09-07-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
	07-11-94	<.005	<.013	<.039	<.009	<.012	<.007	<.010
4731	09-10-93	<.005	<.013	<.039	.003e	<.012	<.007	<.010
Delaware								
Bb24-15	10-13-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
Bb25-28	09-22-93	<.005	<.013	<.039	.002e	<.012	<.007	<.010
Bc12-03	10-13-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
Bc13-19	10-06-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Bc21-07	09-22-93	<.005	<.013	<.039	.001e	<.012	<.007	<.010
Bc21-09	09-30-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Bc22-10	10-07-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Bc23-22	10-18-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
Bc31-08	10-05-93	<.005	<.013	<.039	.002e	<.012	<.007	<.010
Bc31-10	10-04-93	<.005	<.013	<.039	.003e	<.012	<.007	<.010
Bc33-09	11-09-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
Bc34-14	09-20-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Bc34-16	10-05-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Bc41-13	09-30-93	<.005	<.013	<.039	.003e	<.012	<.007	<.010
Bc42-16	10-14-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
Bc42-22	09-28-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Bc42-28	10-19-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010
Bc43-15	10-07-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Cc11-16	09-29-93	<.005	<.013	<.039	<.009	<.012	<.007	<.010
Cc12-02	10-21-93	<.010	<.013	<.039	<.009	<.012	<.007	<.010

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	Pebulate, dissolved (µg/L)	Pendimethalin, dissolved (µg/L)	Prometon, dissolved (µg/L)	Pronamide, dissolved (µg/L)	Propachlor, dissolved (µg/L)	Propanil, dissolved (µg/L)	Propargite, dissolved (µg/L)
3580	08-26-93	<0.009	<0.018	<0.008	<0.009	<0.015	<0.016	<0.010
4343	09-23-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4344	09-27-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-07-94	<.009	<.018	<.008	<.009	<.015	<.016	<.008
4345	08-19-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4361	08-26-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4362	08-30-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4410	07-21-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4412	07-28-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4414	08-04-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4415	08-05-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4416	08-18-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4417	08-24-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4418	08-25-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4552	08-30-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4727	08-31-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4728	09-01-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4729	09-02-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
4730	09-07-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
	07-11-94	<.009	<.018	.013	<.009	<.015	<.016	<.008
4731	09-10-93	<.009	<.018	.010	<.009	<.015	<.016	<.010
Delaware								
Bb24-15	10-13-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bb25-28	09-22-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc12-03	10-13-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc13-19	10-06-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc21-07	09-22-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc21-09	09-30-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc22-10	10-07-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc23-22	10-18-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc31-08	10-05-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc31-10	10-04-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc33-09	11-09-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc34-14	09-20-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc34-16	10-05-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc41-13	09-30-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc42-16	10-14-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc42-22	09-28-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc42-28	10-19-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Bc43-15	10-07-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Cc11-16	09-29-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010
Cc12-02	10-21-93	<.009	<.018	<.008	<.009	<.015	<.016	<.010

Table 24. *Results of chemical analyses for triazines and other herbicides in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, µg/L, micrograms per liter; e, estimated trace quantity]

USGS local well number	Date of sample	Simazine, dissolved (µg/L)	Tebuthiuron, dissolved (µg/L)	Terbacil, dissolved (µg/L)	Thibencarb, dissolved (µg/L)	Triallate, dissolved (µg/L)	Trifluralin, dissolved (µg/L)	Terbuthylazine, surrogate, dissolved percent recovery
3580	08-26-93	<.010	<.015	<.030	<.008	<.004	<.012	93.4
4343	09-23-93	<.010	<.015	<.030	<.008	<.008	<.012	79.8
4344	09-27-93	<.010	<.015	<.030	<.008	<.008	<.012	105.0
	07-07-94	<.008	<.015	<.030	<.008	<.008	<.012	118.0
4345	08-19-93	<.010	<.015	<.030	<.008	<.004	<.012	88.3
4361	08-26-93	<.010	<.015	<.030	<.008	<.004	<.012	85.1
4362	08-30-93	<.010	<.015	<.030	<.008	<.004	<.012	93.0
4410	07-21-93	<.010	<.015	<.030	<.008	<.008	<.012	109.0
4412	07-28-93	<.010	<.015	<.030	<.008	<.004	<.012	97.9
4414	08-04-93	<.010	<.015	<.030	<.008	<.004	<.012	96.7
4415	08-05-93	<.010	<.015	<.030	<.008	<.004	<.012	105.0
4416	08-18-93	<.010	<.015	<.030	<.008	<.004	<.012	79.2
4417	08-24-93	<.010	<.015	<.030	<.008	<.004	<.012	114.0
4418	08-25-93	<.010	<.015	<.030	<.008	<.004	<.012	107.0
4552	08-30-93	<.010	<.015	<.030	<.008	<.004	<.012	82.3
4727	08-31-93	<.010	<.015	<.030	<.008	<.004	<.012	77.5
4728	09-01-93	<.010	<.015	<.030	<.008	<.004	<.012	72.7
4729	09-02-93	<.010	<.015	<.030	<.008	<.004	<.012	74.9
4730	09-07-93	<.010	<.015	<.030	<.008	<.008	<.012	83.5
	07-11-94	<.008	<.015	<.030	<.008	<.008	<.012	92.0
4731	09-10-93	<.010	<.015	<.030	<.008	<.008	<.012	114.0
Delaware								
Bb24-15	10-13-93	<.010	<.015	<.030	<.008	<.004	<.012	99.4
Bb25-28	09-22-93	<.010	<.015	<.030	<.008	<.008	<.012	86.8
Bc12-03	10-13-93	<.010	<.015	<.030	<.008	<.004	<.012	89.7
Bc13-19	10-06-93	<.010	<.015	<.030	<.008	<.008	<.012	104.0
Bc21-07	09-22-93	<.010	<.015	<.030	<.008	<.008	<.012	78.0
Bc21-09	09-30-93	<.010	<.015	<.030	<.008	<.008	<.012	88.2
Bc22-10	10-07-93	<.010	<.015	<.030	<.008	<.008	<.012	102.0
Bc23-22	10-18-93	<.010	<.015	<.030	<.008	<.004	<.012	96.1
Bc31-08	10-05-93	<.010	<.015	<.030	<.008	<.008	<.012	101.0
Bc31-10	10-04-93	<.010	<.015	<.030	<.008	<.008	<.012	97.1
Bc33-09	11-09-93	<.010	<.015	<.030	<.008	<.004	<.012	103.0
Bc34-14	09-20-93	<.010	<.015	<.030	<.008	<.008	<.012	88.2
Bc34-16	10-05-93	<.010	<.015	<.030	<.008	<.008	<.012	106.0
Bc41-13	09-30-93	<.010	<.015	<.030	<.008	<.008	<.012	88.2
Bc42-16	10-14-93	<.010	<.015	<.030	<.008	<.004	<.012	94.4
Bc42-22	09-28-93	<.010	<.015	<.030	<.008	<.008	<.012	106.0
Bc42-28	10-19-93	<.010	<.015	<.030	<.008	<.004	<.012	94.7
Bc43-15	10-07-93	<.010	<.015	<.030	<.008	<.008	<.012	101.0
Cc11-16	09-29-93	<.010	<.015	<.030	<.008	<.008	<.012	91.2
Cc12-02	10-21-93	<.010	<.015	<.030	<.008	<.004	<.012	94.4

Table 25. *Results of chemical analyses for volatile organic compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; concentrations in micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Benzene	o-chlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	Bromoform	Carbon tetrachloride	Chlorodibromomethane	Chloroform	Chlorobenzene	cis-1,2-dichloroethylene	trans-1,2-dichloroethylene	1,1-dichloroethane	1,1-dichloroethylene	1,2-dichloroethane
Pennsylvania																
CH- 21	300WSCKO	07-21-93	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
26	000MFCGH	08-17-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
71	300CCKV	08-30-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
770	300STRS	07-22-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2021	300WSCKO	09-07-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2067	*400FLCGH	08-02-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	1.9	<.2	<.2	<.2	<.2	<.2	<.2
2071	300STRS	08-09-93	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2342	400FLCGH	07-29-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2513	300STRS	08-03-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2593	300STRS	09-09-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2596	000MFCGH	08-11-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3210	300CCKV	08-10-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	<.2	<.2	<.2
3382	400FLCGH	09-10-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3383	300WSCKO	09-08-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3384	400FLCGH	09-08-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3392	300WSCKO	09-08-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3396	400FLCGH	07-27-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3398	400FLCGH	07-29-93	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3405	000MFCGH	08-09-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3426	*300WSCKO	09-01-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3430	400FLCGH	08-04-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3432	300WSCKO	09-08-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3434	300WSCKO	08-31-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3441	300WSCKO	09-09-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3444	000MFCGH	08-10-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3445	300WSCKO	08-19-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3447	**300WSCKO	08-12-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3448	300WSCKO	09-09-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3482	400FLCGH	07-27-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3484	400FLCGH	08-03-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3485	300WSCKO	08-12-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3487	400FLCGH	07-28-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3488	300WSCKO	09-02-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3495	400FLCGH	07-22-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3504	300WSCKO	07-20-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3506	300WSCKO	07-08-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3513	300WSCKO	09-02-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3516	300CCKV	08-02-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3532	400FLCGH	11-16-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3533	300STRS	11-22-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3543	400FLCGH	09-01-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	<.2	<.2	<.2
3558	300WSCKO	08-30-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3573	300WSCKO	09-09-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3580	300WSCKO	08-26-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Table 25. *Results of chemical analyses for volatile organic compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; concentrations in micrograms per liter]

USGS local well number	Date of sample	Dichlorobromomethane	Dichloroidifluoromethane	1,2-dichloropropane	Ethylbenzene	Freon-113	Methylene chloride	Styrene	Tetrachloroethylene	Toluene	Trichlorofluoromethane	1,1,1-Trchloroetylenei	Trichloroethane	Vinyl chloride	Xylene	Methyltertbutylether
Pennsylvania																
CH- 21	07-21-93	<0.2	<0.2	<0.2	<0.2	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
26	08-17-93	<.2	<.2	<.2	<.2	<.5	.9	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
71	08-30-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
770	07-22-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2021	09-07-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.4	<.2	<.2	<.2
2067	08-02-93	<.2	<.2	<.2	<.2	<.5	.4	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2071	08-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2342	07-29-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.7
2513	08-03-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
2593	09-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	2.30	<.2	<.2	<.2	<.4	<.2	<.2	<.2
2596	08-11-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3210	08-10-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	2.10	<.2	<.2	.2	<.2	<.2	<.2	2.7
3382	09-10-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.7	<.2	<.2	<.2
3383	09-08-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3384	09-08-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2
3392	09-08-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3396	07-27-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3398	07-29-93	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<.2
3405	08-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3426	09-01-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3430	08-04-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3432	09-08-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3434	08-31-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3441	09-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3444	08-10-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3445	08-19-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3447	08-12-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	4.8
3448	09-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3482	07-27-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3484	08-03-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3485	08-12-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3487	07-28-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3488	09-02-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3495	07-22-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3504	07-20-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3506	07-08-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3513	09-02-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	.5	<.2	<.2	<.2	<.2
3516	08-02-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	.3	<.2	<.2	<.2
3532	11-16-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3533	11-22-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3543	09-01-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	.4	<.2	<.2	.2	<.2	.6	<.2
3558	08-30-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
3573	09-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2
3580	08-26-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2

***Table 25.** Results of chemical analyses for volatile organic compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; concentrations in micrograms per liter]

USGS local well number	Geologic unit	Date of sample	Benzene	o-chlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	Bromoform	Carbon tetrachloride	Chlorodibromomethane	Chloroform	Chlorobenzene	cis-1,2-dichloroethylene	trans-1,2-dichloroethylene	1,1-dichloroethane	1,1-dichloroethylene	1,2-dichloroethane
4343	300WSCKO	09-23-93	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4344	+300CCKV	09-27-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4345	300WSCKO	08-19-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	.3	<.2	<.2
		07-11-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.3	<.2	<.2	<.2	<.2	<.2	<.2
4361	300WSCKO	08-26-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4362	300WSCKO	08-30-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4410	300WSCKO	07-21-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4412	400FLCGH	07-28-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4414	300WSCKO	08-04-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4415	400FLCGH	08-05-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4416	300WSCKO	08-18-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4417	300STRS	08-24-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4418	400FLCGH	08-25-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4552	300CCKV	08-30-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4727	300WSCKO	08-31-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4728	300CCKV	09-01-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4729	300CCKV	09-02-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4730	*300STRS	09-07-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4731	300STRS	09-10-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Delaware																
Bb24-15	300WSCK	10-13-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bb25-28	300WSCK	09-22-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc12-03	300WSCK	10-13-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc13-19	300WSCK	10-06-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc21-07	300WSCK	09-22-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc21-09	300WSCK	09-30-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc22-10	300WSCK	10-07-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc23-22	300WSCK	10-18-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc31-08	300WSCK	10-05-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc31-10	300WSCK	10-04-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc33-09	000SRPN	11-09-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc34-14	300WSCK	09-20-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc34-16	300WSCK	10-05-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc34-16	300WSCK	10-05-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc41-13	300WSCK	09-30-93	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bc42-16	300WSCK	10-14-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc42-22	300WSCK	09-28-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc42-28	300WSCK	10-19-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc43-15	300WLMG	10-07-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Cc11-16	300WLMG	09-29-93	<.2	<.2	<.2	<.2	<.2	1.5	<.2	.2	<.2	<.2	<.2	<.2	<.2	<.2
Cc12-02	300WLMG	10-21-93	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Table 25. *Results of chemical analyses for volatile organic compounds in water samples from 82 wells, Red Clay Creek Basin, Pennsylvania and Delaware, 1993-94—Continued*

[400FLCGH, felsic gneiss; 300WSCKO, Wissahickon Formation in Pa.; 300WSCK, Wissahickon Formation in Del.; 300STRS, Setters Quartzite; 300CCKV, Cockeysville Marble; 300WLMG, Wilmington complex; 000SRPN, serpentinite; 000MFCGH, mafic gneiss; 000PGMT, pegmatite; concentrations in micrograms per liter]

USGS local well number	Date of sample	Dichlorobromomethane	Dichloroidifluoromethane	1,2-dichloropropane	Ethylbenzene	Freon-113	Methylene chloride	Styrene	Tetrachloroethylene	Toluene	Trichlorofluoromethane	1,1,1-Trchloroetylenei	Trichloroethane	Vinyl chloride	Xylene	Methyltertbutylether
4343	09-23-93	<0.2	<0.2	<0.2	<0.2	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4344	09-27-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4345	08-19-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
	07-11-94	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4361	08-26-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4362	08-30-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4410	07-21-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4412	07-28-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4414	08-04-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4415	08-05-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4416	08-18-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4417	08-24-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4418	08-25-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4552	08-30-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	.4	<.2	<.2	<.2	<.2	<.2	<.2	.3
4727	08-31-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4728	09-01-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4729	09-02-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4730	09-07-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
4731	09-10-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Delaware																
Bb24-15	10-13-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bb25-28	09-22-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc12-03	10-13-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc13-19	10-06-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc21-07	09-22-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc21-09	09-30-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc22-10	10-07-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc23-22	10-18-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc31-08	10-05-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc31-10	10-04-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc33-09	11-09-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc34-14	09-20-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc34-16	10-05-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc34-16	10-05-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc41-13	09-30-93	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<.2
Bc42-16	10-14-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	.4	<.2	<.2	<.2
Bc42-22	09-28-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc42-28	10-19-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Bc43-15	10-07-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.5	<.2	<.2	.7
Cc11-16	09-29-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	.5	<.2	<.2	<.5	<.2	.3	<.2
Cc12-02	10-21-93	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2	<.2	<.2	<.2	<.5	<.2	<.2	<.2

Table 26. *Field measurements of physical properties and constituents and results of chemical analyses for nutrients and major anions in water samples from 8 stream sites, West Branch Red Clay Creek, Pennsylvania, July 1994*

[DDMMSS, degrees, minutes, and seconds; °C, degrees Celsius; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; N, nitrogen; P, phosphorous]

Site code on map	Station name	Latitude (DDMMSS)	Longitude (DDMMSS)	Date sampled	Air temperature (°C)	Water temperature (°C)
H	West Branch Red Clay Creek at Mill Road	395305	0754430	08-02-94	30.5	24.0
G	Unnamed trib. to W. Branch Red Clay Cr. at Mill Road	395323	0754434	08-02-94	27.0	21.0
F	Unnamed trib. to W. Branch Red Clay Cr. at Poplar Road	395323	0754422	08-02-94	--	19.0
E	W. Branch Red Clay Cr. at Walkers off Wollaston Road	395256	0754405	08-02-94	27.0	21.0
D	Unnamed trib. to W. Branch Red Clay Cr. nr. Walkers	395259	0754400	08-02-94	30.0	21.5
C	Unnamed trib. to W. Branch Red Clay Cr. at 2nd bend	395252	0754352	08-02-94	28.0	23.5
B	Unnamed trib. to W. Branch Red Clay Cr. at 1st bend	395240	0754350	08-02-94	28.0	17.0
A	West Branch Red Clay Creek at Rt. 926	395220	0754412	08-02-94	27.5	--

Site code on map	Station name	Discharge (ft^3/s)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Field pH (standard units)	Alkalinity, laboratory, fixed end-point (mg/L as $CaCO_3$)	Ammonia (mg/L as N)
H	West Branch Red Clay Creek at Mill Road	0.48	162	9.6	7.3	33	0.040
G	Unnamed trib. to W. Branch Red Clay Cr. at Mill Road	.19	232	7.1	7.1	52	.040
F	Unnamed trib. to W. Branch Red Clay Cr. at Poplar Road	.23	250	8.2	6.9	60	.030
E	W. Branch Red Clay Cr. at Walkers off Wollaston Road	1.1	199	9.0	7.1	44	.030
D	Unnamed trib. to W. Branch Red Clay Cr. nr. Walkers	.18	210	8.0	6.7	51	.030
C	Unnamed trib. to W. Branch Red Clay Cr. at 2nd bend	.03	265	9.2	7.2	44	.020
B	Unnamed trib. to W. Branch Red Clay Cr. at 1st bend	.08	197	8.9	6.6	34	.050
A	West Branch Red Clay Creek at Rt. 926	1.7	205	8.7	6.9	48	.030

Site code on map	Station name	Nitrite (mg/L as N)	Nitrate + nitrite (mg/L as N)	Ortho-phosphate (mg/L as P)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)
H	West Branch Red Clay Creek at Mill Road	0.010	3.70	0.020	11	9.4	<0.10
G	Unnamed trib. to W. Branch Red Clay Cr. at Mill Road	.020	4.30	.010	16	15	.20
F	Unnamed trib. to W. Branch Red Clay Cr. at Poplar Road	<.010	3.20	.030	18	17	<.10
E	W. Branch Red Clay Cr. at Walkers off Wollaston Road	.010	4.60	.020	13	14	.10
D	Unnamed trib. to W. Branch Red Clay Cr. nr. Walkers	<.010	3.30	<.010	17	13	<.10
C	Unnamed trib. to W. Branch Red Clay Cr. at 2nd bend	<.010	1.60	<.010	31	23	<.10
B	Unnamed trib. to W. Branch Red Clay Cr. at 1st bend	<.010	5.00	.020	6.9	21	<.10
A	West Branch Red Clay Creek at Rt. 926	.010	3.80	.020	13	14	<.10