EFFECT OF URBANIZATION ON THE WATER RESOURCES OF EASTERN CHESTER COUNTY, PENNSYLVANIA

By Ronald A. Sloto

U.S. GEOLOGICAL SURVEY

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DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785 0.003785	liter (L) cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
gallon per minute (gal/min)	0.06309 0.00006309	liter per second (L/s) cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per square mile ($Mgal/mi^2$)	1,461	cubic meter per square kilometer (m^3/km^2)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	0.0169	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

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

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ABSTRACT

The effects of human activity on the water resources of a 207-square-mile area of eastern Chester County was evaluated. The most serious consequence of urbanization is the contamination of ground water by volatile organic compounds, which were detected in 39 percent of the 70 wells sampled. As many as nine compounds were found in one water sample, and the concentration of total volatile organic compounds was as high as 17,400 µg/L (micrograms per liter). In the Chester Valley, volatile organic compounds are moving down the hydraulic gradient caused by quarry dewatering. Movement through the quarries reduces concentrations of these compounds and removes most of them. Phenol was detected in 28 percent of 54 wells sampled, with concentrations up to 7 µg/L.

Metals, except for iron and manganese, and other trace constituents generally are not a water-quality problem. However, ground water in an area in Chester Valley has been contaminated by concentrations of boron as high as 20,000 µg/L and lithium as high as 13,000 µg/L. The ground water discharges to Valley Creek, where concentrations of boron are as high as 130 µg/L and lithium as high as 800 µg/L.

Concentrations of chloride as high as 2,100 mg/L (milligrams per liter) were found in a well at a former highway salt storage site. Wells completed in carbonate rock downgradient from the Pennsylvania Turnpike had chloride concentrations as high as 350 mg/L.

The base-neutral organic compounds bis(2-ethylhexyl) phthalate, di-n-butyl phthalate, and 1,2-dichlorobenzene, and the pesticides alachlor, aldrin, diazanon, DDD, DDT, dieldrin, methyl parathion, picloram, and 2,4-D were detected in a few water samples in low concentrations. However, these organic compounds do not present a widespread water-quality problem. Neither acid organic compounds nor polychlorinated napthalenes (PCN) were detected in ground water.

The growth of public water and sewer systems has resulted in a significant interbasin transfer of water. Estimates for 1984 range from a net loss of 630 million gallons in the Valley Creek basin to a net gain of 783 million gallons in the Chester Creek basin. The quantity of wastewater discharged from treatment plants generally correlates well with the altitude of the water table and poorly with water use or precipitation, indicating substantial ground-water infiltration. Estimated ground-water infiltration to the West Goshen treatment plant for 1980-84 was 0.8 cubic feet per square mile, or 10 percent of the long-term average flow of Chester Creek. Estimated ground-water infiltration to the Valley Forge sewer system was as high as 4.9 million gallons per day.

Dewatering operations at two active quarries in Chester Valley have lowered water levels locally and increased the range of fluctuation of the local water table. The spread of the cones of depression caused by quarry pumping is limited by geologic and hydrologic controls. Pumping of high-capacity wells in Chester Valley has caused small local cones of depression and may have caused some reaches of Valley Creek or its tributaries to lose water.

One of the greatest effects of human activity on the surface-water system has been the accumulation of organic compounds, particularly PCB and pesticides, on stream-bottom material. PCB, DDE, and dieldrin were found in bottom material from all eight streams sampled.

Land-use changes in 10 selected subbasins were quantified and related to stream-benthic invertebrate diversity index. From 1970-80, the diversity index increased at all sites. Subbasins that had a greater change in land use had a greater increase in diversity index. The increase may be due to the banning of certain pesticides such as DDT, a decreasing use of pesticides in urbanizing subbasins, or flushing or burial of older pesticide-contaminated sediment.

INTRODUCTION

Rapid and continuing urbanization of eastern Chester County, Pennsylvania, has affected the water resources, particularly ground-water quality. Approximately 62 percent of the population depends on ground water as a source of supply. These supplies are being threatened by chemical contamination, especially volatile organic compounds. Wastewater, which once recharged the ground-water system through septic systems, is now commonly exported by sewers from basins where it was pumped, resulting in substantial interbasin transfer of water.

Purpose and Scope

This report presents the results of a study to determine the effect of urbanization in eastern Chester County on the quality and quantity of ground water and low streamflow. The study was done by the U.S. Geological Survey in cooperation with the Chester County Water Resources Authority.

The report describes the impact of public-water withdrawals, quarry de-watering, and sewering on ground water and surface water. The effects of agri-cultural, residential, and industrial development on ground-water and surface-water quality are described, especially contamination of the water resources by metals, pesticides, and organic compounds.

Much of the emphasis of this report is on the east-central part of the study area, particularly Chester Valley. This rapidly growing area is the most densely populated and highly industrialized part of the study area, and it is here that the effects of urbanization are most pronounced. This area is underlain by the most productive and most vulnerable aquifers in the county. A large part of eastern Chester County is still mostly rural, and the effect of urbanization has been less in the rural areas than in the more rapidly-growing areas.

Location and Physiography

Chester County is in southeastern Pennsylvania, west of Philadelphia (fig. 1). The 207-mi^2 (square mile) study area is the eastern part of Chester County drained by Pigeon Creek, Stony Run, French Creek, Pickering Creek, Valley Creek, Trout Run, Darby Creek, Crum Creek, Ridley Creek, and Chester Creek (fig. 2). Table 1 gives the drainage area of each basin. All of these streams, except French Creek, have their headwaters entirely within Chester County.

Most of Chester County lies within the Piedmont Physiographic Province of the Appalachian Highlands. This area is characterized by uplands formed of hard crystalline rocks that have been shaped into rolling hills. The highest point, 982 feet above sea level, is in the uplands of the northwest part of the study area. The uplands slope gently to the southeast. The uplands are divided by Chester Valley, which is underlain by carbonate rock, and trends northwest across the middle of the county.

The Triassic Lowlands border the Schuylkill River in the northeastern part of the county. These lowlands were formed by erosion of sandstone and shale, which are less resistant than the crystalline rocks of the uplands. The lowest point, 66 feet above sea level, is on the east edge of the lowlands, where the Schuylkill River leaves the county.

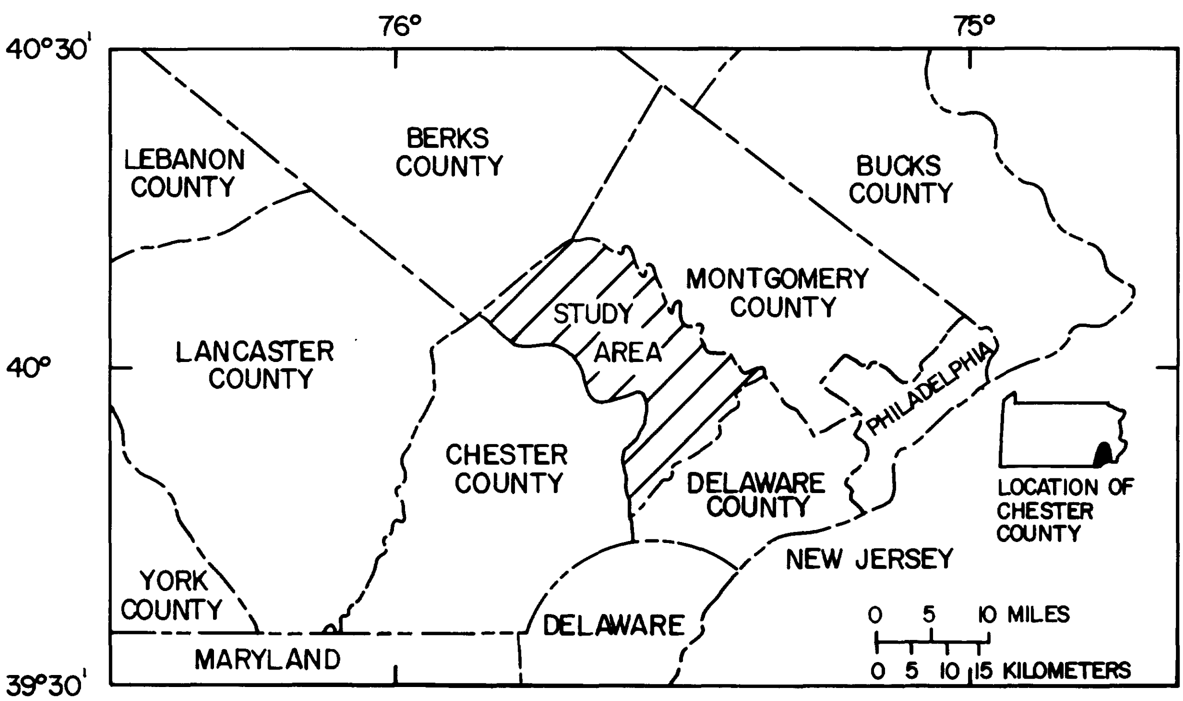


Figure 1.--Location of Chester County.

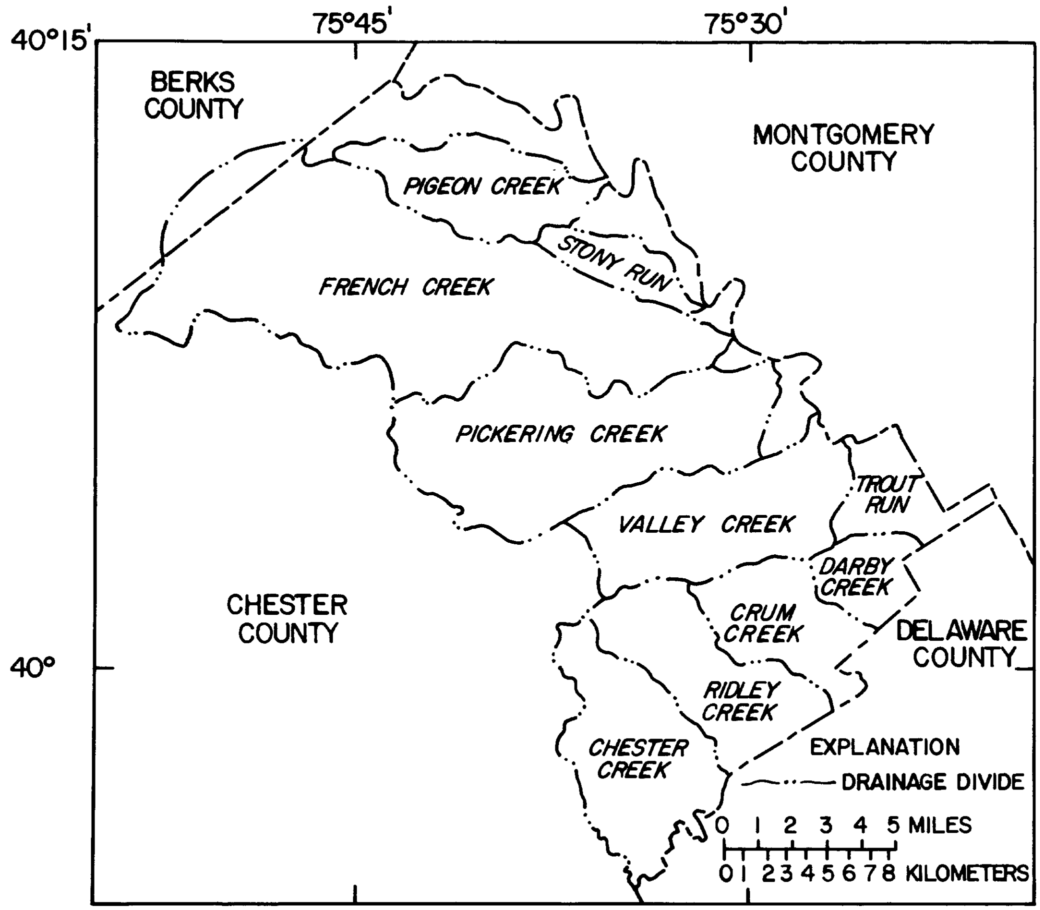


Figure 2.--Major drainage basins in eastern Chester County.

Table 1.--Major drainage basins in eastern Chester County
[Population figures rounded to nearest 100; mi^2, square miles]

Basin	Drainage area in Chester County (mi^2)	Tributary to	Estimated population (Chester County only)
Pigeon Creek	14.5	Schuylkill River	[1]3,900
Stony Run	5.6	Schuylkill River	[1]1,500
French Creek	61.1	Schuylkill River	[2]17,700
Pickering Creek	38.8	Schuylkill River	[2]93,400
Valley Creek	23.4	Schuylkill River	[2]15,600
Trout Run	6.2	Schuylkill River	[2]12,700
Darby Creek	6.7	Delaware River	[2]12,400
Crum Creek	12.9	Delaware River	[2]8,600
Ridley Creek	17.4	Delaware River	[2]8,600
Chester Creek	20.6	Delaware River	[3]27,600
Total	207.0		202,000

[1]1977 population from Reith and others (1979)

[2]1980 population from Chester County Planning Commission (1982b)

[3]1977 population from Reith and others (1978)

Climate

The climate in Chester County is characterized by warm summers and moderately cold winters. The normal annual temperature (1951-80) at Phoenixville is 53.1°F (11.7°C) (National Oceanic and Atmospheric Administration, 1982). The normal temperature for January, the coldest month, is 30.1°F (-1.1°C), and the normal temperature for July, the warmest month, is 74.9°F (23.8°C). The average annual precipitation, at Phoenixville for 76 years of record (1890-95, 1913-84), is 44.10 inches. The minimum annual precipitation, 31.10 inches, occurred in 1963; the maximum annual precipitation, 59.55 inches, occurred in 1979. The 1951-80 normal precipitation is 43.55 inches. Precipitation is generally distributed evenly throughout the year.

Population

The population of Chester County doubled between 1950 and 1980; it increased 14 percent between 1970 and 1980. Over half of this 14-percent increase was due to migration into the county, and as a result, the numerical increase in housing units was greater than in any previous decade. Most of the new housing is near the Route 30 and Route 202 corridors. The three municipalities with the greatest increase in housing units for 1970-80 are East Goshen (2,414 new units), Tredyffrin (1,798 new units) and West Goshen (1,730 new units). East Goshen Township also had the highest percentage increase (158 percent) in housing units (Chester County Planning Commission, 1983). The increase in population for the seven most urbanized townships in eastern Chester County for 1900-80 is shown in figure 3. Population density is shown in figure 4.

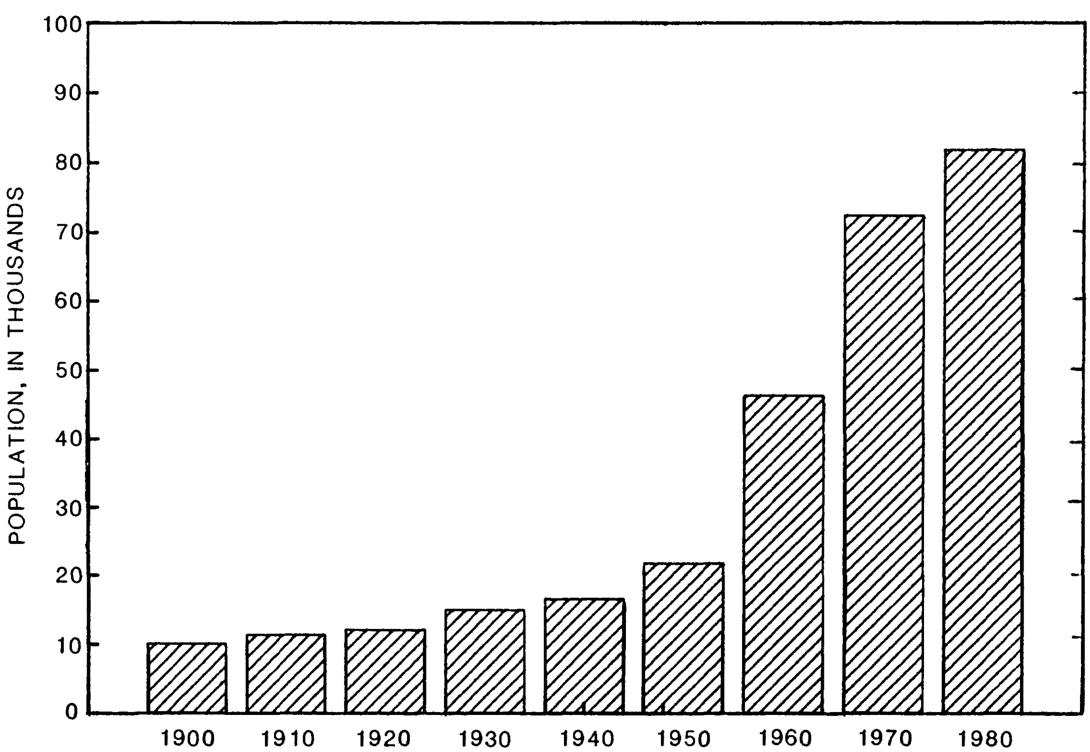


Figure 3.--Population of seven eastern townships, 1900-80.

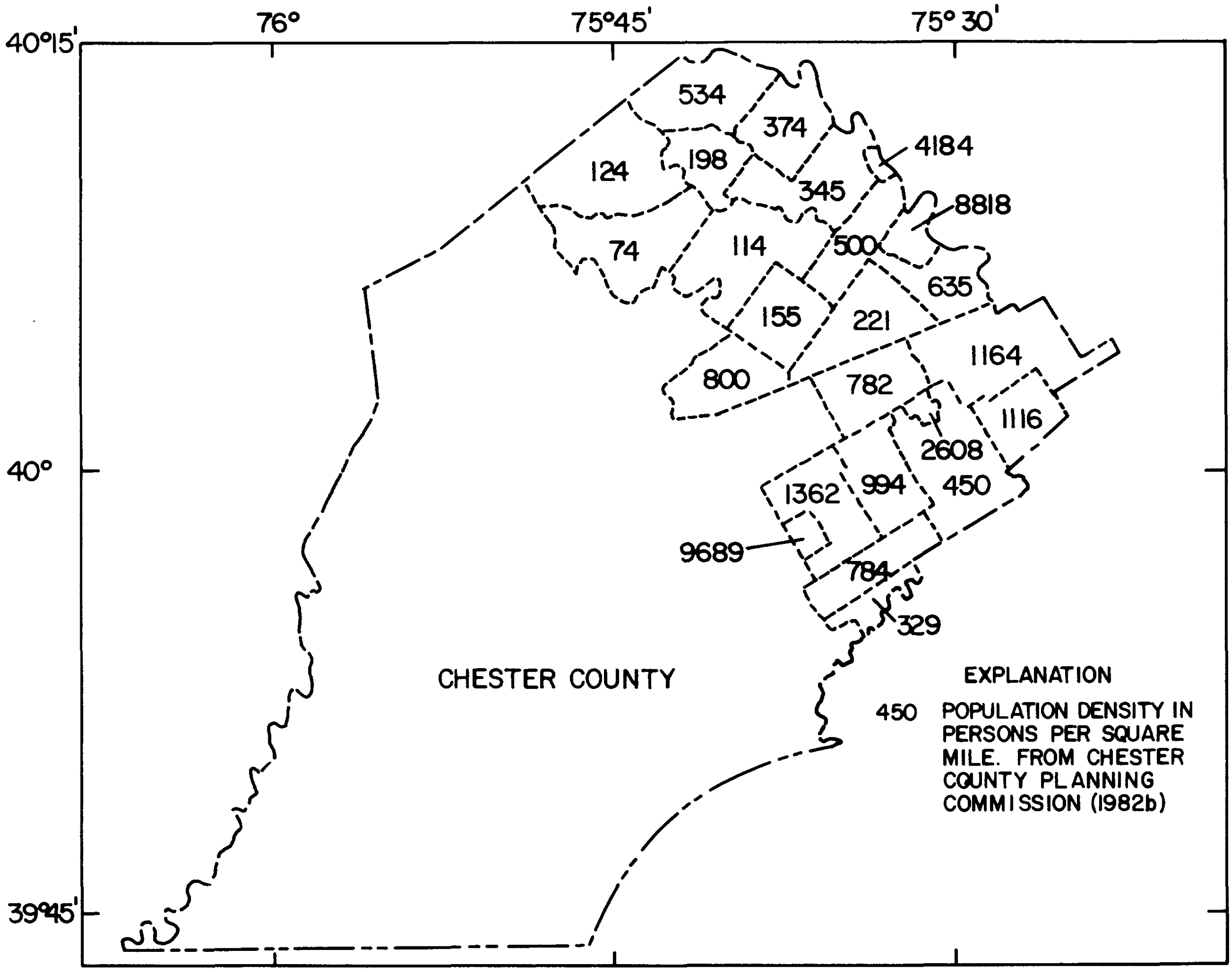


Figure 4 -- Population density of municipalities, 1980.

Land Use

Land-use classifications were taken from maps prepared by the DVRPC (Delaware Valley Regional Planning Commission). The four land-use classifications used in this report are combinations of the 12 categories mapped by DVRPC. Residential land use combines DVRPC's single family detached and multiple unit (duplex and row houses, apartments, and mobile homes) categories. Industrial land use combines DVRPC's manufacturing and mining (quarries) categories. Commercial land use combines DVRPC's commercial (wholesale and retail trade, business and professional services, and hotels and motels), community services (health, educational, governmental, and religious facilities), transportation (rail, air, and highway transportation and parking lots), and communications and utilities categories. Agricultural and open space land use combines DVRPC's agricultural (crops, pastures, and orchards), forest and undeveloped (woodlands, vacant land, and marshes), water areas, and recreational and cultural (parks, playgrounds, and golf courses) categories.

Land-use data for 1970 and 1980 (Delaware Valley Regional Planning Commission, 1984) are given in table 2. The predominant land use is agricultural and open space. However, acreage devoted to agriculture and open space is decreasing as urbanization continues. In 1970, 73 percent of the land was classified as agricultural and open space, 16 percent as residential, 10 percent as commercial, and 1 percent as industrial. In 1980, 69 percent of the land was classified as agricultural and open space, 19 percent as residential, 11 percent as commercial, and 1 percent as industrial. In the seven most urbanized townships in 1970, 59 percent of the land was classified as agricultural and open space, 26 percent as residential, 14 percent as commercial, and 1 percent as industrial. In 1980, 50 percent of the land was classified as agricultural and open space, 31 percent as residential, 17 percent as commercial, and 2 percent as industrial.

Table 2.--Land use for municipalities in eastern Chester County, 1970 and 1980
Land use is given in acres
[Data from Delaware Valley Regional Planning Commission (1984)]

Municipality	Residential 1970	Residential 1980	Industrial 1970	Industrial 1980	Commercial 1970	Commercial 1980	Agricultural and open space 1970	Agricultural and open space 1980
Charlestown	777	907	37	55	454	502	6,668	6,477
East Coventry	879	1,089	13	13	326	382	5,723	5,461
East Goshen	1,254	1,925	5	5	391	869	4,892	3,748
East Nantmeal	347	387	0	0	251	263	9,937	9,889
East Pikeland	769	822	27	27	417	456	4,507	4,420
Easttown	2,001	2,150	7	7	736	780	2,554	2,365
East Vincent	757	835	8	9	826	849	7,167	7,069
East Whiteland	1,129	1,422	396	505	1,723	1,932	3,770	3,165
Malvern Borough	189	209	20	21	181	192	424	397
North Coventry	1,261	1,466	40	40	510	568	6,777	6,519
Phoenixville Borough	688	702	142	143	566	572	1,068	1,052
Schuylkill	1,270	1,417	33	34	880	924	3,561	3,373
South Coventry	487	497	12	13	221	227	4,149	4,136
Spring City	223	234	28	91	97	97	178	166
Thornbury	355	549	0	6	265	361	1,907	1,615
Tredyffrin	4,228	4,917	100	191	2,404	2,994	6,009	4,641
Uwchlan	1,061	1,638	46	47	408	689	5,183	4,328
Warwick	621	750	29	29	1,334	1,369	10,311	10,152
West Chester Borough	550	569	64	76	459	473	102	62
West Goshen	2,013	2,463	70	160	1,375	1,605	4,287	3,522
West Pikeland	332	431	40	41	192	219	5,816	5,692
Westtown	1,353	1,873	1	2	318	486	3,914	3,229
West Vincent	701	723	11	11	266	273	10,294	10,270
Willistown	2,575	2,769	13	14	936	1,004	8,226	7,968
Total	25,820	30,744	1,142	1,477	15,530	18,086	117,424	109,716

Well-Numbering System

The well-numbering system used in this report is a county abbreviation followed by a sequentially assigned number. The prefix CH- stands for Chester County. The prefix CH-SP- denotes a spring in Chester County. Locations of selected wells and springs are shown on plate 1. Missing numbers are those assigned to wells in the part of Chester County not included in this study or wells in the study area that were not used for data analysis in this report.

Previous Investigations

Hall (1934) briefly described the water-bearing characteristics of the geologic formations of southeastern Pennsylvania. A detailed investigation of the hydrology of central Chester County was conducted by Poth (1968). McGreevy and Sloto (1976 and 1977) described the ground-water resources of Chester County. Ground-water occurrence in the Triassic rocks of northern Chester County was described by Rima and others (1962), Longwill and Wood (1965), and Wood (1980). McGreevy and Sloto (1980) used a digital model to simulate ground-water flow in the Pickering Creek basin.

Water resources on a basinwide scale were described by Parker and others (1964) for the Delaware River basin and by Biesecker and others (1968) for the Schuylkill River basin.

Miller and others (1971) discussed the hydrology of the Pickering Creek basin. Lium (1976 and 1977) discussed the limnology of the major streams in Chester County. Moore (1987) described biological monitoring of stream-water quality in Chester County.

The geology of eastern Chester County was mapped and described by Bascom and others (1909) and Bascom and Stose (1932 and 1938). Geological quadrangle maps for Chester County were published by the Chester County Planning Commission (1973) and Berg and Dodge (1981). Stratigraphic correlations were given by Berg and others (1986).

Acknowledgments

The cooperation of well owners for access to wells for water-level measurements and water samples is gratefully acknowledged. The author especially thanks municipal water and sewer authorities, public and private water suppliers, the Chester County Health Department, the Chester County Planning Commission, Earth Data Incorporated, Glasgow Incorporated, the Pennsylvania Department of Environmental Resources, Thomas G. Keyes Incorporated, and the Warner Company for providing data and access to their wells and property.

HYDROGEOLOGIC SETTING

The bedrock units of eastern Chester County can be divided into three general groups: (1) Precambrian to lower Paleozoic crystalline rocks; (2) Cambrian and Ordovician carbonate rocks; and (3) Triassic sedimentary and igneous rocks. The occurrence of these general groups is shown on figure 5. Except for slight modifications, the terminology used for the geologic units in this report are those of the Pennsylvania Topographic and Geologic Survey (Berg and Dodge, 1981; Wood, 1980). Ages of geologic units are from Berg and others (1986). The nomenclature does not necessarily follow the usage of the U.S. Geological Survey. A description of each rock unit is given on plate 1.

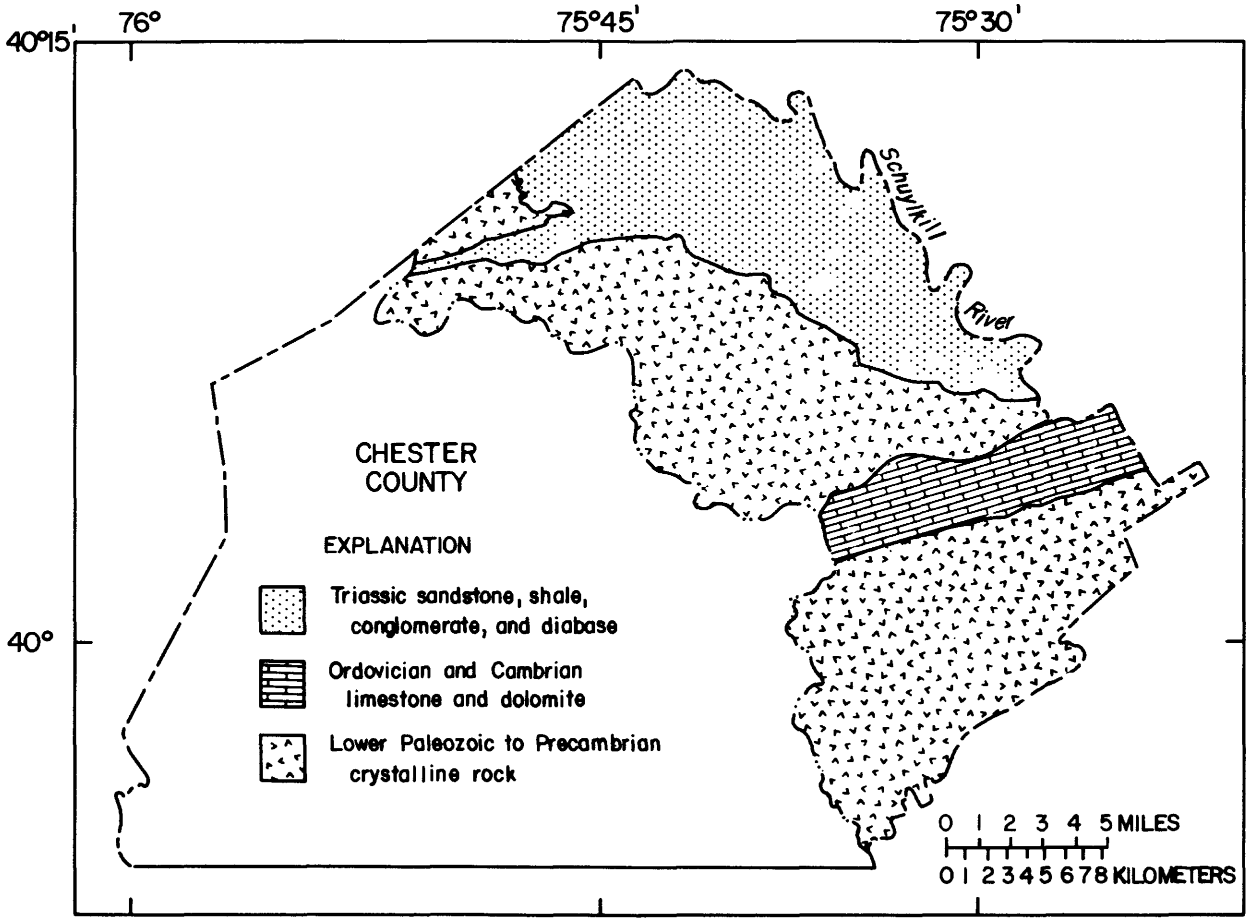


Figure 5.--Generalized geologic map.

The bedrock is generally deeply weathered, and a zone of unconsolidated weathered rock covers most of the area. Minor alluvial deposits are present locally, but, in this report, they are not distinguished from the unconsolidated weathered rock.

The geologic structure consists of a series of extremely complicated anticlines and synclines that trend northeast, approximately parallel to Chester Valley. Major faults also trend northeast and may be normal, reverse, or thrust. Minor normal faults generally trend north or northeast. Triassic sedimentary rocks unconformably overlie older rocks in the northern part of the county. They generally strike east to southeast and dip north 10° to 20°.

Hydrologic data are presented for each geologic unit in table 3. The water-quality characteristics given in table 3 are taken from McGreevy and Sloto (1977, p. 46-47). Yield data include all wells in Chester County in the given formation.

Table 3.—Hydrologic characteristics of the water-bearing units in eastern Chester County
[Dash indicates no data or insufficient data to calculate a median; µS/cm at 25°C, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter]

		Well yield						Water-quality characteristics								
		Domestic			Nondomestic			pH (units)			Specific conductance (µS/cm at 25°C)			Hardness (mg/L as $CaCO_3$)		
Age	Hydrologic unit	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median
Triassic	Diabase	10	0.5-100	11	—	-	—	3	6.0-7.3	—	3	130-210	—	3	50-80	—
	Hammer Creek Formation															
	Shale	43	5-100	14	20	11-1,300	107	15	5.3-7.6	6.3	16	70-680	320	21	10-250	130
	Quartz-pebble conglomerate	19	5-100	12	—	-	—	5	5.4-7.1	5.8	5	20-280	110	5	10-90	30
	Lockatong Formation	5	5-32	12	2	200-380	—	1	7.2	—	1	400	—	1	160	—
	Stockton Formation	39	4-150	15	29	8-800	75	22	5.6-8.0	7.2	23	120-860	300	24	30-330	110
Ordovician and Cambrian	Conestoga Formation	27	1-175	15	24	1.5-1,000	48	13	5.4-7.6	7.1	13	140-1,100	500	14	30-520	250
Cambrian	Elbrook Formation	25	0.4-85	15	21	5.5-1,200	50	9	7.1-8.0	7.4	9	360-960	560	10	160-300	260
	Ledger Formation	22	2-100	20	47	2-1,120	150	10	7.0-7.8	7.4	11	360-1,000	510	11	160-470	260
Cambrian and Precambrian	Antietam and Harpers Formations (undifferentiated)	19	3-50	12	1	23	—	8	5.0-6.8	5.7	7	30-350	130	8	10-60	30
Lower Paleozoic to Precambrian	Serpentinite	27	2-75	12	4	8-80	—	8	7.3-9.1	8.1	13	105-510	350	13	40-250	140
	Wissahickon Formation															
	Albite-chlorite schist	80	0.3-300	10	32	10-230	35	52	5.0-7.6	6.0	60	20-400	120	60	10-180	40
	Oligoclase-mica-schist	320	1-400	12	140	1-350	30	148	5.1-7.9	6.1	170	25-1,150	120	168	10-420	30

Table 3.—Hydrologic characteristics of the water-bearing units in eastern Chester County--Continued
[Dash indicates no data or insufficient data to calculate a median; µS/cm at 25°C, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter]

		Well yield						Water-quality characteristics									
		Domestic			Nondomestic			pH (units)			Specific conductance (µS/cm at 25°C)			Hardness (mg/L as $CaCO_3$)			
Age	Hydrologic unit	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median
Precambrian	Chickies Formation	61	2-50	13	15	0.3-100	20	27	4.9-6.6	5.7	30	15-400	100	29	10-90	30
	Anorthosite	36	3-100	30	6	25-225	45	21	5.6-6.6	6.3	21	50-810	110	21	10-260	40
	Quartz monzonite snd quartz monzonite gneiss	53	3-100	22	8	1-180	40	25	5.5-7.3	6.1	25	40-600	110	26	10-210	40
	Granodiorite and granodiorite gneiss	103	0.8-100	15	29	1-167	35	41	5.6-8.3	6.2	41	60-450	160	43	10-210	60
	Gabbroic gneiss and gabbro	143	0.8-100	14	56	4-300	47	51	5.9-7.1	6.4	56	50-360	180	55	10-160	60
	Granite gneiss	39	0.7-50	10	4	3-80	25	30	5.8-6.9	6.2	40	70-375	190	40	30-150	70
	Felsic gneiss, hornblende-bearing	83	2-270	15	29	6-300	48	40·	4.1-7.3	6.3	51	60-460	185	50	30-390	70
	Felsic gneiss, pyroxene-bearing	108	0.3-100	12	44	10-300	38	52	5.9-7.4	6.5	53	80-360	190	59	30-170	70
	Mafic gneiss, hornblende-besring	20	5-100	14	5	17-100	45	6	5.5-7.1	6.1	6	100-400	230	6	30-150	90
	Mafic gneiss, pyroxene-bearing	6	2-40	10	3	50-150	100	6	6.2-7.0	6.5	6	80-480	170	6	30-190	70
	Graphitic gneiss	56	0.5-150	12	21	2-650	30	20	5.6-7.4	6.3	21	50-420	180	21	10-180	60
	Franklin marble	—	—	—	2	75-225	—	1	7.4	—	1	330	—	1	140	—

Triassic Rocks

Triassic sedimentary and igneous rocks of the Newark Supergroup occur in northern Chester County along the Schuylkill River (fig. 5). The principal formations are the Hammer Creek, Lockatong, and Stockton Formations (plate 1). The Hammer Creek Formation includes a major interbedded quartz pebble conglomerate, for which separate hydrologic data are available. Diabase occurs as intruded dikes and sills. Hydrologic characteristics for the Triassic formations are given in table 3.

In the Triassic sedimentary rocks, most ground water occurs and moves through a network of interconnecting secondary openings, such as bedding planes, joints, and fractures. Some water may move through pores in the rock where the cement has been removed and the permeability has increased. At depth, water is often confined under pressure greater than atmospheric. This confinement is caused by vertical changes in permeability that result from the cementing material in some zones being less susceptible to removal by solution, gradations in the textures of the sediments, and varying degrees of fracturing (Greenman, 1955, p. 28). If the hydrostatic pressure is sufficient, the well will flow at the surface. Water levels in deep wells respond to changes in pressure; most deep wells penetrate several major water-bearing zones and are thus multiaquifer wells. Each zone may have a different hydraulic head. The hydraulic head in a deep well is the composite head of the several water-bearing zones it penetrates. Where differences in hydraulic head exist between water-bearing zones, water in the well under nonpumping conditions flows in the direction of decreasing head.

Cambrian-Ordovician Carbonate Rocks

Chester Valley, which cuts through the center of the county, is underlain by Cambrian and Ordovician limestones and dolomites (fig. 5). The principal formations are the Cambrian Ledger and Elbrook Formations and the Cambrian and Ordovican Conestoga Formation (plate 1). The Cambrian Vintage and Kinzers Formations also occur locally, but they are of limited areal extent. Hydrologic characteristics of the carbonate rocks are given in table 3.

In carbonate rock, ground water occurs in and moves through a network of interconnecting joints, fractures, and bedding planes, some of which may be enlarged by solution. Permeability of carbonate rock is predominately the result of solution. Where solution has been active, permeability may be high; elsewhere, the same unit may be nearly impermeable. Water in carbonate rock is generally under water-table conditions, but confined ground-water conditions may exist locally. Because acidic precipitation dissolves carbonate rock, water from wells is generally hard and high in dissolved solids.

Carbonate rock is generally more susceptible to ground-water contamination than most other rock terranes because of the formation of solution channels. Solution causes enlargement of openings along the more direct flow paths creating channels for the movement of contaminants. When a contaminant enters a solution channel, it may move a great distance in a short time toward a point of discharge. Ground-water and surface-water divides commonly do not coincide in carbonate-rock terranes, so that contaminates in solution channels may move rapidly beneath surface-water divides.

Carbonate rocks are susceptible to the formation of sinkholes. A sinkhole is a depression in the land surface, often round or funnel-shaped, caused by the collapse of a subterranean cavity. The following discussion of sinkhole formation is taken largely from Newton (1976) and Newton and Hyde (1971).

Sinkholes can be divided into two categories: induced and natural. Induced sinkholes are those that can be related to human activity, whereas natural ones cannot. This discussion will be restricted to induced sinkholes. Some induced sinkholes can develop within minutes or hours after the effects of human activity are exerted on existing geologic and hydrologic conditions. Induced sinkholes are particularly dangerous because they usually form instantaneously, and because they often occur in populated areas. Figure 6 shows several sinkholes that formed following a 1.12-inch rainfall on April 29, 1979. The sinkholes caused the failure of State Route 29, about 1 mile north of U.S. Route 202.

Figure 6.--Collapse beneath State Route 29,
1 mile north of U.S. Route 202.

Sinkholes develop above cavities in carbonate rock. Clay and soil materials migrate downward into openings in the underlying rock. The enlargement and collapse of such a cavity is illustrated in figure 7. The downward movement of material is often initiated by surface water that infiltrates unconsolidated deposits interconnected with openings in bedrock. The water moves with sufficient velocity to cause erosion and stoping of the unconsolidated material, resulting in the formation of a cavity. The conditions may be aggravated by a lowered water table caused by pumping. Downward migration of unconsolidated material and stoping continues until the roof of the cavity collapses, causing a sinkhole to form. Induced sinkholes in urbanized areas are often caused by the concentration of runoff from roofs, parking lots, and other impervious areas. All of the sinkholes observed by the author in eastern Chester County during 1979-86, such as the one shown in figure 8, formed during or immediately after a heavy rainfall.

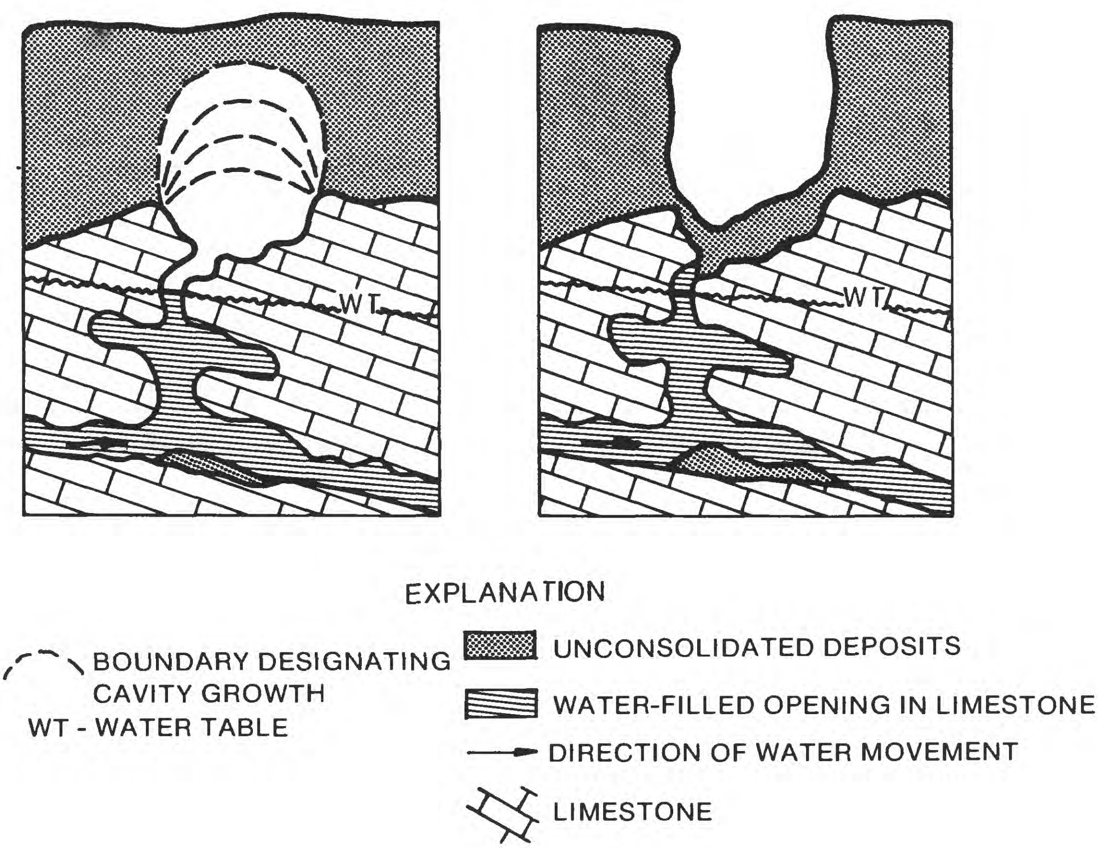


Figure 7.--Formation of sinkhole. (From Newton, 1976)

Figure 8.--Sinkhole along Flat Road, 0.1 mile west of State Route 29.

Precambrian and Lower Paleozoic Crystalline Rocks

The area underlain by crystalline rock is divided by Chester Valley (fig. 5). North of Chester Valley, the crystalline rocks are chiefly Precambrian graphitic gneiss, quartz monzonite and quartz monzonite gneiss, granodiorite and granodiorite gneiss, Franklin Marble, and Precambian and Cambrian quartzites (plate 1).

The quartzites comprise the North Valley Hills north of Chester Valley. They are the Chickies, Antietam, and Harpers Formations. The Antietam and Harpers Formations are undifferentiated. South of Chester Valley, the crystalline rocks are predominately the Precambrian and Lower Paleozoic Wissahickon Formation and serpentinite, and Precambrian felsic and mafic gneisses. The Wissahickon Formation is divided into two facies--an albite chlorite schist to the north and an oligoclase mica schist to the south.

In the crystalline rocks, ground water is present in and moves through intergranular openings in the weathered zone and through a network of interconnecting fractures and joints in the underlying bedrock. The permeability of fractured crystalline rock depends on the number of fractures, the size of the fracture openings, and the degree of interconnection of the fractures. Compression tends to close the openings with depth. Therefore, they are generally best developed near the surface. They occur less frequently and are not as wide with depth.

The crystalline rock is generally deeply weathered. The thickness of the unconsolidated weathered rock ranges from zero to a few hundred feet. Because most wells in Chester County have well casing set in the upper few feet of solid rock, casing length usually indicates the thickness of the unconsolidated zone. Based on median casing lengths, the average thickness of the unconsolidated weathered rock is 40 to 60 feet. The weathered materials overlying bedrock contain a considerable quantity of water in storage.

RELATION OF URBANIZATION TO WATER USE

Public Water Supplies

Public water companies and municipal authorities serve the more densely populated areas. In addition, some residential subdivisions in rural areas are served by small public water companies or by subsystems of the Great Valley Division of the Philadelphia Suburban Water Company. The public water companies that serve these residential subdivisions depend upon ground water for their source of supply.

Public water utilities that serve eastern Chester County and their source of water supply are listed in table 4; their service areas are shown in figure 9. In addition, a small part of the study area around Lionville is served by the Uwchlan Township Municipal Authority.

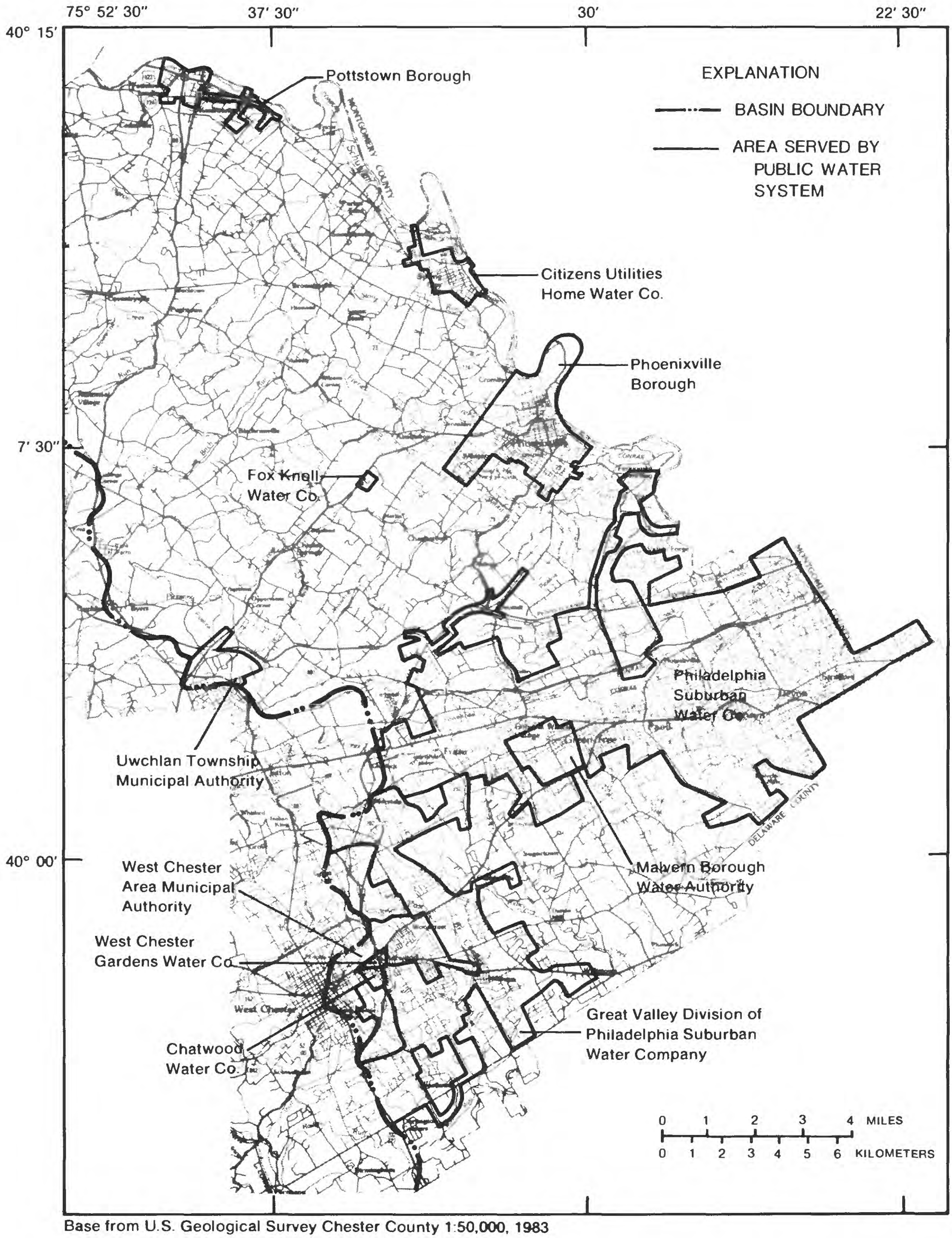


Figure 9.--Areas served by public-water systems.

Table 4.--Public water systems in eastern Chester County

Name	Source of supply	Average daily use, 1984 (gallons per day)
Chatwood Water Company	2 wells	11,500
Citizens Home Utilities Water Company	1 well[1]	[2]400,000
Fox Knoll Water Company	1 well	4,000
Great Valley Division of the Philadelphia Suburban Water Company	11 wells[3]	1,281,000
Malvern Borough Water Authority	4 springs 4 wells	266,000
Philadelphia Suburban Water Company	3 wells[1] Pickering Creek	1,507,000 6,272,000
Phoenixville Borough	Schuylkill River	3,332,000
Pottstown Borough	Schuylkill River	[2]200,000
Uwchlan Township Municipal Authority	wells	--
West Chester Area Municipal Authority	East Branch Brandywine Creek	3,796,000
West Chester Gardens Water Company	2 wells	24,000

[1]In Chester County only

[2]Estimated use for Chester County only

[3]In study area only

Most of the larger public water purveyors depend on surface water or on a combination of surface water and ground water for their source of supply. The smaller water purveyors generally depend on ground water. In 1984, public water suppliers served approximately 95,000 people, or about 47 percent of the population of eastern Chester County. The rest of the population was self-supplied by domestic wells and springs. In 1984, public water purveyors supplied approximately 6,246 Mgal (million gallons) of water, an average of 17 Mgal/d (million gallons per day). Wells and springs supplied approximately 3.3 Mgal/d or 19 percent of the water; the rest came from surface-water sources.

Sewer Systems

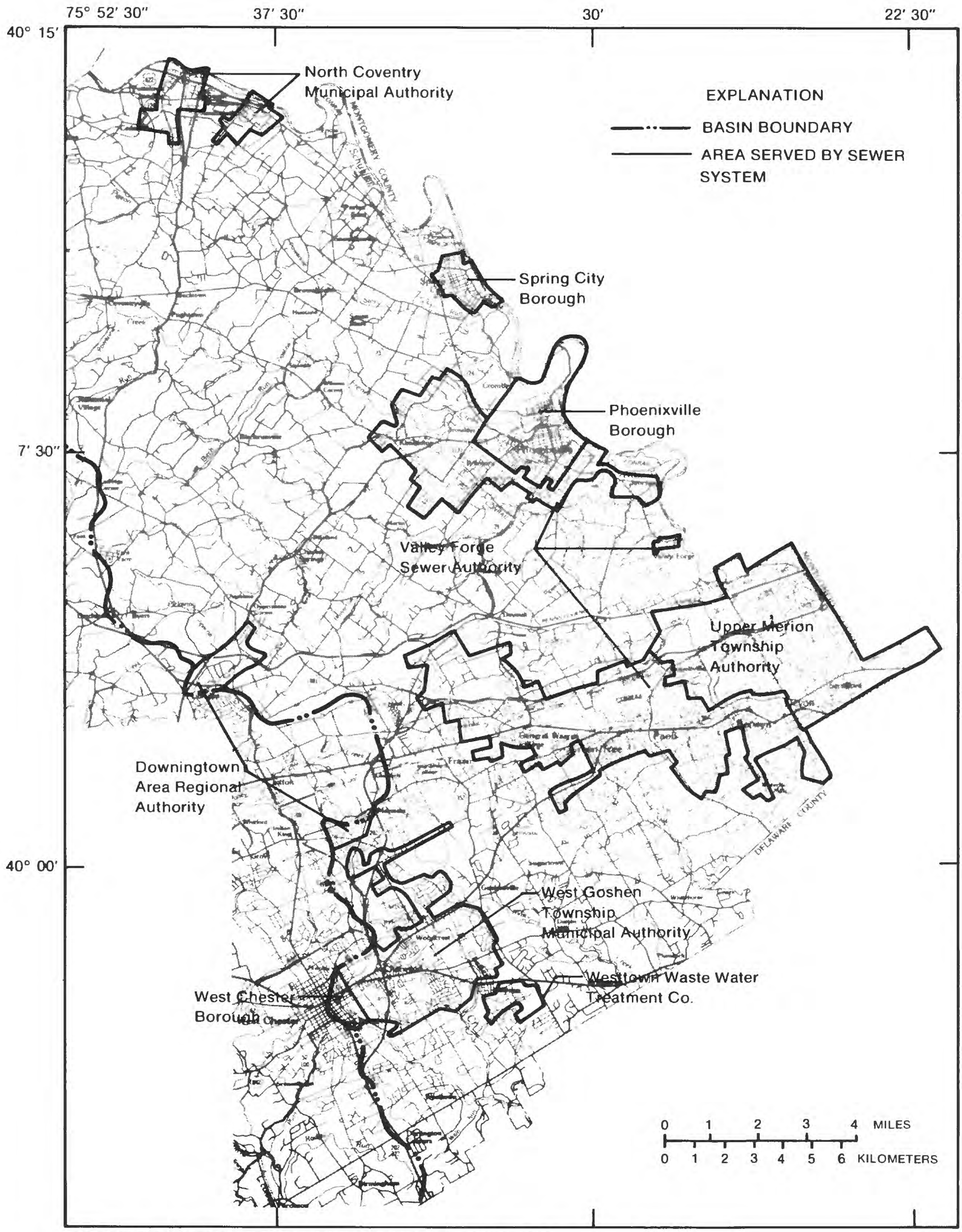
Most of the area served by public water systems is also served by sewer systems. The major sewer systems that serve eastern Chester County and their points of discharge are listed in table 5. Their service areas are shown in figure 10.

Table 5.--Major sewer systems in eastern Chester County

[Dash indicates discharge is not in study area]

Name	Point of discharge	Average daily discharge, 1984 (gallons per day)
Downingtown Area Regional Authority	Brandywine Creek	---
North Coventry Township Municipal Authority	Schuylkill River	450,000
Phoenixville Borough	Schuylkill River	2,700,000
Spring City Borough	Schuylkill River	309,757
Upper Merion Municipal Authority	Trout Run	[1]1,700,000
Valley Forge Sewer Authority	Schuylkill River	5,114,018
West Chester Borough	Goose Creek, tributary to Chester Creek	1,384,000
West Goshen Township Municipal Authority	Goose Creek, tributary to Chester Creek	3,039,000
Westtown Waste Water Treatment Company	Chester Creek	200,000

[1]For study area only



Base from U.S. Geological Survey Chester County 1:50,000, 1983

Figure 10.--Areas served by major sewer systems.

Interbasin Transfer of Water

Prior to urbanization, water supplies were obtained from onsite wells and springs, and wastewater was eliminated by onsite wastewater systems. As population density increased, public water and sewer systems were created. As urbanization progressed, public water suppliers began to withdraw water from wells and surface-water sources in one basin and distribute it in other basins. Interbasin transfer of water also occurs when wastewater moves from one basin to another through sewers. Also, ground water infiltrates sewers in one basin and flows through the system to points of discharge in other basins. Large regional sewer systems, such as the Valley Forge Sewer Authority, treat wastewater from many basins, resulting in a significant interbasin transfer of water.

Interbasin transfer of water does not occur in the less urbanized Pigeon Creek and Stony Run basins. Most of the population of these basins depends on domestic wells and onsite septic systems. Public water and sewer systems that serve small areas of these basins rely on the Schuylkill River as both their source of water supply and point of wastewater discharge. Water from a surface-water source, such as the Schuylkill River, imported into a basin and then discharged as wastewater to the same source is not considered an inter-basin transfer in this report.

Although interbasin transfer of water occurs in the highly urbanized Darby Creek and Trout Run basins, the net transfer is zero. In these basins, all of the public water is imported by public water suppliers and all of the wastewater is exported by sewer systems.

The net interbasin transfer of water in 1984 was estimated for each basin and is summarized in table 6. Most basins showed a net loss of water, ranging from a net loss of 3 Mgal from the French Creek basin to a net loss of 630 Mgal from the Valley Creek basin. The Chester Creek basin had a net gain of 783 Mgal of water, due to importation of water by public water and sewer systems.

All of the public water in the French Creek basin is provided by the Borough of Phoenixville, which uses the Schuylkill River as its source of supply; all public wastewater treatment is provided by either the Phoenixville or Valley Forge Sewer Authority treatment plants, both of which discharge to the Schuylkill River. Based on data published by the Chester County Planning Commission (1982a, p. 46-47), an estimated 3 Mgal of ground water pumped from private wells was removed from the basin as wastewater and discharged to the Schuylkill River in 1984.

Public water in the Pickering Creek basin is provided by the Fox Knoll Water Company, the Philadelphia Suburban Water Company, Phoenixville Borough, and the Uwchlan Township Municipal Authority. Wastewater is treated by the Downingtown Area Regional Authority, Phoenixville, and Valley Forge Sewer Authority treatment plants. The same area supplied with public water from outside the basin by the Uwchlan Township Municipal Authortiy is sewered by the Downingtown Area Regional Authority, also located outside the basin. Based on data from the Chester County Planning Commission (1982a, p. 38-39), an estimated 47 Mgal of ground water pumped from private wells was removed from the basin as wastewater discharged to the Schuylkill River in 1984.

Table 6.--Estimated net interbasin transfer of water, 1984
[Mgal, million gallons]

Basin	Imported water: Quantity (Mgal)	Imported water: Source	Exported water: Quantity (Mgal)	Exported water: Destination	Net interbasin transfer (Mgal)
French Creek	0	--	3	Schuylkill River	-3
Pickering Creek	0	--	47	Schuylkill River	-47
Valley Creek	0	--	530	Schuylkill River	-630
			100	Ridley Creek basin	
Crum Creek	0	--	90	Schuylkill River	-97
			7	Ridley Creek basin	
Ridley Creek	100	Valley Creek basin	128	Chester Creek basin	-24
	7	Crum Creek basin	3	Brandywine Creek	
Chester Creek	677	Brandywine Creek basin	22	Brandywine Creek	+783
	128	Ridley Creek basin			

Public water in the Valley Creek basin is provided by Malvern Borough and the Philadelphia Suburban Water Company. All public wastewater treatment is provided by the Valley Forge Sewer Authority treatment plant. The Philadelphia Suburban Water Company pumped 552 Mgal of water from three wells in the Valley Creek basin in 1984. All of this water was exported, either by water distribution or sewer systems. In addition, about 78 Mgal of ground water pumped by commercial and industrial users was exported as wastewater. Water distributed by Malvern Borough in the Valley Creek basin was pumped in the Crum Creek basin and then exported from the Valley Creek basin as wastewater. In 1984, approximatly 630 Mgal of ground water pumped in the Valley Creek basin was exported.

Public water in the Crum Creek basin is supplied by Malvern Borough and the Philadelphia Suburban Water Company. All public wastewater treatment is provided by the Valley Forge Sewer Authority. In 1984, Malvern Borough pumped 97 Mgal of water from the Crum Creek basin, which was exported from the basin through water mains and sewers.

Public water in the Ridley Creek basin is provided by the Great Valley Division of the Philadelphia Suburban Water Company, the Philadelphia Suburban Water Company, and Malvern Borough. In 1984, the Great Valley Division pumped 170 Mgal from four wells in the basin; much of this was exported from the basin through water mains and sewers. Wastewater treatment is provided by the Downingtown Area Regional Authority, West Goshen Township Municipal Authority, and several small private wastewater treatment plants. These small treatment plants discharged about 38 Mgal of wastewater to Ridley Creek in 1984. An estimated 3 Mgal of wastewater was exported to the

Brandywine Creek basin and 128 Mgal to the Chester Creek basin for treatment (estimates based on data published by the Chester County Planning Commission, 1982a, p. 12-14 and 60-63). The net export of water from the Ridley Creek basin was approximately 24 Mgal in 1984.

Public water in the Chester Creek basin is supplied by the Chatwood Water Company, the Great Valley Division of the Philadelphia Suburban Water Company, the West Chester Area Municipal Authority, and the West Chester Gardens Water Company. In 1984, the Great Valley Division pumped 297 Mgal of ground water, and the Chatwood Water Company pumped about 4 Mgal from wells in the Chester Creek basin. The West Chester Area Municipal Authority imported 526 Mgal of surface water from the Brandywine Creek in 1984 (Phillips, Neil, West Chester Area Municipal Authority, oral commun., 1986). An additional 151 Mgal of ground water pumped by the Great Valley Division in 1984 from wells in the Brandywine Creek basin and 128 Mgal pumped from wells in the Ridley Creek basin was imported into the Chester Creek basin through water mains and sewers. Wastewater treatment in the Chester Creek basin is provided by West Chester Borough, West Goshen Township Municipal Authority, and the Westtown Waste Water Treatment Company. In 1984, these plants discharged 1.7 billion gallons of wastewater to Chester Creek. An estimated 22 Mgal of wastewater was exported to the Brandywine Creek basin. The net transfer was an importation of 783 Mgal of water into the Chester Creek basin in 1984.

EFFECT OF URBANIZATION ON WATER QUANTITY

Effect of Sewering

Most sewer lines are not watertight, and some exchange of water between sewers and the ground-water system probably occurs. Infiltration of ground water into sewers can occur when the water table is above the sewer line, and leakage from sewers to the ground-water system can occur when the water table is below the sewer line. Infiltration and leakage probably occur simultaneously, but each occurs in different areas depending on whether the water table is above or below the sewer line.

Ground-water infiltration to sewers generally increases as the altitude of the water table increases. Discharge from a wastewater-treatment plant usually correlates much better with the altitude of the water table than with water use or precipitation, indicating that the quantity of water arriving at a wastewater treatment plant is controlled to some extent by the altitude of the water table, and that some part of the water arriving at the plant is infiltrated ground water. This relation between the altitude of the water table and discharge from a wastewater-treatment plant was observed in Bucks County by Sloto and Davis (1982, p. 19-22). The same relation exists between discharge from wastewater-treatment plants in eastern Chester County and the altitude of water table. When the water table is low, it is possible for a sewer system to lose water to the ground-water system, and wastewater arriving at a treatment plant is less than that contributed by users of the system.

Ground-water infiltration to sewer systems is difficult to quantify in eastern Chester County because water-use and wastewater-discharge data for the same area are difficult to obtain. An area served by a wastewater-treatment plant is often served by several public water suppliers as well as private wells. For example, water being treated at the Valley Forge Sewer Authority treatment plant originates from private wells, the Malvern and Phoenixville Borough water systems, and the Philadelphia Suburban Water Company. All of these water suppliers also provide water to users served by other wastewater-treatment plants and onsite septic systems. However, some estimates of ground-water infiltration to sewers were made. These estimates show that the quantity of ground-water infiltration to sewers is substantial, sometimes being a greater percentage of the flow to a treatment plant than wastewater.

Ground-water infiltration to sewers can result in a decrease in base flow. The sewers act as drains for the ground-water system and intercept ground water that would be discharged to streams. When the sewer system and point of discharge are in the same basin, the sewer system can short-circuit the natural flow path. When wastewater is removed from the sewered basin and discharged in another basin, it can result in a loss of streamflow in the sewered basin and an increase in streamflow in the basin where the wastewater is discharged.

The general relations among discharge from the Valley Forge Sewer Authority treatment plant, the level of the water table observed in well CH-210 in the sewered area, and monthly precipitation at Phoenixville for 1980-84 is shown in figure 11. The discharge from the Valley Forge Sewer Authority treatment plant correlates well with the altitude of the water table observed in well CH-210 (correlation coefficient = 0.71). The discharge from the treatment plant does not correlate well with precipitation (correlation coefficient = 0.50); and the altitude of the water table observed in well CH-210 does not correlate well with precipitation (correlation coefficient = 0.45).

The quantity of ground-water infiltration to or leakage from a sewer system can be estimated by comparing water use and the return flow to a wastewater-treatment plant. Assuming an average water use of 3 Mgal/d for 1980-84, and an average consumptive loss of 10 percent, the estimated average ground-water infiltration to the Valley Forge Sewer Authority system would be about 1.2 Mgal/d or 1.9 ft^3/s (cubic feet per second). The average flow of French Creek for 1968-84 was 1.6 $(ft^3/s)/mi^2$ (square mile). Assuming 65 percent of the flow is base flow (McGreevy and Sloto, 1977, p. 38), the average base flow is 1 $(ft^3/s)/mi^2$. Therefore, average ground-water infiltration to the Valley Forge Sewer System is about equal to the total base flow from 2 mi^2 of the French Creek basin. The greatest estimated average monthly infiltration, 4.9 Mgal/d, occurred in April 1984. During this month, infiltrated ground water made up a higher percentage of the flow to the Valley Forge treatment plant than did wastewater. The Chester County Planning Commission estimated ground-water infiltration to the Valley Forge treatment plant after rainfall to be 3.4 Mgal/d (Chester County Planning Commission, 1985, p. 53).

Some of the same area supplied with water by the Great Valley Division of the Philadelphia Suburban Water Company is sewered by the West Goshen Township Municipal Authority. However, many homes with domestic wells are served by the West Goshen treatment plant and many homes with onsite septic systems are served by the Great Valley Division. The relations among the discharge from the West Goshen treatment plant, water distributed by the Great Valley Division, and the level of the water table observed in nearby well CH-1387 are shown in figure 12. Both the wastewater discharge from the West Goshen treatment plant and water distributed by the Great Valley Division show an increasing trend for 1980-84 because of population growth in the service areas. This increasing trend was not considered in calculating correlation coefficients and probably affects them. Discharge from the West Goshen treatment plant correlated best with the altitude of the water table observed in well CH-1387 (correlation coefficient = 0.69), and almost as well with water distributed by the Great Valley Division (correlation coefficient = 0.61). Discharge from the West Goshen treatment plant did not correlate well with precipitation at West Chester (correlation coefficient = 0.40), and the altitude of the water table observed in well CH-1387 did not correlate well with precipitation (correlation coefficient = 0.32).

The quantity of water distributed by the Great Valley Division fluctuates over a much narrower range than does the quantity of wastewater discharged from the West Goshen treatment plant. The difference between the annual minimum and maximum for the Great Valley Division ranged from 0.116 Mgal/d in 1981 to 0.403 Mgal/d in 1983. The difference between the annual minimum and maximum for the West Goshen treatment plant ranged from 0.619 Mgal/d in 1981 to 1.811 Mgal/d in 1983.

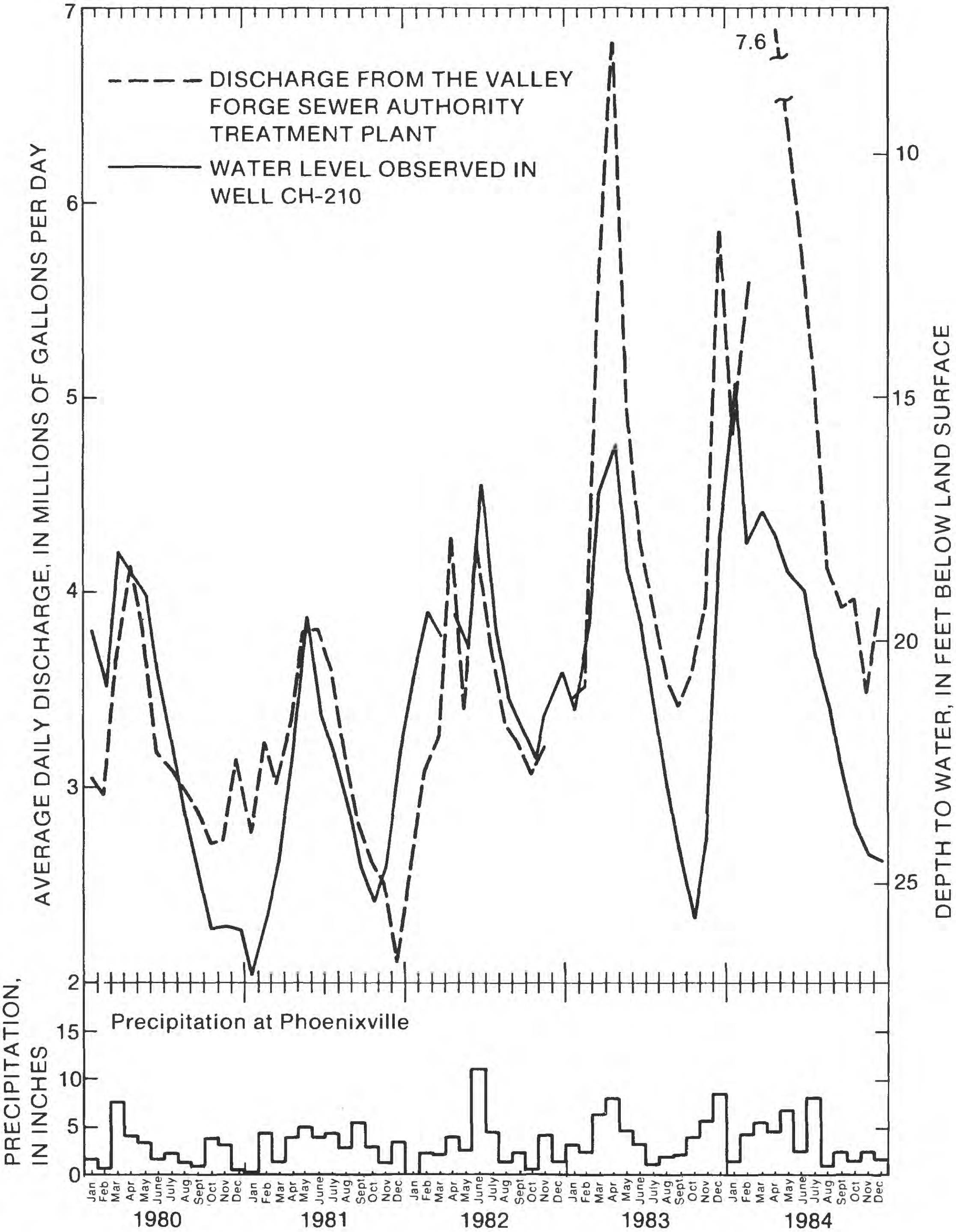


Figure 11.--Relations among discharge from the Valley Forge Sewer Authority treatment plant, water level observed in well CH-210, and precipitation at Phoenixville, 1980-84.

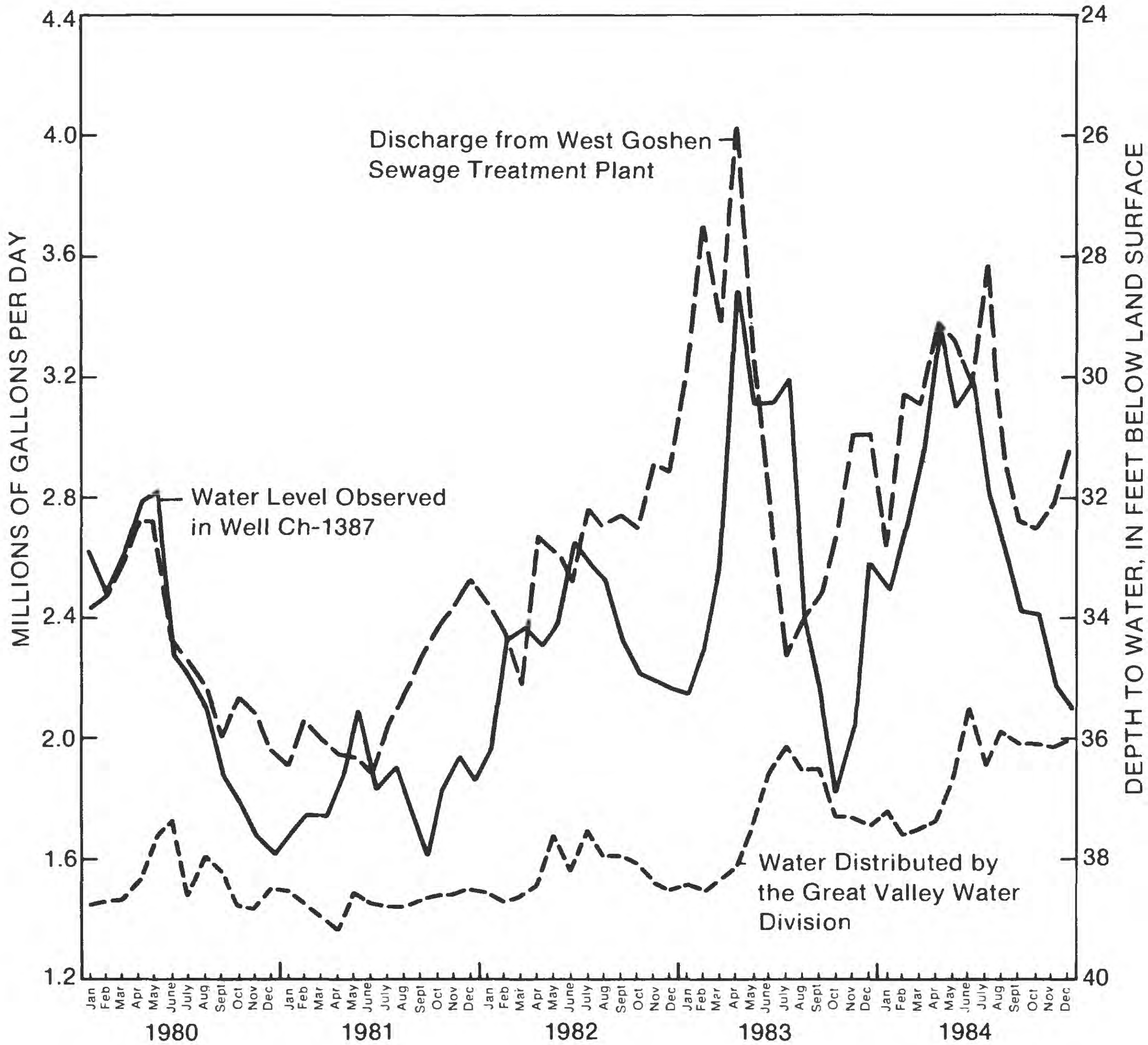


Figure 12.--Relations among discharge from the West Goshen treatment plant, water distributed by the Great Valley Division of the Philadelphia Suburban Water Company, and level of the water table observed in well CH-1387, 1980-84.

Assuming that pumpage from private wells and water supplied by the West Chester Area Municipal Authority is equal to 40 percent of pumpage by the Great Valley Division and consumptive use is 10 percent, estimates of monthly ground-water infiltration to the West Goshen sewer system were as much as 2.1 Mgal/d, which occurred in April 1983. This coincides with the highest water level measured in well CH-1387 from 1980-84. The average estimated ground-water infiltration to the sewer system for 1980-84 is 0.5 Mgal/d. This would be equal to an average reduction in streamflow of 0.8 ft^3/s because of intercepted base flow. The West Goshen treatment plant serves about 5.9 mi^2; therefore, the average estimated ground-water loss to the sewer system would be 0.14 $(ft^3/s)/mi^2$ of sewered area. The average flow of Chester Creek for 1931-84 was 1.45 $(ft^3/s)/mi^2$. Base flow comprises about 64 percent of the streamflow of Chester Creek, based on hydrograph separations for 1932-82 (Balmer, W. T., U.S. Geological Survey, written commun., 1986). Estimated interception of base flow by the sewer system is 15 percent of the average long-term base flow in the sewered area. The Chester County Planning Commission estimates normal ground-water infiltration to the West Goshen treatment plant to be 1.2 Mgal/d (Chester County Planning Commission, 1985, p. 175). This would be equal to the interception by the sewer system of 33 percent of the long-term base flow of Chester Creek in the sewered area.

The area served with public water by Malvern Borough approximately coincides with the area for which Malvern Borough meters wastewater sent to the Valley Forge treatment plant. Water-use and wastewater data are available for part of 1982, all of 1983, and most of 1984. Wastewater flow from Malvern Borough for this period correlates better with the altitude of the water table observed in nearby well CH-2521 (correlation coefficient = 0.56) than with water use (correlation coefficient = -0.08). Wastewater flow to the sewer system is lower than water use, except in some periods when the water table is high (fig. 13). Part of this difference is due to consumptive use and a few large institutional water users not on the Malvern Borough sewer system. When the water table was near its highest point (April 1983), water use was 0.266 Mgal/d and wastewater flow was 0.325 Mgal/d, or 0.059 Mgal/d greater than water use, indicating substantial ground-water infiltration.

In municipalities with older water and sewer systems, the quantity of water distributed may be higher than the return flow to the sewer system because of water main breaks and leakage from old water distribution pipes. However, the flow to the wastewater-treatment plant can still be at least partially controlled by the altitude of the water table. Phoenixville's water and sewer systems date to the 1890's (Roth, R., Phoenixville Borough, oral commun., 1985). Although a few of Phoenixville's water system users are not on the borough's sewer system, water distribution is generally greater than the return flow to the sewer system (fig. 14). Average water distribution for 1980-84 was 3.06 Mgal/d, while average wastewater discharge was 2.47 Mgal/d. Water use did not correlate well with discharge from the wastewater treatment plant (correlation coefficient = -0.26); however, the altitude of the water table observed in well CH-1633 in the borough correlated very well with the discharge from the wastewater-treatment plant (correlation coefficient = 0.89) for November 1982 to December 1984--the period of record for well CH-1633.

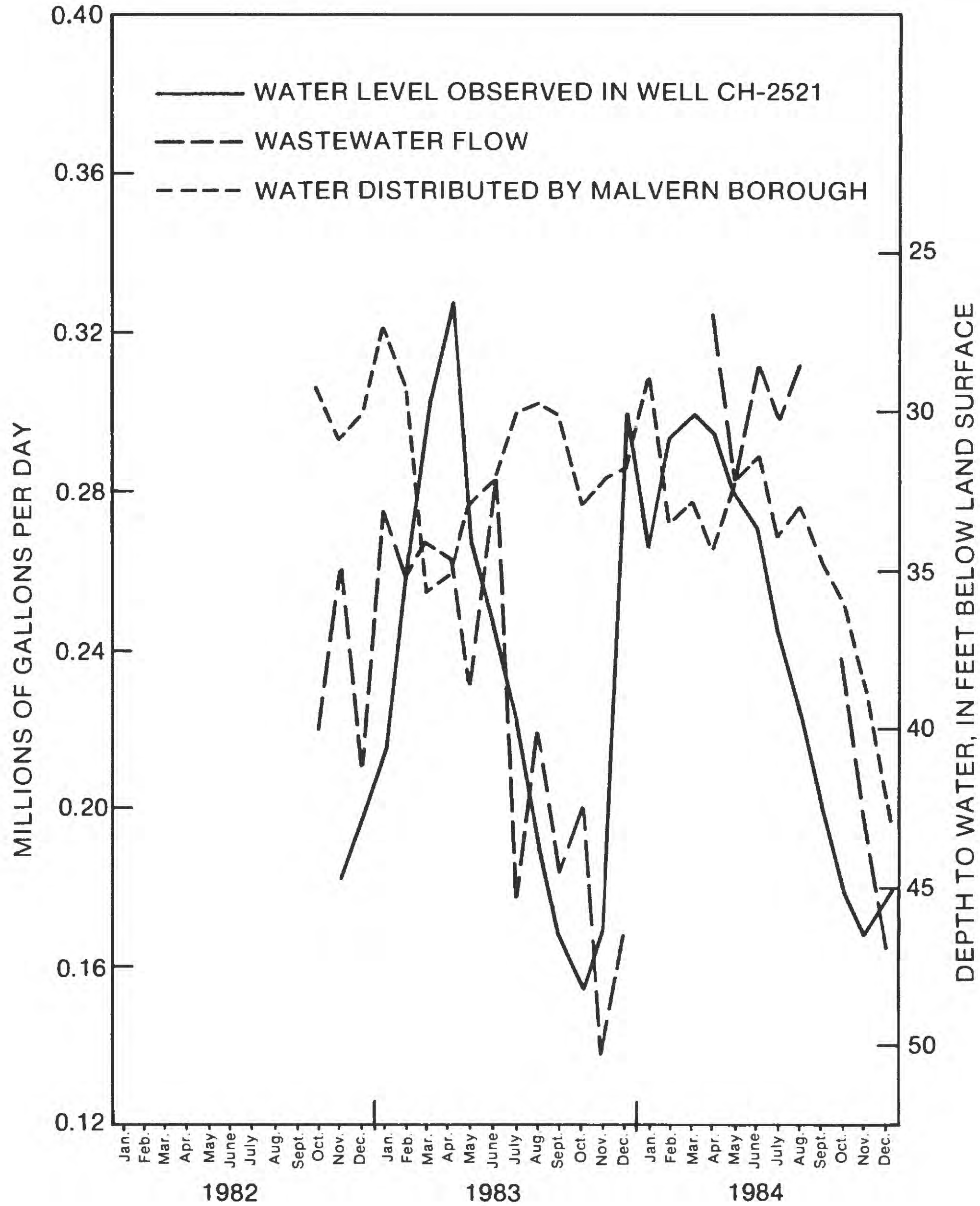


Figure 13.--Relations among wastewater flow from Malvern Borough, water distributed by Malvern Borough, and level of the water table observed in well CH-2521, 1982-84.

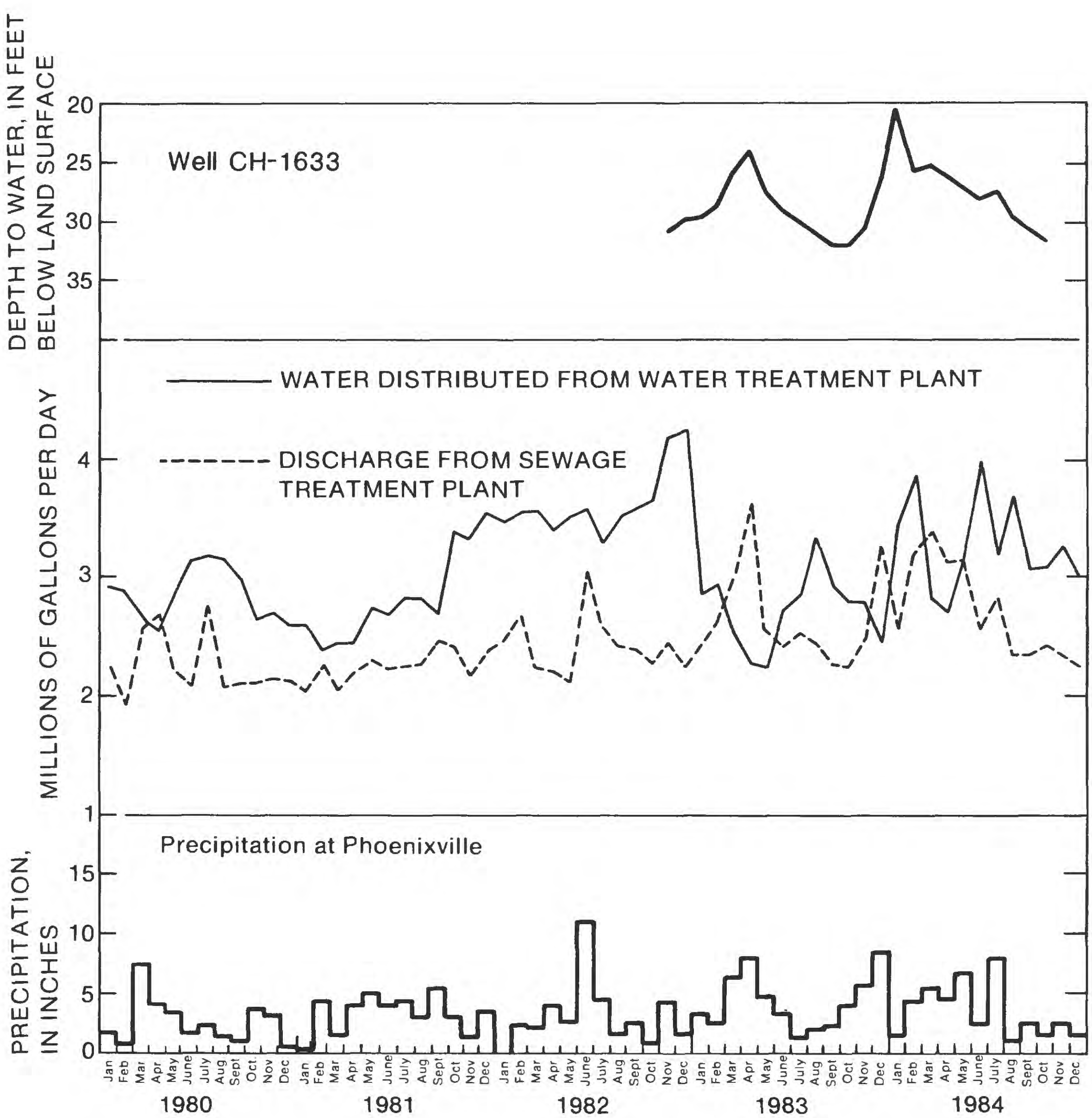


Figure 14.--Relations among discharge from the Phoenixville wastewater treatment plant, water distributed by the Phoenixville water system, the water level observed in well CH-1633, and precipitation at Phoenixville, 1980-84.

Effect of Pumping High-Capacity Wells

The Philadelphia Suburban Water Company obtains part of its water supply from three wells in Chester Valley. Two of these wells were pumping during water-level measurements made in October 1983, while the water table in eastern Chester Valley was being mapped (plate 2): well CH-2199, near State Route 401 and U.S. Route 202; and well CH-209, at State Route 252 and the Pennsylvania Turnpike (well locations are shown on plate 1). The observable extent of the cones of depression caused by the pumping of wells CH-2199 and CH-209 are approximately 1,000 feet in diameter (plate 2) in the Ledger and Elbrook Formations. The cones of depression are probably elliptical with the long axis aligned along strike; however, data are insufficient to define them exactly. The cone of depression caused by the pumping of a public supply well in the Conestoga Formation in Montgomery County adjacent to Chester County had a diameter of about 3,400 feet and extended into Chester County (plate 2).

A seepage study of Valley Creek was made in October 1984, to determine which reaches of Valley Creek gained or lost water. Measurement sites are shown on figure 15 and measurements are given in table 27. Streamflow measurements indicate that pumping of large-capacity wells may cause some stream reaches to lose water or to go dry at a distance from the well. However, no loss was measured from streams in the immediate vicinity of the pumping wells. During streamflow measurements, three public-supply wells were pumping. Valley Creek was flowing 0.23 ft^3/s at site 10 (fig. 15), but was dry from site 11 to the confluence with a tributary (900 feet). Site 11 is 1,100 feet west of well CH-207 and is along strike. An unnamed tributary flowing perpendicular to strike past well CH-207 did not lose flow. An unnamed tributary to Valley Creek was flowing 0.12 ft^3/s at site 2, but was dry at and above site 3. The dry reach is 1,700 feet northwest of well CH-2199, and also coincides with a normal fault through the Ledger Formation. An unnamed tributary to Valley Creek flowing 0.05 ft^3/s at site 63, was dry from site 64 to Valley Creek (1,500 feet). This tributary is 2,700 feet west of well CH-209, and flows perpendicular to strike in the Elbrook Formation. A loss of 0.66 ft^3/s was measured between sites 65 and 66 on Valley Creek. This reach is 2,300 feet from well CH-209. Additional streamflow measurements made during low-flow conditions on July 1, 1985, showed a loss of 1.45 ft^3/s in this reach (table 7). Valley Creek flows perpendicular to strike in this reach, and some of this loss is probably due to underflow to the east, as Valley Creek leaves the carbonate rocks of Chester Valley at site 66.

Well CH-2457, which is 1,300 feet west of public-supply well CH-2667 in the oligoclase mica schist facies of the Wissachickon Formation, was equipped with a continuous water-level recorder. No effects of pumping were observed in the hydrograph of well CH-2457.

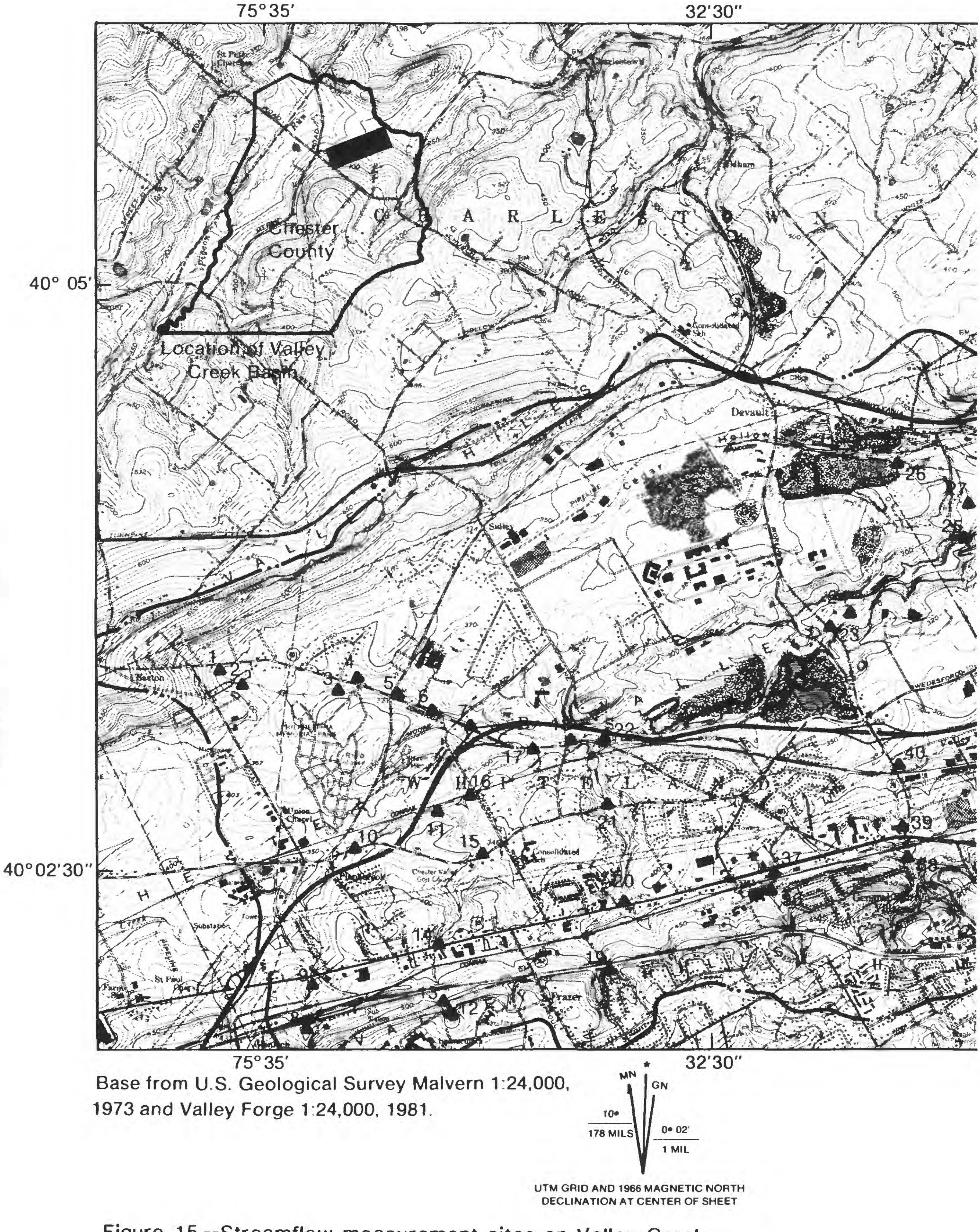
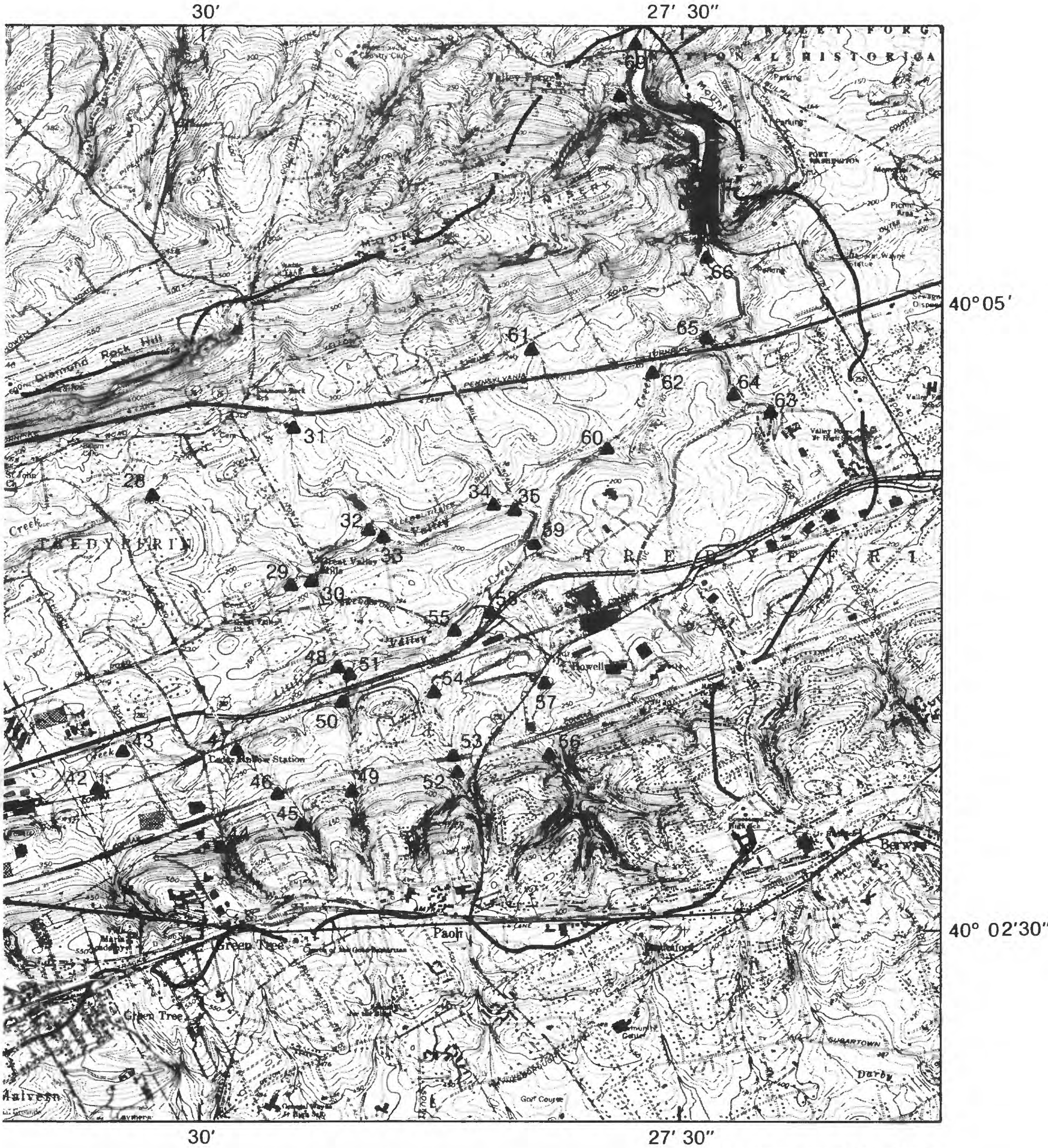


Figure 15.--Streamflow measurement sites on Valley Creek.



Hydrology by R.A. Sloto

1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

BASIN BOUNDARY

1▲ STREAMFLOW MEASUREMENT SITE AND NUMBER

Table 7.--Streamflow measurements on Valley Creek, July 1, 1985
[Measurement sites are shown on figure 15; ft^3/s, cubic feet per second]

Site number	Measured discharge (ft^3/s)	Gain or loss in Valley Creek and(or) measurement error (ft^3/s)
35	10.9	---
59	4.14	---
60	15.1	+0.08
62	14.9	-0.23
65	17.7	+2.78
66	16.21	-1.45

Effect of Quarry Dewatering

In the past, many quarries operated in Chester Valley; in 1986, only two quarries were operating. They are on opposite sides of State Route 29 in East Whiteland Township. The Catanach Quarry, operated by Glasgow Inc., is west of Route 29. The Cedar Hollow Quarry, operated by the Warner Company, is east of Route 29. The quarries are about 1,200 feet apart. Both quarry operators pump large quantities of ground water to keep the quarries dewatered. Pumpage from the Catanach Quarry is discharged to a closed surface depression. Pumpage from the Cedar Hollow Quarry is discharged to a tributary to Valley Creek. Between June 10 and September 30, 1984, daily pumpage from the Cedar Hollow Quarry ranged from 1.7 to 7.2 Mgal/d, and averaged about 5 Mgal/d (Whitcomb, Thomas, Pennsylvania Department of Environmental Resources, written commun., 1985). Quarry discharge was measured at a weir maintained by the Warner Company.

The effect of quarry dewatering on the water table in Chester Valley is shown on plate 2. The cone of depression around the Cedar Hollow Quarry is approximately 5,000 feet long and 2,000 feet wide. The cone of depression around the Catanach Quarry is approximately 5,000 feet long and 3,500 feet wide.

Several hydrologic and geologic controls act to keep the cones of depression caused by quarry dewatering confined to a small part of Chester Valley. The contact between the carbonate rocks of the Ledger and Elbrook Formations and the crystalline rock of the Chickies Formation and granodiorite and grandiorite gneiss is about 1,000 feet north of the Cedar Hollow Quarry and about 2,000 feet north of the Catanach Quarry. The cone of depression of the Cedar Hollow Quarry extends only a short distance beyond this contact; the cone of depression of the Catanach Quarry does not extend past this contact. The crystalline rocks are much less permeable than the carbonate rocks and act as a barrier to keep the cones of depression confined to the carbonate rocks. To the south, both quarries extend into the Elbrook Formation, which forms a ridge parallel to the quarries (plate 1). The strike of the Elbrook along this ridge is parallel to the ridge and the quarries. The dip of the Elbrook, measured at

State Route 29, is 70° to the southeast. Because the bedding of this ridge is parallel to the quarries, nearly vertical, and the parting planes are coated with sericite, ground-water flow perpendicular to the ridge is restricted, and the extent of the cone of depression is also restricted. Pumpage from the Catanach Quarry is discharged to a closed depression east of the quarry, and causes a ground-water recharge mound that separates the two cones of depression caused by quarry dewatering. West of the Catanach Quarry, the cone of depression is not restricted.

The effect of quarry dewatering on local water-level fluctuations is shown in figure 16. All five wells are in the carbonate rocks of Chester Valley. The range of fluctuation in water level in four wells (CH-210, CH-323, CH-2313, and CH-2522) not near an active quarry was from 6 to 15 feet between January 1984 and September 1985, and water levels were less than 40 feet below land surface. The water level in well CH-2561, near an active quarry, was much deeper, up to 156.80 feet below land surface, because it is in the cone of depression caused by quarry dewatering. The range of fluctuation in the water level in well CH-2561 was more than 34 feet during the same period, almost three times as great as the average fluctuation observed in the other wells. The greater range in fluctuation may be partly caused by the zone of fluctuation being deeper in the bedrock where storage is less.

Discharge measurements were made at 10 sites below the Cedar Hollow Quarry on June 27, 1985, (fig. 17) to determine gain or loss of quarry discharge water. The quarry pumps were shut off on June 26 and the quarry was allowed to flood. Pumping began again on June 27. Quarry discharge was maintained at a constant 8.56 ft^3/s (5.53 Mgal/d) by quarry personnel and monitored at a weir equipped with a continuous recorder. The reach between sites Q1 and Q3 (500 feet) is an artificial channel constructed to form a pool behind the weir. Loss in this reach was 0.62 ft^3/s (table 8). The reach between sites Q3 and Q5 is a former quarry drainage tunnel cut through bedrock and later opened to the surface. A settling pond is between sites Q5 and Q6. Between sites Q3 and Q6 (1,100 feet), a gain of 1.10 ft^3/s was measured. Between sites Q6 and Q9 (750 feet), where the tributary to Valley Creek flows perpendicular to strike, a loss of 1.55 ft^3/s was measured. Some of this loss may be due to quarry pumping. Between sites Q9 and Q10 (200 feet), near the confluence of this tributary and Valley Creek, a gain of 2.45 ft^3/s was measured. Between the quarry discharge point and Valley Creek, a net gain of 1.43 ft^3/s was measured.

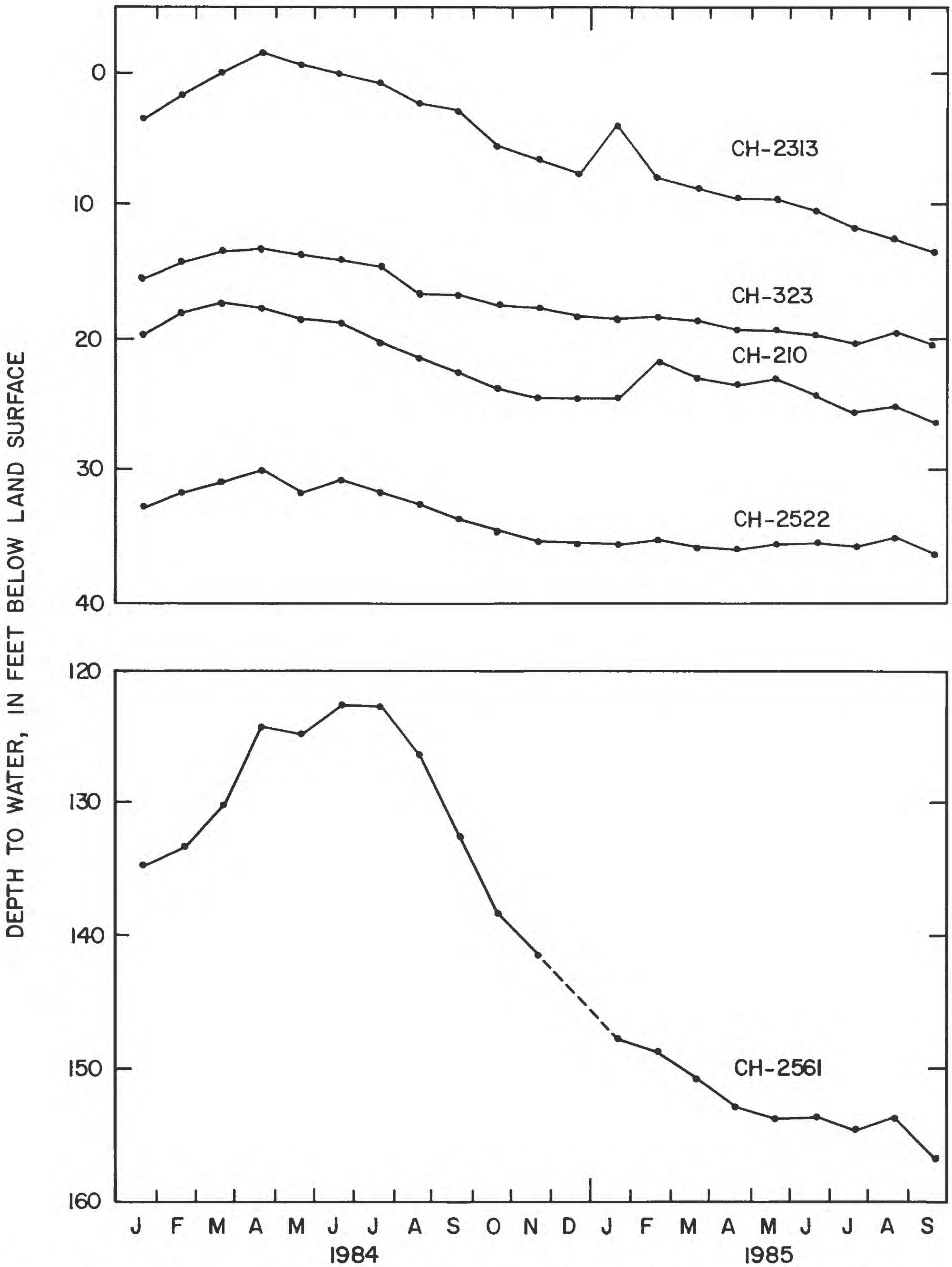
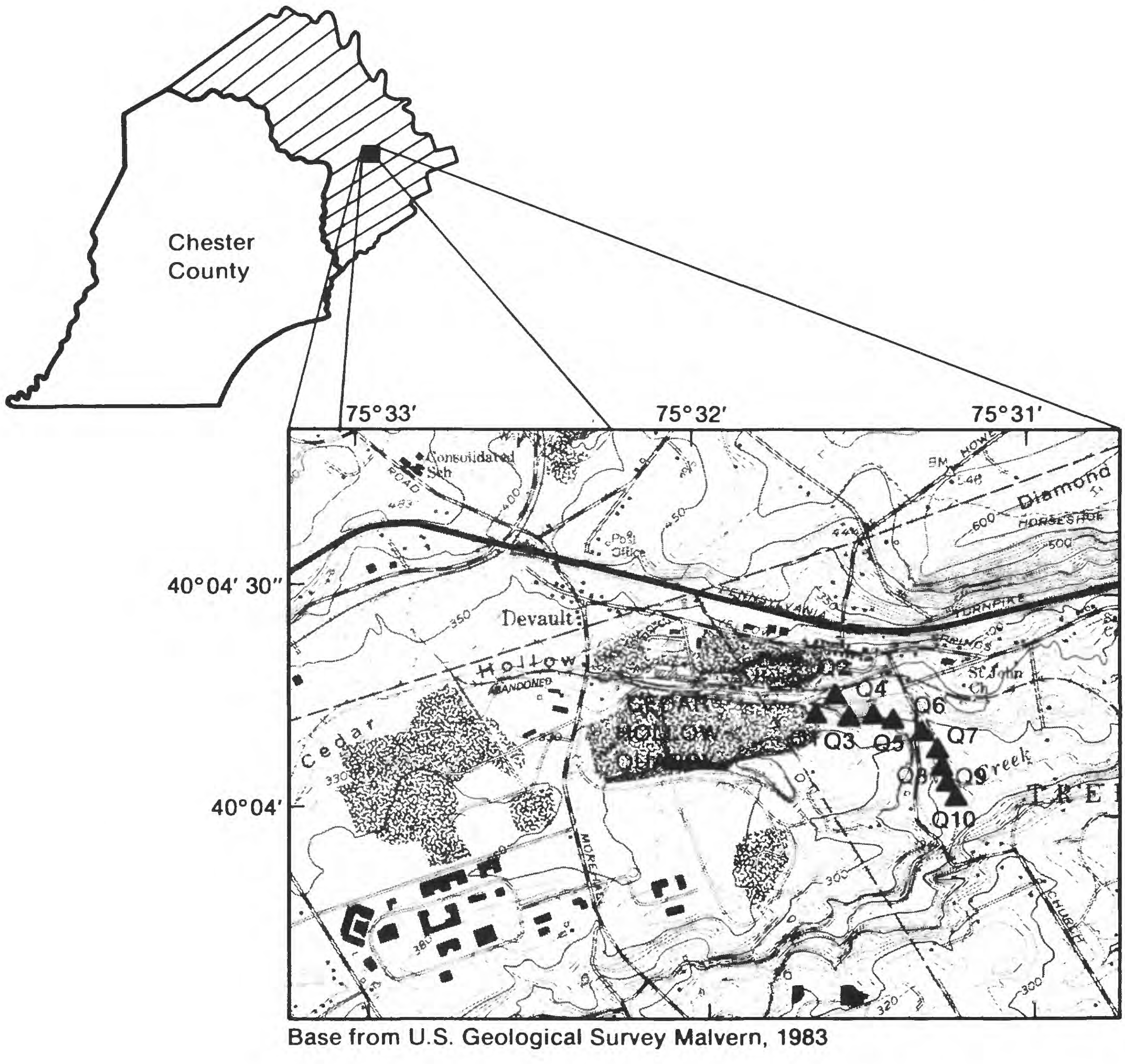


Figure 16.--Hydrographs of five wells in the carbonate rocks of Chester Valley, January 1984 to September 1985.



EXPLANATION

▲Q1 DISCHARGE MEASUREMENT SITE AND NUMBER

0 1000 2000 Feet
0 300 600 Meters

Figure 17.--Discharge measurement sites below the Cedar Hollow Quarry, June 27, 1984.

Table 8.--Discharge measurements made below the Cedar Hollow Quarry, June 27, 1985

[Measurement sites are shown on figure 17; ft^3/s, cubic feet per second]

Site number	Location	Discharge (ft^3/s)	Gain (+) or loss (-) and measurement error (ft^3/s)
Q1	Below discharge pipes	8.56	
Q2	Tributary 60 feet below weir	[1]0.030-0.063	
Q3	100 feet below weir	7.99	-0.62
Q4	Between weir and settling pond	8.60	+ .61
Q5	Inflow to settling pond	8.99	+ .39
Q6	100 feet below settling pond	9.09	+ .10
Q7	Approximately 400 feet below settling pond	8.12	- .97
Q8	Approximately 600 feet below settling pond	7.72	- .40
Q9	Approximately 900 feet below settling pond	7.54	- .18
Q10	Above confluence with Valley Creek	9.99	+2.45

[1]Measurement by modified 3-inch Parshall flume. Flow was 0.03 ft^3/s at beginning of measurement 3 and 0.063 ft^3/s at end of measurement 3. Assumed inflow from tributary is 0.05 ft^3/s.

EFFECT OF URBANIZATION ON GROUND-WATER QUALITY

Organic Compounds

One of the most serious consequences of urbanization has been the introduction of man-made organic compounds into the subsurface environment. Some of these compounds have been entering the ground-water system for decades, but awareness of their presence in drinking-water supplies did not begin until the mid-1970's, when analytical techniques became available to detect their presence. The USEPA (U.S. Environmental Protection Agency) has classified 110 compounds, known as priority pollutants, as toxic organic compounds. They are divided into four fractions by gas chromatography-mass spectroscopy analysis: (1) volatile, (2) acid, (3) base-neutral, and (4) pesticide (Office of the Federal Register, 1983, p. 97-98).

Volatile Organic Compounds

Volatile organic compounds (VOCs) are extensively used in industrial, commercial, and household applications. Their occurrence in ground water presents a serious problem for public water suppliers, industries, and domestic well owners that rely on ground water. Many of the VOCs are confirmed or suspected human or animal carcinogens (Council on Environmental Quality, 1981, p. 64). They generally enter the ground-water system by spills, leakage from storage tanks, discharge from septic systems, and from lagoons and disposal sites. Once in the ground-water system, they are very difficult to remove, and treatment is generally expensive.

VOCs have been in use for many years, but the length of time VOCs have been present in ground water is unknown. Analysis by the U.S. Geological Survey for VOCs in ground water in Chester County began in 1980. Trichloroethylene (TCE), a commercial solvent and industrial metal degreaser, became a common degreasing agent in the 1920's and its use in the dry cleaning industry began in the 1930's (Petura, 1980). Awareness of its presence in ground water began in the 1970's.

Water samples for analysis for VOCs were collected from 70 wells during 1980-85. Compounds analyzed and their frequency of occurrence are given in table 9. Analytical results are given in table 28. Not all compounds were analyzed for all water samples. The choice of wells for sampling was not random, but was biased towards wells in areas that had the potential for the presence of VOCs in ground water.

VOC samples were collected in glass vials sealed with teflon septa; head space was avoided to prevent degassing of the sample. Samples were refrigerated and shipped in ice to the U.S. Geological Survey laboratory for analysis.

Because of sampling and analytical procedures, concentrations of VOCs probably represent minimum concentrations. Ideally, a sample for VOC analysis should be collected at ambient pressure and temperature in the well with a downhole sampling device. Because almost all of the wells sampled were equipped with pumps, this was not possible. In the process of collecting the

Table 9.--Frequency of occurrence of volatile organic compounds in ground water

Compound	Number of wells sampled	Number of wells with concentration above detection limit	Percentage of wells with concentration above detection limit
Benzene	70	8	11
Bromofom	70	1	1
Carbon tetrachloride	70	0	0
Chlorobenzene	70	1	1
Chlorodibromomethane	70	0	0
Chloroethane	41	0	0
2-chloroethyl vinyl ether	50	0	0
Chloroform	70	2	3
1,2,-trans-dichloroethylene	70	10	14
Dichlorobromomethane	70	0	0
Dichlorodifluoromethane	62	0	0
1,1-dichloroethane	70	2	3
1,2-dichloroethane	70	2	3
1,1-dichloroethylene	70	2	3
1,2-dichloropropane	70	0	0
1,3-dichloropropane	50	0	0
Ethylbenzene	70	0	0
Methylbromide	41	0	0
Methyl chloride	70	4	6
1,1,2,2-tetrachloroethylene	70	0	0
Tetrachloroethylene	70	7	10
Toluene	70	3	4
1,1,1-trichloroethane	70	11	16
1,1,2-trichloroethane	70	0	0
Trichloroethylene	70	17	24
Trichlorofluoromethane	61	0	0
Vinyl chloride	41	0	0
Total	70	27	39

sample and in the laboratory extraction process, some of the compounds may have been lost to the atmosphere.

VOCs were detected in 39 percent of the wells sampled (table 9), and 13 of 27 compounds analyzed were detected. The most commonly occurring compounds were trichloroethylene (24 percent of sampled wells), 1,1,1-trichloroethane (16 percent), 1,2,-trans-dichloroethylene (14 percent), benzene (11 percent), and tetrachloroethene (10 percent). The compounds detected and range of concentrations are given in table 10. Total VOC concentrations were as high as 17,400 µg/L (micrograms per liter) with concentrations of a single compound (1,1-dichloroethylene and 1,1,1-trichloroethane) as high as 5,400 µg/L.

Table 10--Volatile organic compounds detected in ground water

[All concentrations are in micrograms per liter; a dash indicates insufficient data to calculate a median]

Compound	Number of wells sampled	Number of wells with concentration above detection limit	Minimum concentration above detection limit	Maximum concentrations	Median concentrations
Benzene	70	8	3	20	3
Bromoform	70	1	10		-
Chlorobenzene	70	1	2		-
Chloroform	70	2	49	190	-
1,2-trans-dichloroethylene	70	10	8	560	24
1,1-dichloroethane	70	2	39	62	-
1,2-dichloroethane	70	2	20	140	-
1,1-dichloroethylene	70	2	7	5,400	-
Methyl chloride	70	4	32	300	-
Tetrachloroethylene	70	7	5.1	1,200	20
Toluene	70	3	2	20	-
1,1,1-trichloroethane	70	11	11	5,400	70
Trichloroethylene	70	17	6	4,400	2
Total VOC concentration	70	27	3	17,400	78

Water samples from 74 percent of the wells in which VOCs were detected had more than one compound present. As many as nine compounds were detected in one water sample. The compounds most often found occurring together were trichloroethylene and 1,1,1-trichloroethane (10 samples), trichloroethylene and tetrachloroethylene (9 samples), and trichloroethylene and 1,2-trans-dichloroethylene (6 samples).

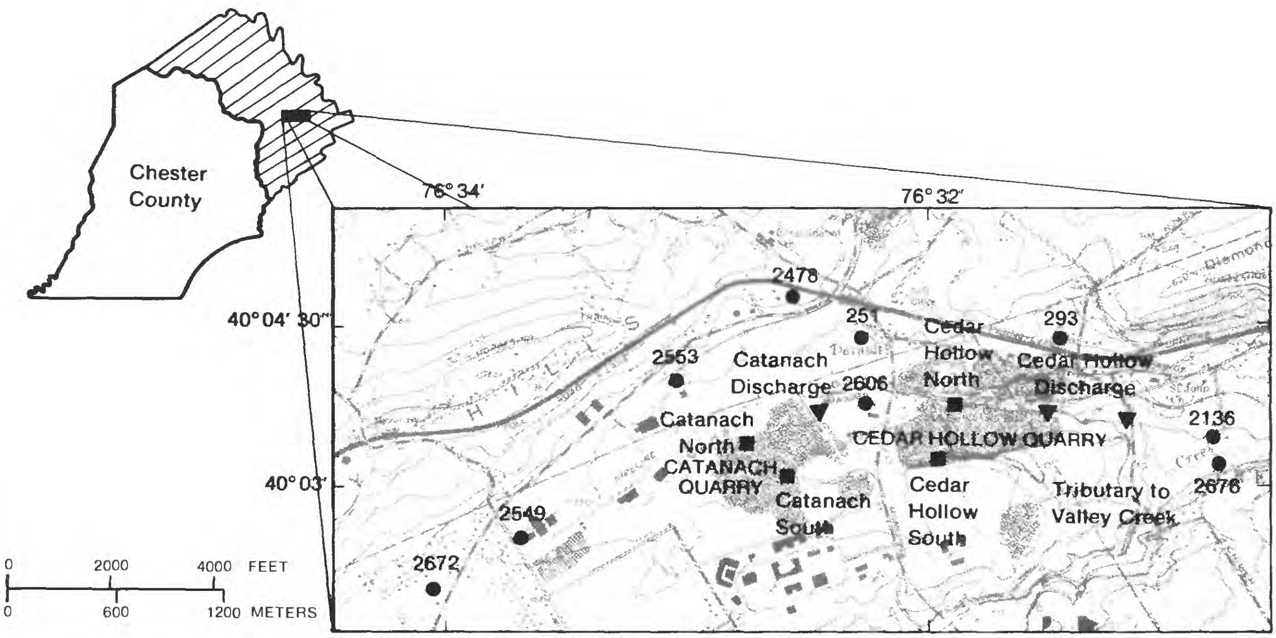
Some of the compounds present in ground water may be the result of biodegradation. Some investigations have shown that some VOCs may be transformed by microorganisms in anaerobic subsurface material. Parsons and others (1984, p. 56-59) found that microorganisms were able to transform trichloroethylene and tetrachloroethylene into cis- and trans-1,2,-dichloroethylene. Other laboratory studies have shown significant biodegradability of trichloroethylene, tetrachloroethylene, and other VOCs (Tabak and others, 1981, p. 1514).

Many of the VOCs detected in ground water are industrial solvents. Trichloroethylene, tetrachloroethylene, 1-2,-trans-dichloroethylene, and 1,1,1-trichloroethane are commonly used as degreasers in the metals, electronics, and plastics industries. Trichloroethylene (TCE) has also been used as a septic tank cleaner, a solvent for paints and varnishes, and has been used extensively in the dry cleaning, chemical, and pharmaceutical industries. Tetrachloroethylene, also known as perchloroethane (PCE), is commonly used in dry cleaning.

Benzene and toluene are fractional components of gasoline, diesel fuel, and fuel oil. Gasoline and fuel oil float on water, but benzene and toluene are soluble. Benzene and toluene are also used as industrial solvents and in the manufacture of pharmaceuticals and organic chemicals.

In other parts of Chester County not included in this study, chloroethane and 1,1,2-trichloroethane also have been detected in ground water.

Water samples from nine wells, four quarry inflow sites, two quarry discharge points, and one surface-water site were analyzed for the presence of VOCs in the vicinity of the active quarries in Chester Valley (fig. 18). Inflow to the Catanach Quarry was sampled from fractures in the north and south quarry walls. Discharge from the quarry was sampled as flow from the settling pond. Inflow to the Cedar Hollow Quarry was sampled from a fault in the south wall and from a solution opening in the north wall, about 15 feet above the quarry floor. Discharge from the quarry was sampled below the discharge pipe and from a tributary to Valley Creek below the settling pond. The flow in this tributary is almost entirely quarry discharge water. The concentrations of VOCs detected are given in table 11.



Base from U.S. Geological Survey Malvern, 1983

EXPLANATION

251 ● WELL--Number is Well Identification Number

CATANACH NORTH ■ QUARRY INFLOW--Name is Sampling Site Location Name

CATANACH DISCHARGE ▼ QUARRY DISCHARGE OR SURFACE WATER SITE--Name is Sampling Site Location Name.

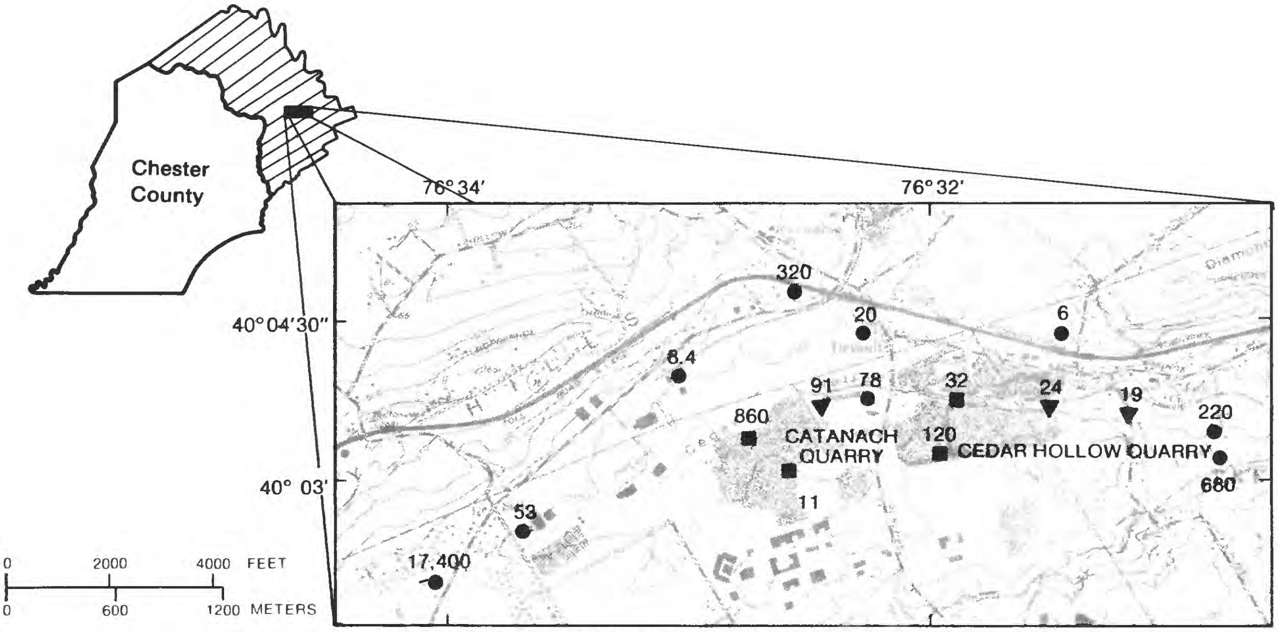
Figure 18.--Sampling locations for volatile organic compounds in the vicinity of active quarries in Chester Valley.

Table 11.-- Concentrations of volatile organic compounds detected in ground water and surface water in the vicinity of active quarries in Chester Valley

[Concentrations are in micrograms per liter]

SITE	DATE OF SAMPLE	TRI-CHLORO-ETHYL-ENE TOTAL	TETRA-CHLORO-ETHYL-ENE TOTAL	1,2-TRANSDI CHLORO-ETHYL-ENE TOTAL	1,1-DI-CHLORO-ETHYL-ENE TOTAL	1,1,1-TRI-CHLORO-ETHANE TOTAL	1,1-DI-CHLORO-ETHANE TOTAL	1,2-DI-CHLORO-ETHANE TOTAL	METHYL-ENE CHLO-RIDE TOTAL	CHLORO-FORM TOTAL
CH-251	81-08-19	20.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
293	81-08-19	6.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2136	81-08-19	200	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	82-06-22	220	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2478	82-08-03	22.0	<1.0	<1.0	31	260	<1.0	<1.0	<1.0	<1.0
	83-07-07	34.0	10	<1.0	7.0	190	<1.0	<1.0	<1.0	<1.0
2549	85-04-30	19.0	<3.0	<3.0	<3.0	34	<3.0	<3.0	<3.0	<3.0
2553	85-07-30	5.4	<3.0	3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
2606	85-04-30	24.0	5.1	15	<3.0	34	<3.0	<3.0	<3.0	<3.0
2672	85-05-13	4400	1200	560	5400	5400	39	140	49	190
2676	84-06-07	470	<3.0	210	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
CATANACH QUARRY NORTH	85-07-05	200	25	140	<3.0	300	<3.0	<3.0	<3.0	13
CATANACH QUARRY SOUTH	85-07-05	11.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
CATANACH QUARRY DISCHARGE	85-07-05	30.0	<3.0	24	<3.0	37	<3.0	<3.0	<3.0	<3.0
CEDAR HOLLOW QUARRY SOUTH	85-04-29	98.0	<3.0	25	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
CEDAR HOLLOW QUARRY NORTH	85-04-29	21.0	<3.0	<3.0	<3.0	11	<3.0	<3.0	<3.0	<3.0
CEDAR HOLLOW QUARRY DISCHARGE	85-04-29	24.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
TRIBUTARY TO VALLEY CREEK	84-08-24	19.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
	85-04-29	13.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

VOCs are moving eastward through the Elbrook and Ledger Formations down the hydraulic gradient caused by quarry dewatering. An area about 3 miles long and 0.4 miles wide has been affected. Concentrations of VOCs generally decrease with distance eastward. Water flows downgradient to the Catanach Quarry, where it is pumped out and discharged to a settling pond. Outflow from the settling pond is to a closed surface depression, where infiltration has created a ground-water recharge mound between the quarries. The water then flows downgradient back into the Catanach Quarry and into the adjacent Cedar Hollow Quarry. Water is pumped from the Cedar Hollow Quarry to a discharge channel leading to a settling pond. Outflow from the settling pond is to a tributary to Valley Creek. As ground water moves through this quarry system, the concentrations of VOCs are reduced, and some VOCs may be completely volatilized as concentrations fall below the detection limit. Inflow to the Catanach Quarry from the north contained 860 µg/L of total VOCs (fig. 19) Because of dilution and volatilization, discharge from the quarry contained only 91 µg/L of total VOCs. Water from a well sampled between the quarries contained 78 µg/L of total VOCs. Inflow to the Cedar Hollow Quarry from the south contained 120 µg/L of total VOCs and inflow from the north contained 32 µg/L of total VOCs. Due to dilution and volatilization, discharge from the



Base from U.S. Geological Survey Malvern, 1983

EXPLANATION

NUMBER IS CONCENTRATION OF TOTAL VOLATILE ORGANIC COMPOUNDS IN MICROGRAMS PER LITER.

320● WELL

860■ QUARRY INFLOW

91▼ QUARRY DISCHARGE OF SURFACE WATER SITE

Figure 19.--Concentrations of total volatile organic compounds in water in the vicinity of active quarries in Chester Valley.

quarry contained 24 µg/L of total VOCs. A water sample from the tributary to Valley Creek below the Cedar Hollow Quarry settling pond contained 19 µg/L of total VOCs.

Five out of the nine VOCs detected in water from well CH-2672 have migrated as far as the Catanach Quarry. 1,1,-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, and methlyene chloride were not present or were below the detection limit (3 µg/L) in inflow to the Catanach Quarry. Except for 1,1-dichloroethylene, concentrations of these compounds in water from well CH-2672 were less than 150 µg/L. A concentration of 5,400 µg/L of 1,1-dichloroethylene was detected in water from well CH-2672; however, this compound was not detected in inflow to the Catanach Quarry. Chloroform, detected at a concentration of 190 µg/L in water from well CH-2672, was detected at a concentration of 13 µg/L in inflow to the Catanach

Quarry from the north, and was not present or was below the detection limit in discharge from the quarry. Chloroform was not detected in water samples from the other sites.

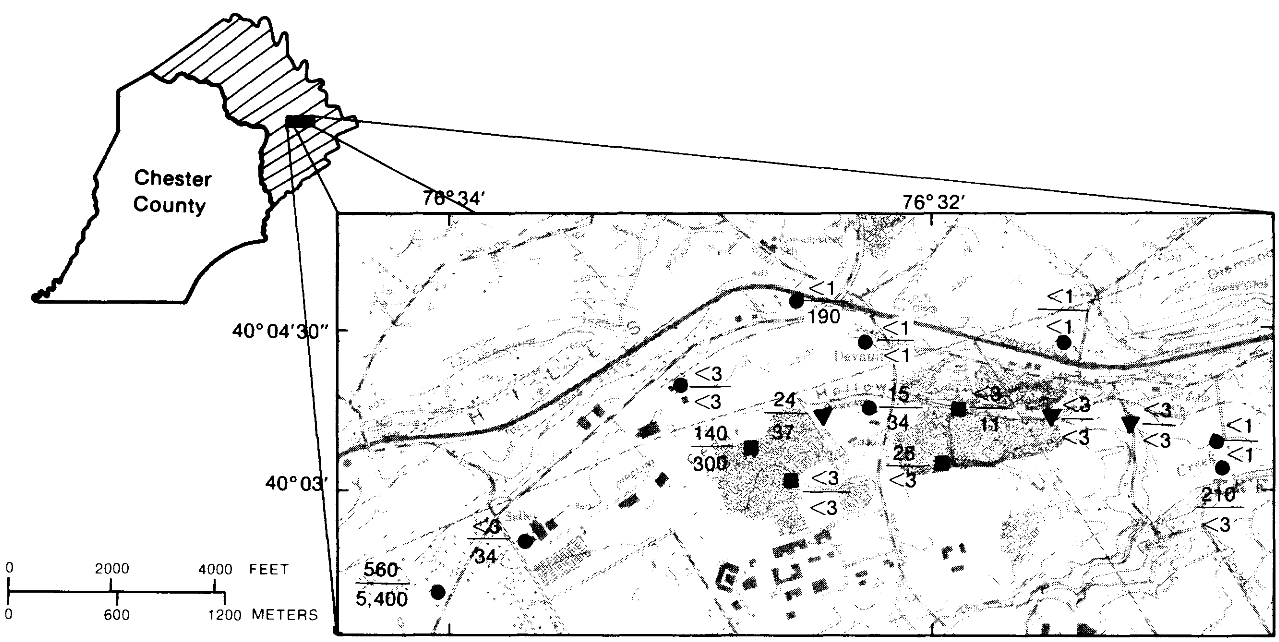
Tetrachloroethylene was detected at a concentration of 1,200 µg/L in water from well CH-2672. Inflow to the Catanach Quarry from the north contained a concentration of 25 µg/L. Tetrachloroethylene was not present or was below the detection limit in discharge from the quarry, but was detected at a concentration of 5.1 µg/L in water from well CH-2606 between the quarries. It was not detected in inflow to or discharge from the Cedar Hollow Quarry.

1,2-trans-dichloroethylene was detected at a concentration of 560 µg/L in water from well CH-2672. Inflow to the Catanach Quarry from the north had a concentration of 140 µg/L; discharge from the quarry had a concentration of 24 µg/L (fig. 20). Water from well CH-2606 between the quarries had a concentration of 15 µg/L. Inflow to the Cedar Hollow Quarry from the south had a concentration of 25 µg/L; 1,2-trans-dichloroethylene was not present or was below the detection limit in the discharge from the Quarry.

1,1,1-trichloroethane was detected at a concentration of 5,400 µg/L in water from well CH-2672. Inflow to the Catanach Quarry from the north had a concentration of 300 µg/L; discharge from the quarry had a concentration of 37 µg/L (fig. 20). Water from well CH-2606 between the quarries had a concentration of 34 µg/L. Inflow to the Cedar Hollow Quarry from the north had a concentration of 11 µg/L; 1,1,1-trichloroethane was not present or was below the detection limit in discharge from the quarry.

Trichloroethylene was the only VOC detected at every sampling site (fig. 21). Water from well CH-2672 had a trichloroethylene concentration of 4,400 µg/L. Inflow to the Catanach Quarry from the north had a concentration of 200 µg/L, and inflow from the south had a concentration of 11 µg/L. Discharge from the quarry had a concentration of 30 µg/L. Water from well CH-2606 between the quarries had a concentration of 24 µg/L. Inflow to the Cedar Hollow Quarry from the south had a concentration of 98 µg/L and inflow from the north had a concentration of 21 µg/L. Discharge from the quarry had a concentration of 24 µg/L. Water from the tributary to Valley Creek below the Cedar Hollow Quarry settling pond had a concentration of 19 µg/L. The reason for high concentrations of trichloroethylene in water from two wells on opposite sides of Valley Creek east of the quarries (CH-2136 and CH-2676) is unknown. Trichloroethylene is the most prevelant VOC in the vicinity of the quarries because: (1) it has a high concentration at well CH-2672; (2) it is relatively dense compared to the other VOCs; and (3) it is introduced to the subsurface from multiple sources.

Generally, occurrence of VOCs in the vicinity of the quarries appears related to the concentration at well CH-2672 and the density of the compound. The higher the concentration at well CH-2672 and the denser the compound, the more likely it is to be detected in the vicinity of the quarries.



Base from U.S. Geological Survey Malvern, 1983

EXPLANATION

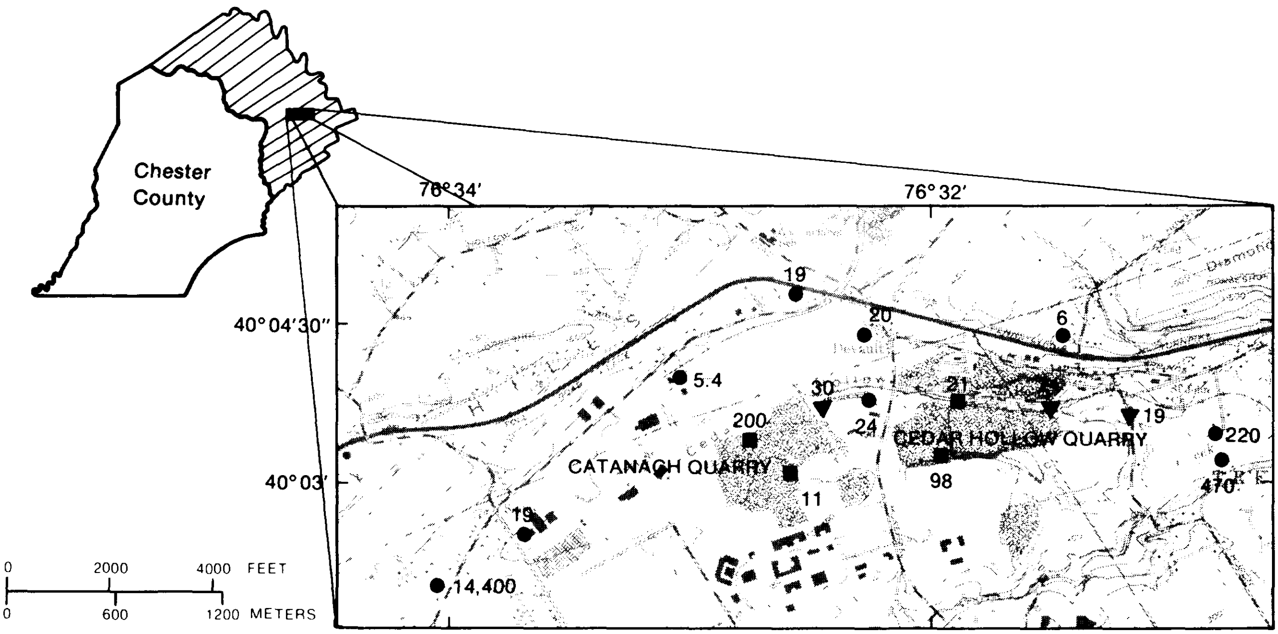
UPPER NUMBER IS CONCENTRATION OF 1,2-TRANS-DICHLOROETHYLENE IN MICROGRAMS PER LITER. LOWER NUMBER IS CONCENTRATION OF 1,1,1-TRICHLOROETHANE IN MICROGRAMS PER LITER.

15/34 ● WELL

140/300 ■ QUARRY INFLOW

24/37 ▼ QUARRY DISCHARGE OR SURFACE WATER SITE

Figure 20.--Concentration of 1,2-trans-dichloroethylene and 1,1,1-trichloroethane in water in the vicinity of active quarries in Chester Valley.



Base from U.S. Geological Survey Malvern, 1983

EXPLANATION

NUMBER IS CONCENTRATION OF TRICHLOROETHYLENE IN MICROGRAMS PER LITER.

19 ● WELL

21 ■ QUARRY INFLOW

24 ▼ QUARRY DISCHARGE OR SURFACE WATER SITE

Figure 21.--Concentrations of trichloroethylene in water in the vicinity of active quarries in Chester Valley.

Acid Compounds

From 1982-85, water from five wells (CH-2046, 2444, 2469, 2672, and 2801) was analyzed for compounds in the acid fraction listed in table 12. The detection limit was 1.0 µg/L. None of these compounds were detected. In five water samples from four wells in other parts of Chester County not included in this study, 4-chloro-3-methylphenol was detected in one water sample.

Table 12.--Acid organic compounds analyzed in ground water

4-Chloro-3-methylphenol	2-Nitrophenol
2-Chlorophenol	4-Nitrophenol
2,4-Dichlorophenol	Pentachlorophenol
2,4-Dimethylphenol	Phenol
4,6-Dinitro-2-methylphenol	2,4,6-Trichlorophenol
2,4-Dinitrophenol	

Base-Neutral Compounds

Sixteen water samples from 15 wells were analyzed for the 46 base-neutral compounds in table 13. Not all compounds were analyzed for all water samples. Water samples from two wells contained base-neutral compounds. Three compounds were detected in low concentrations. One water sample from well CH-2046 contained the phthalate esters bis(2-ethylhexyl) phthalate (2 µg/L) and di-n-butyl phthalate (2 µg/L). This well is in an industrial area. One water sample from well CH-2411 contained the noncyclic chlorinated aromatic compound 1,2-dichlorobenzene at the detection limit of 1 µg/L.

Eight water samples from seven wells in other parts of Chester County not included in this study were analyzed for base-neutral compounds. In addition to the phthalate esters listed above, acenaphene, diethyl phthalate, dimethyl phthalate, isophorone, napohalene, and nitrobenzene were detected.

Pesticides

Pesticides are widely used in both rural and urban areas of Chester County. Pesticides are divided into insecticides and herbicides based on use. Insecticides are widely used in agricultural areas to control crop-damaging pests and in urban areas to control household and garden pests. Herbicides are used to eradicate weeds that compete with crops in agriculture and home gardens. They are also used to control broad-leaf weeds on lawns and turf, and to defoliate utility, railroad, and highway rights-of-way. Table 14 lists the insecticides and herbicides most commonly used on crops in Pennsylvania, according to a pesticide use survey conducted by Hartwig and others (1980, p. 8-9). Sampling for herbicides generally was biased towards areas where herbicides were used. Most sampled wells were in or near cropland, orchards, or golf courses.

Table 13.--Base-neutral organic compounds analyzed in ground water

Acenaphthene	Dimethyl phthalate
Acenaphthylene	2,4-Dinitrotoluene
Anthracene	2,6-Dinitrotoluene
Benzidine	Di-*n*-octylphthalate
Benzo(a)anthracene	Bis(2-ethylhexyl)phthalate
Benzo(b)fluoranthene	Fluoranthene
Benzo(k)fluoranthene	Fluorene
Benzo(g,h,i)perylene	Hexachlorobenzene
Benzo(a)pyrene	Hexachlorobutadiene
4-Bromophenyl phenyl ether	Hexachlorocyclopentadiene
Butyl benzyl phthalate	Hexachloroethane
Bis(2-chloroethoxy)methane	Indeno(1,2,3-cd)pyrene
Bis(2-chloroethyl)ether	Isophorone
Bis(2-chloroisopropyl)ether	Naphthalene
2-Chloronaphthalene	Nitrobenzene
4-Chlorophenyl phenyl ether	*n*-Nitrosodimethylamine
Chrysene	*n*-Nitrosodiphenylamine
Dibenzo(a,h)anthracene	*n*-Nitrosodi-n-propylamine
Di-n-butyl phthalate	Phenanthrene
1,2-Dichlorobenzene	Pyrene
1,3-Dichlorobenzene	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
1,4-Dichlorobenzene	1,2,4-Trichlorobenzene
3,3-Dichlorobenzidine	
Diethyl phthalate	

Table 14.--The 10 most used insecticides and herbicides on crops in Pennsylvania (from Hartwig and others, 1980, p. 8-9)

Pesticides are listed from most to least used

Insecticides	Herbicides
Carbofuran	Atrazine
Sevin	Alachlor
Malathion	Dicamba
Fonofos	Cyanazine
Guthion	Metolachlor
Toxaphene	Paraqat
Diazanon	2,4,-D
Terbufox	Simazine
Dimethoate	Butylate
Methomyl	Glyphosate

Organochlorine insecticides

Organochlorine insecticides are insoluble in water, persistent in the environment, and strongly bioaccumulated by many organisms. The use of many of the organochlorine insecticides has been prohibited or restricted by the USEPA. In Chester County, chlorodane, endrin, lindane, methoxychlor, and toxaphene are commonly used by the mushroom industry. Methoxychlor and toxaphene are also commonly used on crops. Chlorodane is used by licensed commercial operators for subsurface termite control.

Fifty-six water samples from 48 wells were analyzed for organochlorine insecticides. A summary of the compounds analyzed, compounds detected, and range of concentrations are given in table 15. Four organochlorine insecticides were found in concentrations above the detection limit: aldrin, DDD, DDT, and dieldrin. Aldrin was detected in two water samples from well CH-2469. DDD and DDT were detected in a water sample from well CH-2801. Dieldrin was detected in three water samples from well CH-2469 in concentrations ranging from 0.32 to 0.40 μg/L, and in one water sample from well CH-2502 at a concentration of 0.02 μg/L.

Table 15.--Organochlorine insecticides analyzed and detected in ground water [A dash indicates compound was not detected; μg/L, micrograms per liter]

Compound	Number of wells compound is present above detection limit	Number of samples compound is present above detection limit	Concentration (μg/L)
Aldrin	1	2	0.070-.081
Chlorodane	0	0	---
DDD	1	1	3.2
DDE	0	0	---
DDT	1	1	.610
Dieldrin	2	4	.020-.400
Endosulfan	0	0	---
Endrin	0	0	---
Heptachlor	0	0	---
Heptachlor Epoxide	0	0	---
Lindane	0	0	---
Methoxychlor	0	0	---
Mirex	0	0	---
Perthane	0	0	---
Toxophene	0	0	---

Aldrin and dieldrin have been used as contact insecticides to control soil pests, termites, and many other pests. Most uses of aldrin and dieldrin have been prohibited by the USEPA, and they are no longer manufactured in the United States. Aldrin, however, is still used for subsurface termite control.

DDT is the common name for a mixture of compounds in which the main component is 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane. DDT is the best known, as well as the first, of the organochlorine insecticides introduced to agriculture. It was first synthesized in 1874, but its insecticidal properties were not discovered until 1939. It was patented in 1942 and introduced in 1944 (O'Brien, 1967, p. 108). Most uses of DDT and DDD have been prohibited by the USEPA. DDE and methoxychlor are analogs of DDT. Methoxychlor is widely used and is registered for use on 87 crops, and for home and garden use.

In 72 water samples from 59 wells in other parts of Chester County not included in this study, lindane was found in concentrations above the detection limit in three wells.

Organophosphorous insecticides

Organophosphorous 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, produced in 1943, was the first organophosphorous compound available for crop protection. Malathion, guthion, and diazanon are commonly used in Pennsylvania (table 14) (Hartwig and others, 1980, p. 8-9). Malathion was introduced in 1950 as the first organophosphorous insecticide with low mammalian toxicity (Flecher, 1974, p. 50-51). It is the most widely used orthophosphorous insecticide in Pennsylvania and is used to control a wide variety of insects on a wide variety of food and nonfood crops. Malathion and diazanon are widely used in the mushroom industry (Tetrault and Wuest, 1979).

Fifteen water samples from 11 wells were analyzed for organophosphorous insecticides: diazanon, ethion, guthion, malathion, methyl parathion, methyl trithion, parathion, and trithion. Two organophosphorous insecticides were detected. Diazanon was detected at a concentration of 0.02 µg/L in water from well CH-2469. Methyl parathion was detected at a concentration of 0.01 µg/L in water from well CH-2502.

Diazanon is widely used in agriculture, homes, and gardens for insect control. It is used to control soil insects; for many pests of fruits, vegetables, and forage crops; for cockroaches and other household insect pests; for grubs and nematodes in turf; and for fly control. It is commonly used in Chester County for control of the European corn borer, lawn-damaging insects, and on trees and shrubs. The well in which diazinon was detected is near an apple orchard.

Methyl parathion is used for control of many insects of economic importance. Its use as a pesticide in the United States is restricted.

No organophosphorous insecticides were detected in water samples from nine wells in other parts of Chester County not included in this study.

Triazine herbicides and alachlor

The triazine herbicides are mainly used for pre-emergence applications on corn, soybeans, and other crops for control of grassy and broadleaf weeds. They were discovered in 1952 and introduced in 1954. Atrazine, which is sold under various commercial names, is the most widely used pesticide in Pennsylvania (table 14) and the U.S. (Hartwig and others, 1980, p. 8-9). It is commonly used to control weeds in corn, soybeans, and hay crops in Chester County. Simazine is used primarily on alfalfa and hay fields and in apple orchards. Atrazine, promotone, prometryne, propozine, and simazine have been detected in base flow of streams in adjacent Lancaster County (Lietman and others, 1983, p. 31-32).

Alachlor is an aetonilide herbicide introduced in 1969. It is a pre-emergent herbicide used to control annual grass and broadleaf weeds, primarily in corn and soybeans. It is the second most-used herbicide in Pennsylvania (table 14) and is widely used in Chester County. Alachlor also has been found in base flow of streams in adjacent Lancaster County (Lietman and others, 1983, p. 31-32).

Water from seven wells and one spring was analyzed for the triazine herbicides: ametryne, atrazine, cyanozine, prometone, prometryne, propazine, simazine, and simetryne. Water from six wells and one spring was analyzed for alachlor. One well (CH-2488) was in a cornfield and the other wells and the spring were near and downgradient from cropland, primarily cornfields. None of the triazine herbicides were detected. Alachlor, at a concentration of 0.18 μg/L, was found in water from well CH-2488.

Water samples from five wells in other parts of Chester County not included in this study were analyzed for triazine herbicides and alachlor. Atrazine was detected in water from one well.

Organic-acid herbicides

Organic-acid herbicides analyzed include the phenoxy-acid herbicides silvex, 2,4,-D, 2,4-DP, and 2,4,5-T; the benzoic-acid herbicide dicamba; and the substituted picolinic-acid compound picloram. Dicamba is the third most used, and 2,4-D is the seventh most used herbicide in Pennsylvania (table 14).

Eleven water samples from nine wells and one spring were analyzed for organic-acid herbicides. Picloram was detected at a concentration of 0.01 μg/L in a water sample from well CH-207, which is close to a railway. Picloram is often used for brush control along rights-of-way. 2,4-D was detected at a concentration of 0.12 μg/L in a water sample from well CH-1978, which is in a golf course. The USEPA has set a maximum contaminant level of 100 μg/L for 2,4-D (Office of the Federal Register, 1983, p. 234). 2,4-D was first introduced in 1945. It is a selective, post-emergent herbicide widely used to control broadleaf weeds in corn, grains, pastureland, and turf. 2,4-D and dicamba are extensively used in Chester County for control of perennial broadleaf weeds in corn, grain, and turf. 2,4-D also is used as a defoliant along rights-of-way.

In water samples from six wells in other parts of Chester County not included in this study, silvex, dicamba, and 2,4,5-T were detected in water from a well in an apple orchard.

Other Organic Compounds

Fifty-two water samples from 51 wells were analyzed for gross polychlorinated biphenyls (PCB) and gross polychlorinated napthalene (PCN). Sixty-eight water samples from 54 wells were analyzed for gross phenols. Chemical analyses are given in table 29. PCN was not detected.

PCB was found at the detection limit (0.1 μg/L) in a water sample from well CH-2136. However, a subsequent water sample from this well taken by the Pennsylvania Department of Environmental Resources in 1981 did not show the presence of PCB (Shup, Marilyn, Pennsylvania Department of Environmental Resources, written commun., 1982). Another water sample collected by the U.S. Geological Survey in 1982 also did not show the presence of PCB. Because PCB is insoluble, its presence in ground water is unlikely.

Phenol was detected in 15 wells or 28 percent of the wells sampled. Concentrations of phenol ranged from less than 1 to 7 μg/L. Phenol is a poisonous, caustic compound that is soluble in water. One gram of phenol will dissolve in 15 milliliters of water. It is used as a general disinfectant, and in the manufacture of resins, pharmaceuticals, and industrial organic compounds (Windholtz and others, 1976, p. 941).

Water from 10 percent of 61 wells sampled in other parts of Chester County not included in this study were found to contain phenol, with concentrations as high as 190 μg/L.

Inorganic Compounds

Metals and Other Trace Constituents

Metals and other trace constituents, such as arsenic and selenium, typically occur in concentrations of less than 1 mg/L in natural waters. Some of these constituents, such as iron and manganese, are commonly determined and are usually present. Other constituents, such as beryllium and silver, are not commonly determined and, if present, concentrations are generally below the detection limit of analytical instruments.

Most of the 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 are present in precipitation. Copper, lead, and zinc may be leached from plumbing systems by acidic ground water. Copper precipitates are commonly deposited as blue or green stains on plumbing fixtures.

The USEPA has set mandatory and recommended limits for some constituents in drinking water (table 16). Mandatory limits or maximum contaminant levels (MCLs) are generally set because elevated concentrations of these constituents may cause health problems. Recommended limits are generally set for aesthic reasons.

Table 17 is a summary of data on the concentration of metals and other trace constituents in ground water. Complete chemical analyses are given in table 30. Metals, except for iron and manganese, and trace constituents are generally not a water-quality problem in Chester County. Concentrations of aluminum, arsenic, barium, cadmium, chromium, cobalt, lead, selenium, silver, and strontium in table 30 represent natural background concentrations.

Data for most metals are difficult to evaluate statistically because concentrations are often below detection limits. In addition, a constituent may have several detection limits. For example, detection limits for chromium (table 30) are 1, 2, 3, 10 and 20 μg/L, and some values are reported as 0 or ND (not detected).

The natural background concentration for boron is generally 30 μg/L or less, and, for lithium, generally 10 μg/L or less (table 30). Water samples collected from wells near Planebrook in the carbonate rocks of Chester Valley had boron concentrations as high as 20,000 μg/L and lithium concentrations as high as 13,000 μg/L. In this area, boron and lithium from processing wastes are moving through the ground-water system.

Figure 22 shows the locations of six wells and one surface-water site sampled near Planebrook and concentrations of boron and lithium. Ground water containing elevated concentrations of boron and lithium is moving through the Ledger Formation down the hydraulic gradient and along a fault separating an upfaulted anticlinal block of Chickies quartzite from the Ledger Formation. The fault dips southeast beneath the Ledger Formation. The ground water containing elevated concentrations of boron and lithium is being discharged to Valley Creek near Mill Lane. Water samples from Valley Creek at Mill Lane (surface-water sampling site 400303075331701) showed boron and lithium concentrations somewhat less than concentrations in water from well CH-207. The affected area is narrow and extends approximately 1.5 miles northeast of the lithium-processing plant.

Monthly base flow water samples from Valley Creek at Mill Lane were analyzed for dissolved lithium from March to December 1984, and for dissolved boron from September to December 1984 (table 18). Lithium concentrations ranged from 330 to 800 μg/L (fig. 23) and were inversely related to discharge (fig. 24). Concentrations of boron ranged from 90 to 130 μg/L and also were inversely related to discharge. As discharge decreased, the concentrations of boron and lithium increased. Concentrations of lithium and boron were directly proportional (fig. 25).

The ratio of boron to lithium was approximately 1:6.4 in water samples from Valley Creek at Mill Lane. The ratio was less in ground water and was directly related to distance from the processing plant. At well CH-207, the ratio of boron to lithium was 1:4.3; at well CH-2545, the ratio was 1:2. At well CH-2535, the ratio was 1:1 for one sample and 1:0.7 for two samples.

Table 16.--Federal mandatory and recommended limits for selected constituents in drinking water

[Limits in micrograms per liter except as indicated; mg/L, milligrams per liter; a dash indicates no limit]

Constituent	Mandatory limit1/ (Maximum contaminant level)	Recommended limit2/
Arsenic	50	---
Barium	1,000	---
Cadmium	10	---
Chloride (mg/L)	---	250
Chromium	50	---
Copper	---	1,000
Iron	---	300
Lead	50	---
Mercury	2	---
Nitrate as nitrogen (mg/L)	10	---
Selenium	10	---
Silver	50	---
Sulfate (mg/L)	---	250
Total dissolved solids (mg/L)	---	500
Zinc (mg/L)	---	5

1/ Office of the Federal Register (1983, p. 233)

2/ U.S. Environmental Protection Agency (1977, p. 17146)

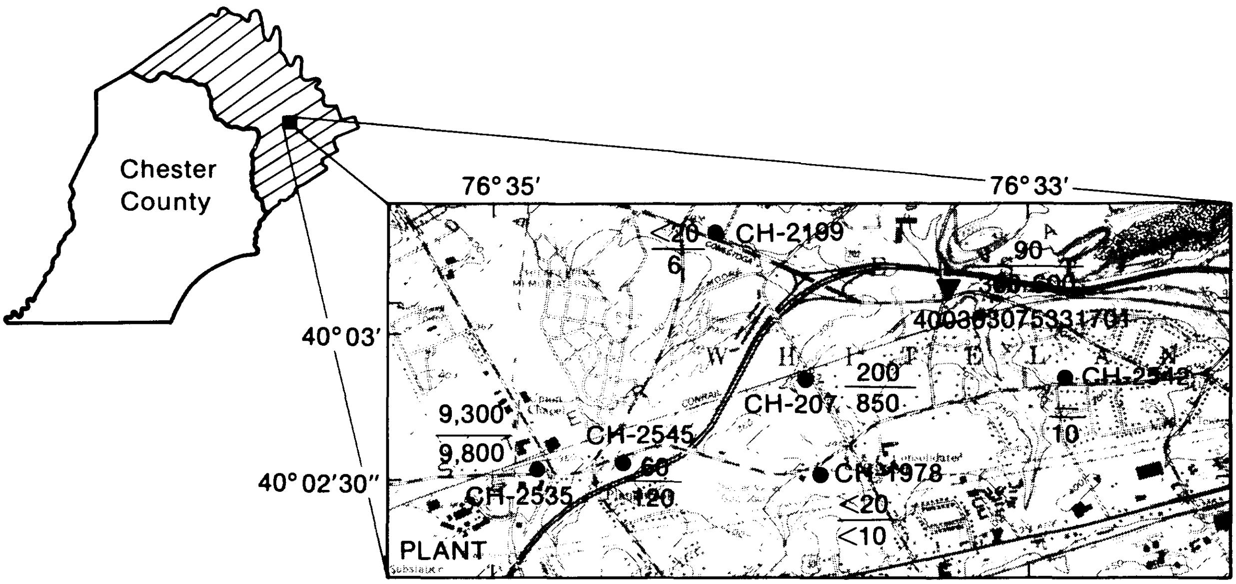
Table 17.—Summary of concentrations of metals and other trace constituents in ground water

[All concentrations are in micrograms per liter; a dash indicates no data or no USEPA limit]

Constituent	Number of wells sampled	Number of analyses	Detection limit	Number of analyses below upper detection limit	Minimum concentration above lowest detection limit	Maximum concentration	Median concentration	Number of analyses exceeding USEPA maximum contaminant level 2/
Aluminum	32	40	10-100	35	10	200	1/	—
Arsenic	107	142	1	40	1	8	1	0
Barium	28	33	10-100	29	13	500	1/	0
Beryllium	1	4	2-10	4	—	—	—	—
Boron	32	39	20	27	20	20,000	1/	—
Cadmium	107	147	1-6	147	1	5	1/	0
Chromium	107	147	1-20	139	1	50	1/	0
Cobalt	23	28	2-6	28	2	2	1/	—
Copper	92	122	1-20	84	1	430	11	0
Gallium	1	4	1-3	4	—	—	—	—
Germanium	1	4	2-6	4	—	—	—	—
Iron	116	200	3-10	76	3	61,000	16	30
Lead	108	147	1-6	129	1	20	1/	0
Lithium	38	48	4-10	38	4	13,000	1/	—
Manganese	115	196	1-10	117	1	3,100	1/	42
Mercury	107	140	0.1-0.5	138	0.1	2	1/	0
Molybdenum	1	4	—	0	100	120	105	—
Nickel	103	142	1-6	126	1	51	1/	—
Selenium	58	60	1	43	1	4	1/	0
Silver	22	27	2	27	—	—	—	0
Strontium	4	8	—	0	40	850	—	—
Titanium	1	4	1-5	4	—	—	—	—
Vanadium	1	4	2-3	3	6	—	—	—
Zinc	89	117	3-20	57	4	1,400	20	0

1/ Median is below upper detection limit.

2/ U.S. Environmental Protection Agency (1977, p. 17146)



Base from U.S. Geological Survey Malvern, 1983

EXPLANATION

60 UPPER NUMBER IS CONCENTRATION OF BORON IN MICROGRAMS PER LITER
120 LOWER NUMBER IS CONCENTRATION OF LITHIUM IN MICROGRAMS PER LITER

CH-2545 ● WELL--Number is Well Identification Number

▼ SURFACE-WATER SAMPLING SITE

0 2000 4000 FEET
0 600 1200 METERS

Figure 22.--Concentration of boron and lithium in ground water and surface water near Planebrook, June to September 1984.

Table 18.--Concentrations of dissolved boron and lithium at Valley Creek at Mill Lane (site 7 on figure 26)

[A dash indicates no data; ft^3/s, cubic feet per second; μg/L, micrograms per liter]

Date of sample	Discharge (ft^3/s)	Boron (μg/L)	Lithium (μg/L)
10-21-83	---	---	830
3-20-84	11	---	380
4-26-84	12	---	330
5-22-84	8.5	---	350
6-12-84	7.9	---	360
7-17-84	6.9	---	360
8-22-84	3.9	---	500
9-18-84	2.4	90	600
10-11-84	2.9	110	720
11-21-84	2.1	130	800
12-12-84	2.7	120	760
3-13-85	2.4	120	780

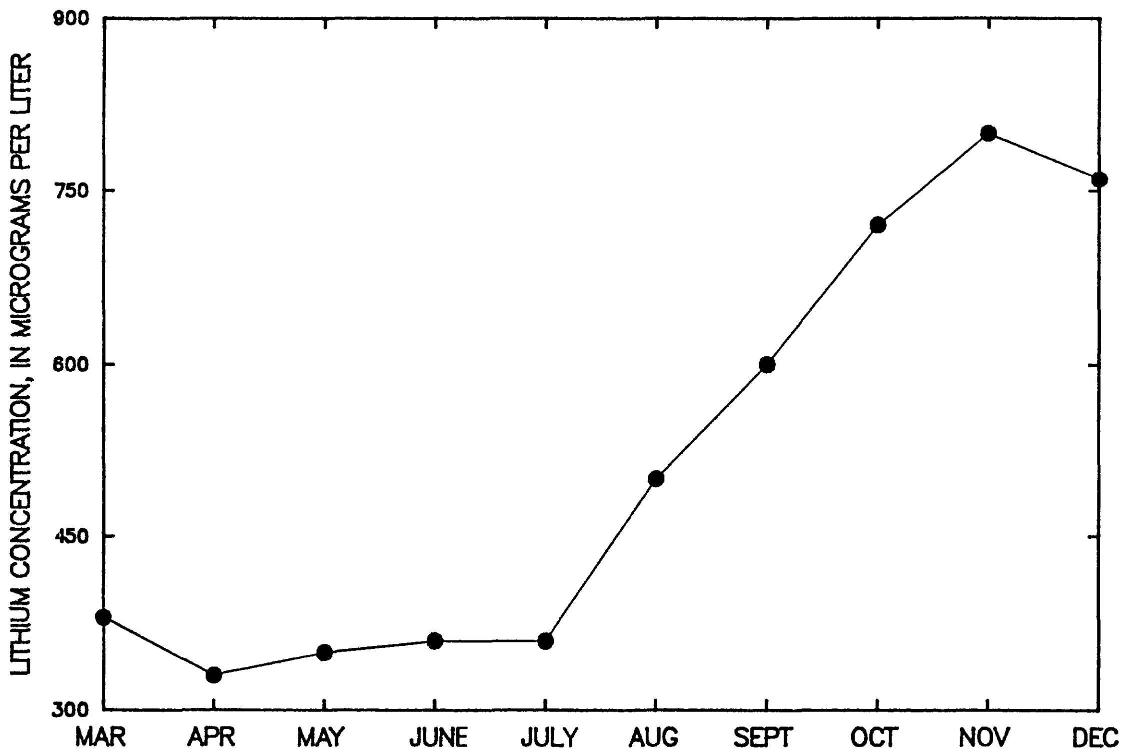


Figure 23.--Concentration of dissolved lithium in Valley Creek at Mill Lane, March to December 1984.

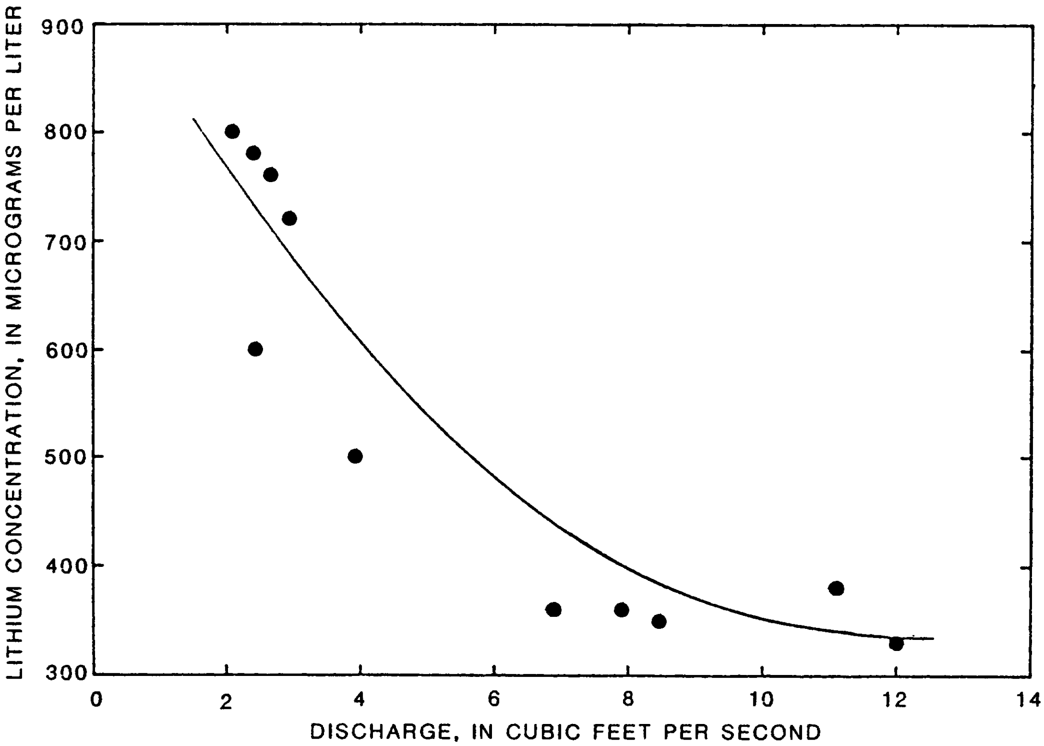


Figure 24.--Relation between concentration of dissolved lithium and discharge for Valley Creek at Mill Lane.

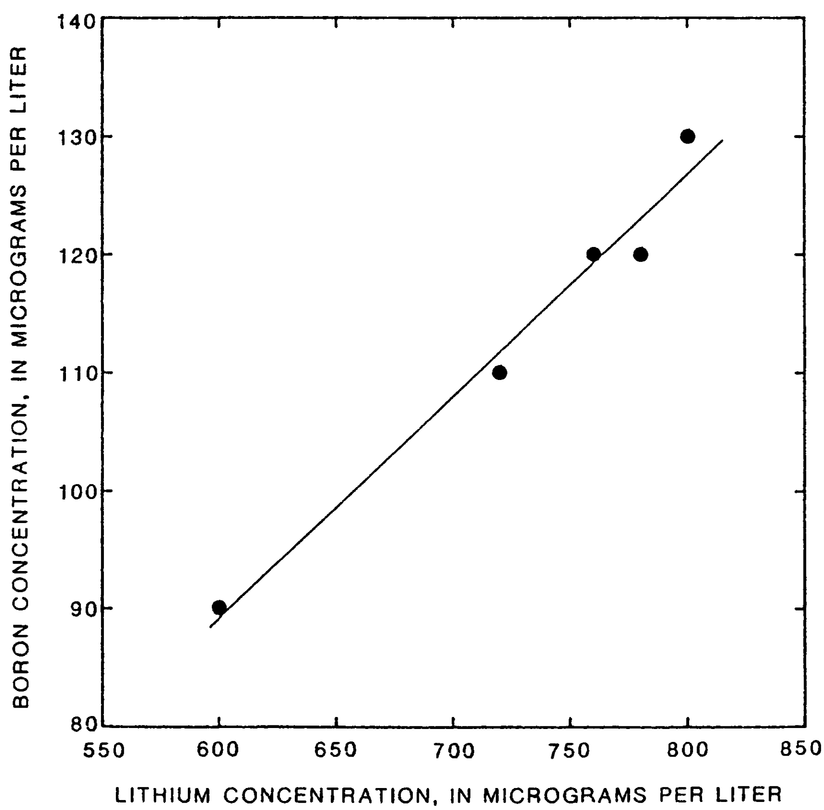


Figure 25.--Relation between concentrations of dissolved boron and lithium for Valley Creek at Mill Lane.

Water samples collected from Valley Creek and its tributaries at base flow from nine sites October 10-12, 1984, and from one additional site on March 13, 1985, were analyzed for dissolved boron and lithium (fig. 26). Stream discharge and concentrations of boron and lithium are given in table 19. The reach of Valley Creek from site A2 to just above site A3 generally is a losing reach and recharges the ground-water system. Some ground water containing boron and lithium is discharged to Valley Creek in the reach between sites A4 and A5, as concentrations increased. Most of the ground water containing elevated concentrations of boron and lithium was discharged to Valley Creek between sites A6 and A7.

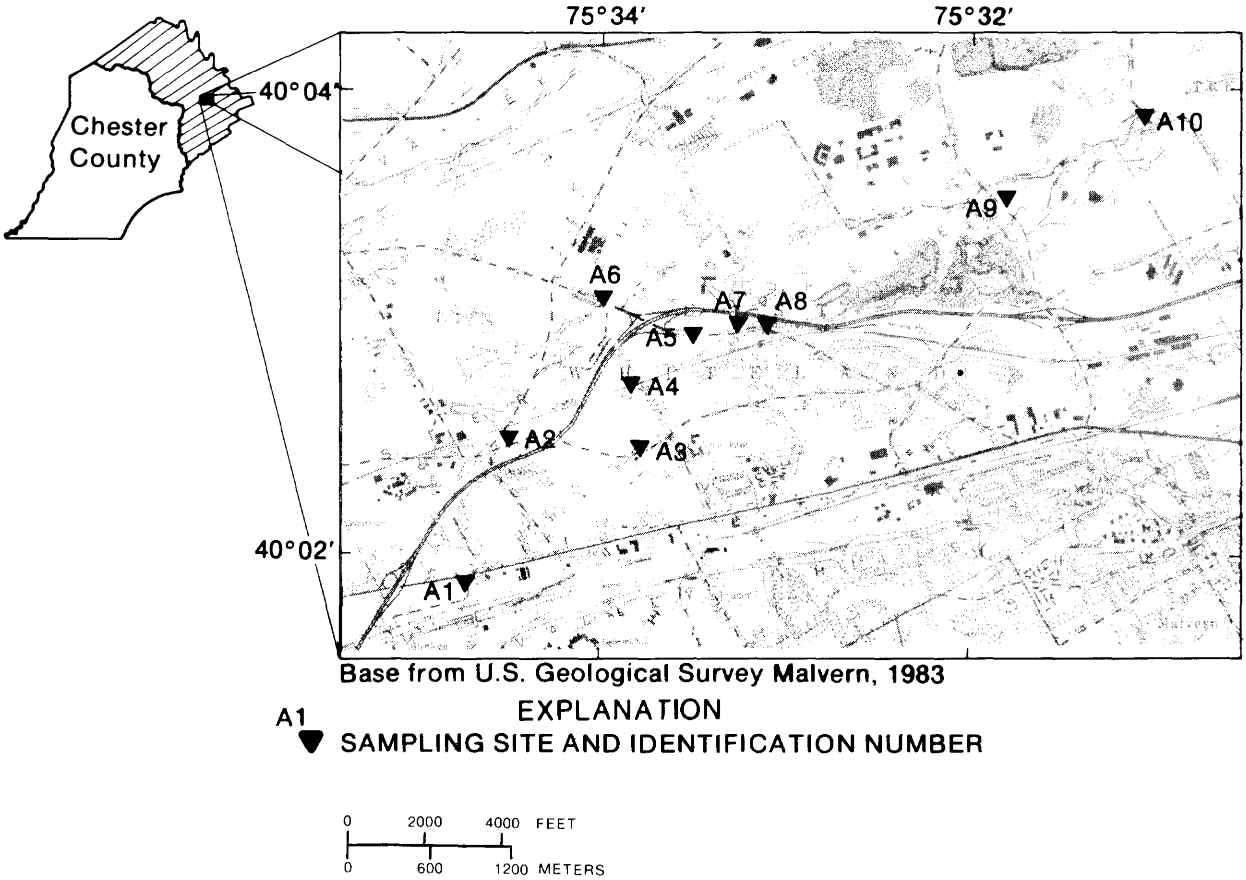


Figure 26.--Sites sampled for dissolved boron and lithium on Valley Creek.

Table 19.--Concentrations of dissolved boron and lithium in Valley Creek, October 10-12, 1984, and March 13, 1985
[ft^3/s, cubic feet per second; µg/L, micrograms per liter]

Site Number	Date of sample	Discharge (ft^3/s)	Boron (µg/L)	Lithium (µg/L)
A1	10-11-84	0.20	<20	<10
A2	10-11-84	.23	<20	<10
A3	10-11-84	.70	30	10
A4	10-11-84	.89	30	10
A5	10-11-84	.87	40	50
A6	3-13-85	.09	40	<10
A7	10-11-84	2.9	110	720
	3-13-85	2.4	120	780
A8	10-12-84	2.9	110	710
A9	10-12-84	4.9	130	300
A10	10-10-84	5.3	120	260

Out of 140 analyses for mercury in ground water, 138 were below the upper detection limit of 0.5 µg/L. Two samples contained mercury concentrations of 1.1 and 2.0 µg/L. The USEPA maximum contaminant level is 2 µg/L. These concentrations, however, may not represent the actual concentration of mercury in the ground water. Beginning in 1980, water samples for nutrient analysis were preserved with mercuric chloride and were collected and shipped in polyethylene bottles. From 1980-84, samples for analysis for mercury were also collected and shipped in polyethylene bottles. Mercury can diffuse through polyethylene (Mahan and Mahan, 1977, p. 662-664), with a resultant loss of mercury from the water sample. An increase in mercury in a water sample also can occur by contamination from mercuric chloride in nutrient samples previously shipped in the same container.

Twenty-one percent of the 196 analyses for manganese and 15 percent of the 200 analyses for iron in ground water exceed the USEPA recommended limits. These limits (50 µg/L for manganese and 300 µg/L for iron) are set for aesthetic rather than health reasons, as concentrations of these metals above the recommended limit may impart a bitter taste to drinking water and stain plumbing fixtures and laundry. Sources of manganese in ground water include minerals in the bedrock, such as biotite and hornblende, and bioaccumulation by plants. Sources of iron in well water include: (1) minerals in the bedrock such as pyroxenes, amphiboles, hematite, magnetite, and pyrite; (2) corrosion of iron well casings; and (3) bacterial activity.

The USEPA has recommended that the concentration of nickel in ground water not exceed 13.4 µg/L for the protection of human health from the toxic properties of nickel ingested through water (U.S. Environmental Protection Agency, 1980, p. 79-337). Five water samples (three percent of samples) contained concentrations of nickel greater than 13.4 μg/L; one concentration was 51 μg/L. Nickel is a common constituent of igneous rocks. Minerals containing nickel, such as genthite and zaratite, are commonly found in serpentinite; however, none of the wells with concentrations of nickel greater than 13.4 μg/L were in serpentinite.

Common Ions and Other Determinations

Forty-four wells, previously sampled for laboratory chemical analysis between 1949 and 1976, were sampled again in 1982-83 to determine if long-term changes in water chemistry had occurred. Two wells were resampled in 1982 and 42 wells were resampled in 1983. Of the wells that were resampled, one was first sampled in 1949, four from 1956-57, 11 from 1961-65, and 28 from 1972-76. Six wells were sampled monthly from December 1983 to December 1984 to determine short-term fluctuations in water chemistry and to provide a basis for determining if observed long-term changes in water chemistry were actually short-term fluctuations. Results of laboratory analyses for common ions are given in table 31.

Five wells were sampled monthly for 13 months and one well (CH-2664) was sampled monthly for 12 months for selected inorganic constituents. The wells sampled, general land use, and geological setting are given in table 20. Monthly determinations were made for pH, total dissolved solids, chloride, and nitrate. The range, mean or median, and standard deviation for these constituents for each well are given in table 21. Quarterly determinations were made for sodium, sulfate, iron, and manganese. The range and mean for these constituents for each well are given in table 22. Each of these constituents are described in the following sections.

Table 20.--Wells sampled monthly and quarterly for selected constituents

Well number	General land use	Geologic unit
CH-1231	Rural, agricultural	Graphitic gneiss (crystalline)
1565	Rural, residential	Lockatong Formation (Triassic)
1973	Rural, residential	Elbrook Formation (carbonate)
2491	Urban, commercial	Stockton Formation (Triassic)
2542	Urban, residential	Elbrook Formation (carbonate)
2664	Urban, commercial	Wissahickon Formation, albite chlorite facies (crystalline)

Table 21.--Summary of monthly fluctuations in concentrations of selected constituents in water from six wells, December 1983 to December 1984

[mg/L, milligrams per liter]

	pH (units)			Total dissolved solids (mg/L)			Chloride (mg/L)			Nitrste (mg/L)		
Well number	Range	Median	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation
CH-1231	6.1-6.6	6.3	0.1	106-142	119	10	1.5-4.2	2.8	0.6	1.0-1.2	1.1	0.1
1565	6.8-7.7	7.4	.3	165-256	225	26	4.8-7.4	6.4	.8	1.5-3.6	2.4	.7
1973	6.9-7.4	7.2	.2	288-413	339	39	8.5-11	9.7	.8	1.3-3.0	2.55	.6
2491	5.2-6.0	5.7	.3	180-235	203	18	20-24	22	1	2.6-9.8	6.7	2
2542	7.0-7.6	7.2	.2	299-381	329	29	8.1-10	9.6	.6	0.10-0.23	0.17	.04
2664	5.2-6.2	5.7	.2	107-159	132	17	15-18	17	1	4.8-8.4	6.4	.8

Table 22.--Summary of quarterly fluctuations in concentrations of selected constituents in water from six wells, December 1983 to December 1984

[mg/L, milligrams per liter; μg/L, micrograms per liter]

	Sodium (mg/L)			Sulfate (mg/L)			Iron (μg/L)			Manganese (μg/L)		
Well number	Number of samples	Range	Mean	Number of samples	Range	Mean	Number of samples	Range	Mean	Number of samples	Range	Mean
CH-1231	5	6.1-6.2	6.1	5	19-28	23	4	<3-8	-	4	2-6	3.8
1565	5	7.7-16	12	5	27-38	31	4	<3-5	-	4	<1-4	-
1973	5	3.5-5.1	4	5	31-44	39	4	1/	-	4	<10	-
2491	5	23-24	23	5	34-55	45	4	24-1,600	-	4	62-260	128
2542	5	4.3-4.5	4.4	5	63-67	65	4	6-9	8	4	2-3	2.5
2664	4	10-11	11	4	9.8-18	13	5	5-11	9	4	<10-60	-

1/ All samples below detection limit. Detection limit varied from <3 to <10.

pH

Water with a pH of 7.0 is considered neutral. A pH below 7.0 indicates acidic water, and a pH above 7.0 indicates alkaline water. The pH of distilled water is about 5.6. The range of fluctuation in the pH of water from six wells sampled monthly was from 0.5 units for wells CH-1231 and CH-1973 to 1.0 unit for well CH-2664. The median pH fluctuation was 0.7 units. The median is calculated for pH because its distribution is generally lognormal. Figure 27 shows monthly pH.

Data for early (1949-79) and later (1982-83) pH values were available for 43 wells. The median pH of the early samples was 6.8; the median pH of the later samples was 6.4. The pH of water from 33 wells decreased, with a median decrease of 0.4 units. The pH of water from 10 wells increased, with a median increase of 0.2 units. The median change was a decrease of 0.3 units. These changes were less than the smallest short-term fluctuation.

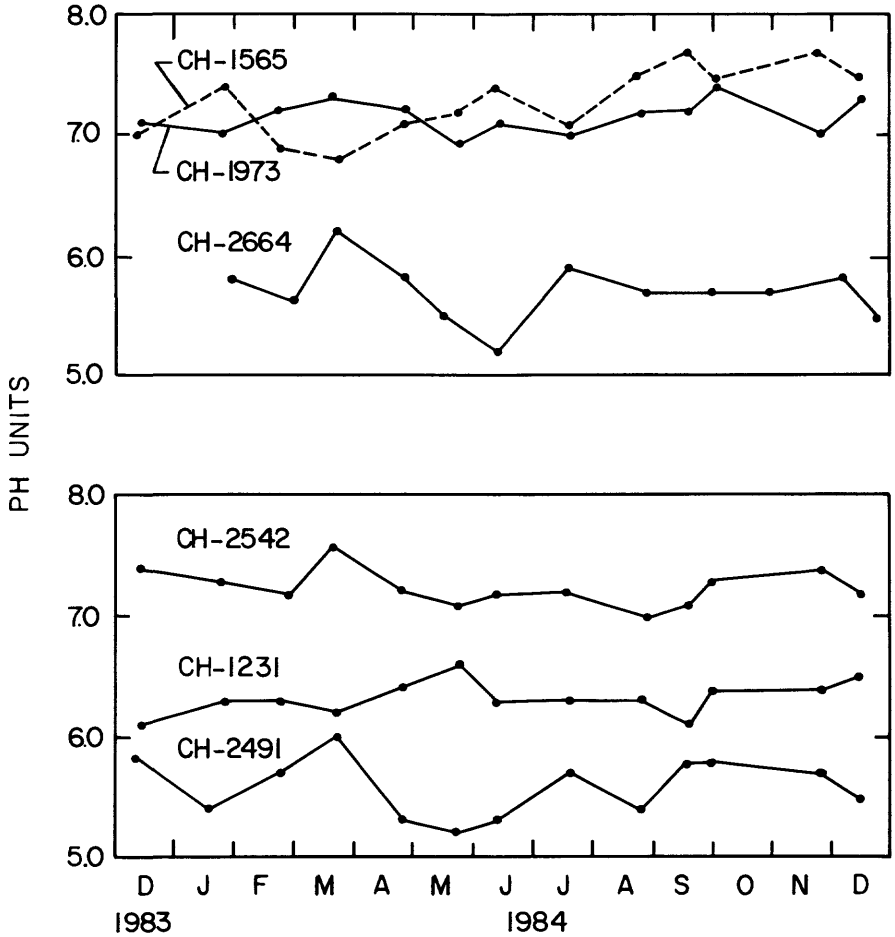


Figure 27.--Fluctuation of pH in water from six wells sampled monthly from December 1983 to December 1984.

Total dissolved solids

Dissolved constituents are defined as those that can pass through a filter with a porosity of 0.45 micrometers. The range of fluctuation in total dissolved-solids concentration of water from six wells sampled monthly was from 36 mg/L for well CH-1231 to 125 mg/L for well CH-1973, with a median fluctuation of 69 mg/L. Figure 28 shows monthly total dissolved-solids concentrations. Expressed as a percentage of the lowest measured value, the change in concentration of total dissolved solids ranged from 27 percent for well CH-2542 to 55 percent for well CH-1565, with a median of 39 percent.

The concentration of total dissolved solids correlated well with the water level in wells CH-1973 (correlation coefficient = -0.86), CH-2664 (correlation coefficient = -0.72), and CH-2542 (correlation coefficient = 0.62). Figure 29 shows the relation of total dissolved-solids concentration and water level for well CH-1973. The total dissolved-solids concentration increased as the depth to water decreased for wells CH-1973 and CH-2664. Conversely, total dissolved-solids concentration decreased as the depth to water decreased for well CH-2542.

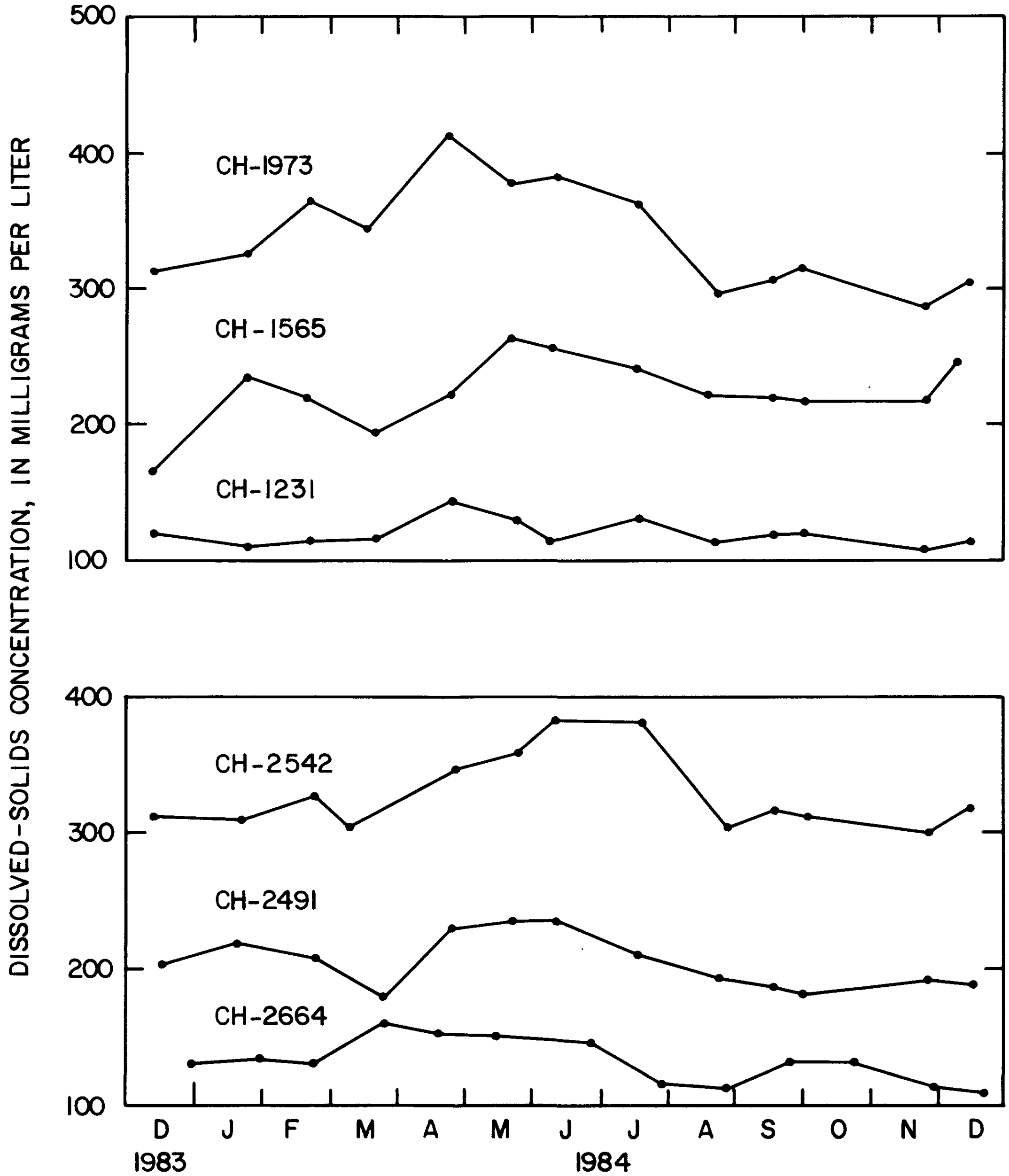


Figure 28.--Fluctuation of total dissolved-solids concentration in water from six wells sampled monthly from December 1983 to December 1984.

Data for early (1949-76) and later (1982-83) total dissolved-solids concentration were available for 41 wells. The median total dissolved-solids concentration for the early samples was 142 mg/L; the median for the later samples was 206 mg/L. Water from 28 wells increased in total dissolved-solids concentration, with a median increase of 62 mg/L. Water from 13 wells decreased in total dissolved solids, with a median decrease of 25 mg/L. The median change was an increase of 25 mg/L. These changes are less than the median short-term fluctuation of 74 mg/L.

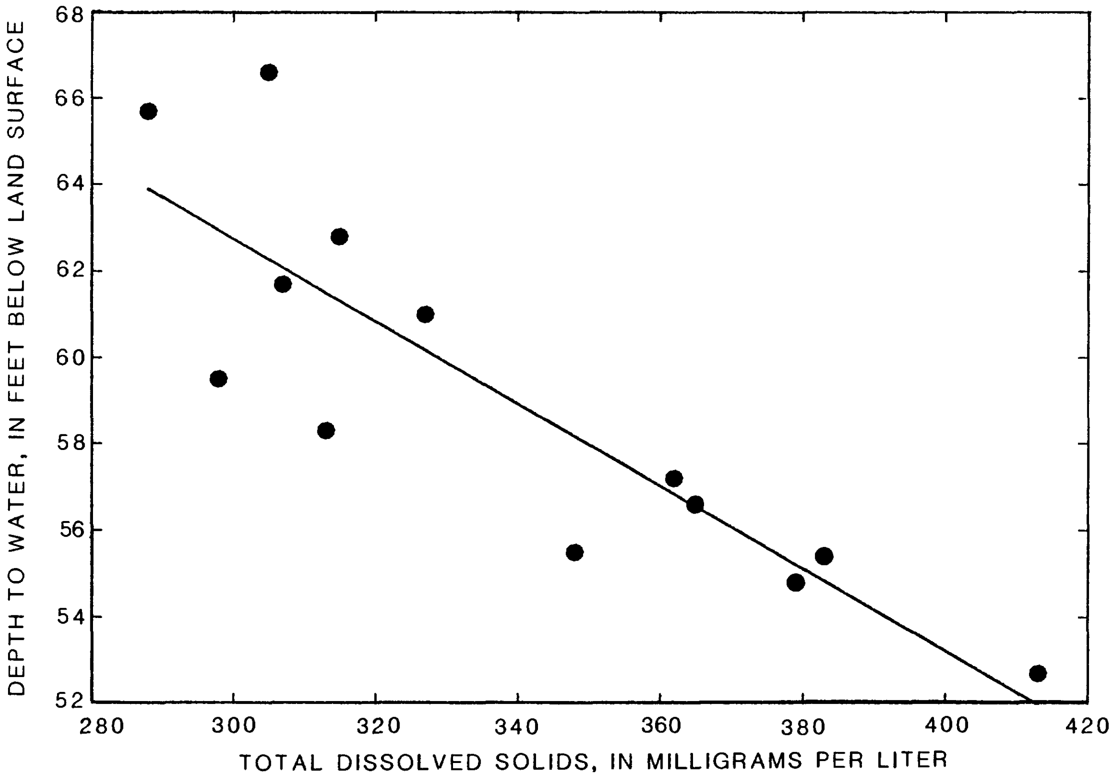


Figure 29.--Relation between total dissolved-solids concentration and depth to water for well CH-1973.

Chloride

Because chloride generally is a nonreactive ion in ground-water systems, changes in the concentration of chloride reflect changes in input concentration to the ground-water system. Small concentrations of chloride are leached from rock materials by circulating ground water. Other sources include precipitation, highway deicing salts, fertilizer, storm runoff, and effluent from sewage and septic systems. The chloride concentration of 19 precipitation samples from a collector at Marsh Creek Lake analyzed between June 1979 and July 1985 ranged from 1.3 to 9.8 mg/L, with an average concentration of 4.4 mg/L.

The range of fluctuation in chloride concentration of water from six wells sampled monthly was from 1.9 mg/L for well CH-2542 to 4 mg/L for well CH-2491; the median was 2.7 mg/L. The change in chloride concentration, expressed as a percentage of the lowest value measured, ranged from 19 percent for well CH-2542 to 180 percent for well CH-1231, with a median of 25 percent. The change in chloride concentration for five of the six wells ranged from 19 to 54 percent. Figure 30 shows monthly chloride concentrations.

Data for early (1949-79) and later (1982-83) chloride concentrations were available for 42 wells. The median chloride concentration of early samples was 8.1 mg/L; the median concentration of later samples was 18 mg/L. Water from 32 wells increased in chloride concentration, with a median increase of 11 mg/L. Water from 10 wells decreased in chloride concentration, with a median decrease of 7.7 mg/L. The median change was an increase of 4 mg/L. These changes are greater than the median short-term fluctuation of 2.7 mg/L.

Changes in chloride concentration were evaluated based on whether an area where a well was located was sewered or unsewered, and on land use. When the change in chloride concentration in water from wells in sewered and unsewered areas was compared, water from wells in sewered areas had a greater increase. Fifteen wells were in sewered areas. Water from 12 wells increased in chloride concentration, with a median increase of 14 mg/L. Water from three wells decreased in chloride concentration. The median change for wells in sewered areas was an increase of 9.5 mg/L. Twenty-eight wells were in unsewered areas. Water from 21 wells increased in chloride concentration, with a median increase of 8.0 mg/L. Water from seven wells decreased in chloride concentration, with a median decrease of 5.4 mg/L. The median change for wells in unsewered areas was an increase of 1.9 mg/L. The source of chloride in ground water in sewered areas probably is salt used for deicing roads. Sewered areas generally have a denser population and a denser network of roads than do unsewered areas. Thus, more salt per unit area is used in sewered areas.

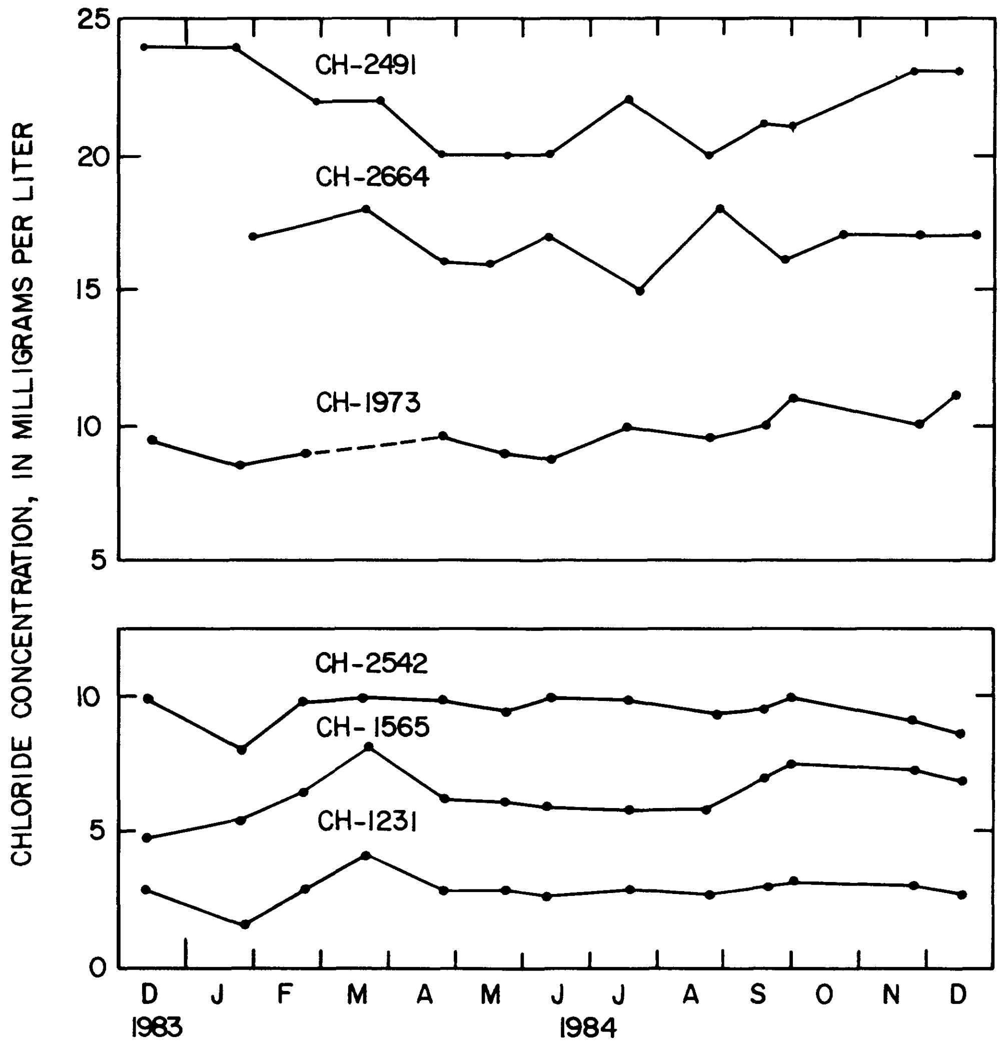


Figure 30.--Fluctuation of chloride concentration in water from six wells sampled monthly from December 1983 to December 1984.

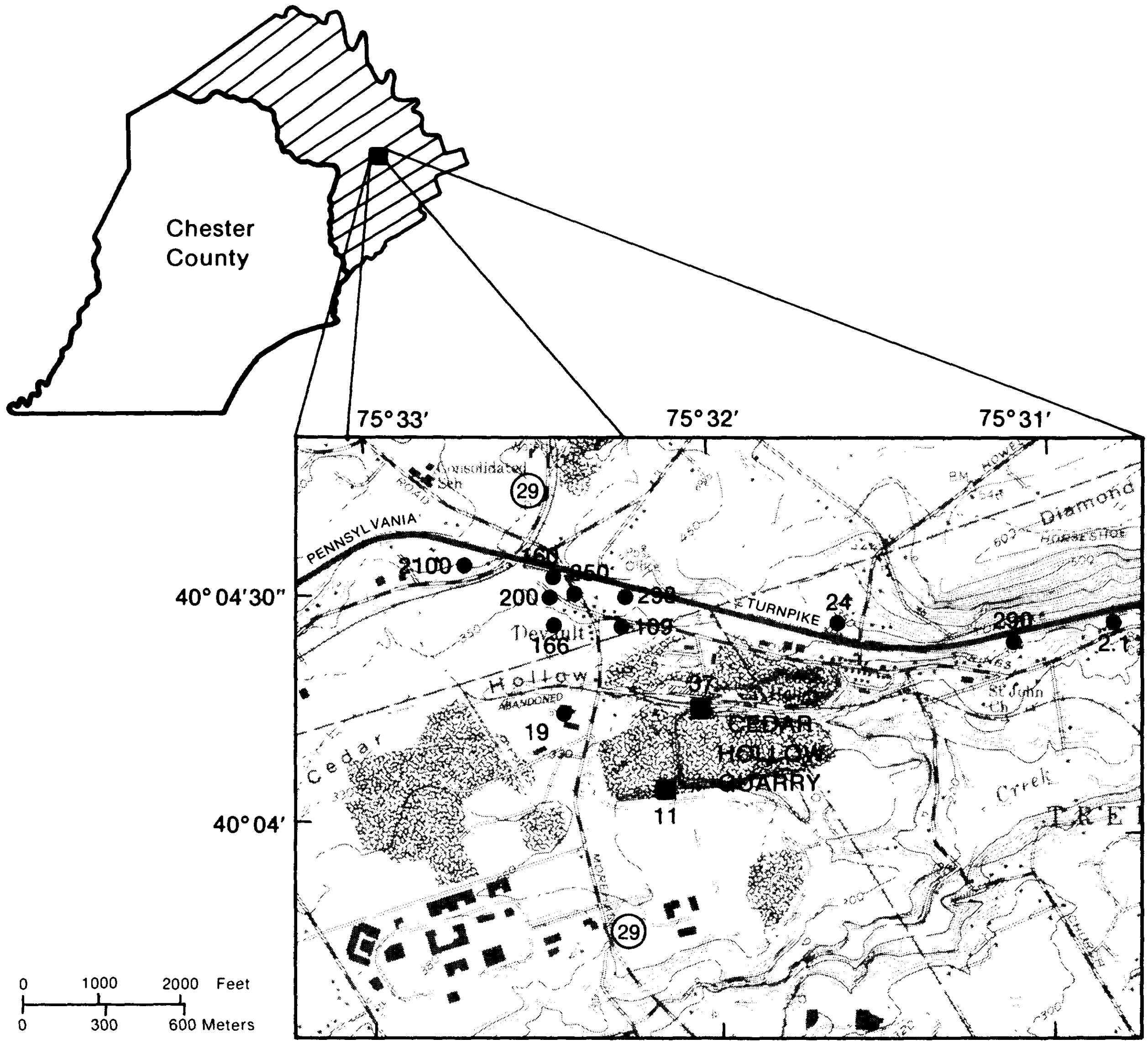
Water from wells in commercial areas had the greatest increase in chloride concentration when water from wells in single family residential, commercial, and agricultural areas were compared. Seven wells were in commercial areas. Water from six wells increased in chloride concentration, with a median increase of 13 mg/L. Water from one well decreased in chloride concentration. The median change for commercial areas was an increase of 12 mg/L. Eleven wells were in single family residential areas. Water from eight wells increased in chloride concentration, with a median increase of 8.9 mg/L. Water from two wells decreased in chloride concentration. The concentration of chloride in water from one well remained the same. The median change for wells in single family residential areas was an increase of 5.0 mg/L. Twenty wells were in agricultural areas. Water from 15 wells increased in chloride concentration, with a median increase of 8.0 mg/L. Water from five wells decreased in chloride concentration, with a median decrease of 5.4 mg/L. The median change for wells in agricultural areas was an increase of 2.5 mg/L. The source of chloride in ground water in commercial areas is probably salt used for melting snow and ice on roadways, parking lots, and sidewalks.

Elevated concentrations of chloride were found in water samples from some wells in carbonate rock near the intersection of the Pennsylvania Turnpike and State Route 29 (fig. 31). Well CH-2478 is on a site where highway deicing salt was stored. Salt leaching into the ground water at this site has caused chloride concentrations as high as 2,100 mg/L. Chloride concentrations in other wells are as high as 350 mg/L (table 23). Elevated chloride concentrations in water from most of these wells probably is due to the use of deicing salt on the Pennsylvania Turnpike. Well CH-2574 is 1.4 miles west of the salt-storage site and is not downgradient from it; however, the well is adjacent to the Pennsylvania Turnpike. Water from this well has a chloride concentration of 290 mg/L. Water from wells CH-293 and CH-2671, which penetrate the Chickies Formation near the Pennsylvania Turnpike, had low chloride concentrations. The other wells near the turnpike with elevated concentrations of chloride penetrate carbonate rock.

Nitrate

Nitrate generally is the most prevelent nitrogen species in ground water. Although small amounts of nitrogen are present in rocks, it is concentrated to a greater extent in soil or biological material. Certain species of bacteria can extract nitrogen from the air and convert it into nitrate; other species of bacteria reduce nitrate to nitrogen or ammonia. Sources of nitrate in ground water include fertilizers, storm runoff, animal wastes, and effluent from sewage and septic systems.

The range of fluctuation in nitrate concentration in water from six wells sampled monthly was 0.2 mg/L for well CH-1231 to 7.2 mg/L for well CH-2491; the median was 1.9 mg/L. The change in concentration expressed as a percentage of the lowest value measured ranged from 20 percent for well CH-1231 to 277 percent for well CH-2491, with a median of 131 percent. Changes greater than 100 percent occurred for four of the six wells. Figure 32 shows monthly nitrate concentrations.



Base from U.S. Geological Survey Malvern, 1983

EXPLANATION

2100 ● WELL--Number is Chloride Concentration in Milligrams Per Liter

■ 37 INFLOW TO QUARRY--Number is Chloride Concentration in Milligrams Per Liter

Figure 31.--Chloride concentration in ground water near the Pennsylvania Turnpike and State Route 29.

Table 23.--Chloride concentrations in ground water near the Pennsylvania Turnpike and State Route 29
Site locations are shown on figure 31

[A dash indicates no data; R is reported value from Mooreshead-Siddiqui and Associates (1982); MG/L, milligrams per liter; US/CM, microsiemens per centimeter at 25 degrees Celcius]

SITE	DATE OF SAMPLE	CHLORIDE, DISSOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SPECIFIC CONDUCTANCE (US/CM)
CH-251 R	81-12-01	166	548	--
293 R	81-12-01	24	138	--
2478	82-08-03	1800	4050	6000
	83-07-07	2100	4370	5600
2549	85-04-30	34	328	430
2556	84-10-31	350	--	1340
2558	84-10-31	160	--	875
2559 R	81-12-21	298	--	--
2560 R	81-12-21	109	--	--
2562	85-03-28	--	--	510
2563	84-10-31	200	--	840
2574	85-03-28	290	672	<1000
2606	85-04-30	19	219	360
2671	85-03-28	2.1	73	124
CEDAR HOLLOW QUARRY SOUTH	85-04-29	11	211	252
CEDAR HOLLOW QUARRY NORTH	85-04-29	37	331	525

Changes in laboratory analytical methods and sample collection and preservation techniques make comparison of nitrate data from different time periods difficult. Using only nitrate data collected and analyzed by the U.S. Geological Survey after July 1971 (Peters and others, 1982, p. 7), comparable data for 21 wells were available. Water from 15 wells increased in nitrate concentration, with a median increase of 0.9 mg/L; water from six wells decreased in nitrate concentration, with a median decrease of 0.25 mg/L. Nitrate concentrations for early (1974-76) samples ranged from 0.18 to 11 mg/L, with a median of 2.4 mg/L. The range for later (1982-83) samples was greater, 0.42 to 19 mg/L; however, the median, 2.2 mg/L, was lower. The median change in nitrate concentration was an increase of 0.8 mg/L. These changes are less than the short-term median fluctuation of 1.9 mg/L.

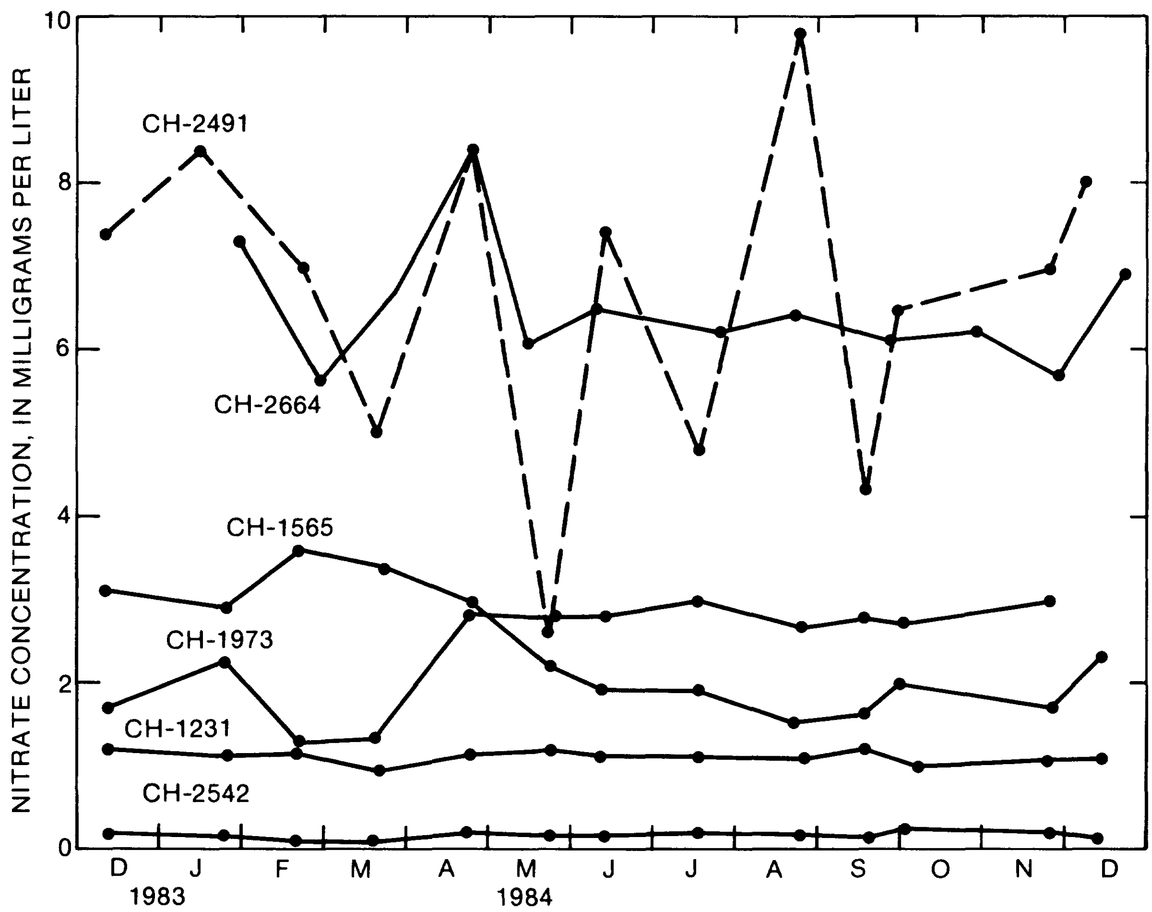


Figure 32.--Fluctuation of nitrate concentration in water from six wells sampled monthly from December 1983 to December 1984.

Sodium

The primary source of sodium in native ground water is from dissolution of igneous and sedimentary rocks, where it is abundant. Another source of sodium is highway deicing salt. Sodium is very soluble and tends to remain in solution. Sodium, however, can be retained by adsorption on minerals with high cation exchange capacities such as clays.

Water samples from six wells were analyzed quarterly for sodium (fig. 33). The range and mean values for sodium concentration are given in table 22. Sodium concentration generally fluctuated within a narrow range, from 0.1 mg/L for well Ch-1231 to 1.6 mg/L for well CH-1973. However, the concentration of sodium in water from well CH-1565 had an 8.3 mg/L range of fluctuation. The median fluctuation for the six wells was 1.0 mg/L. Expressed as a percentage of the lowest measured value, the change in sodium concentration ranged from 0.2 percent for well CH-1231 to 108 percent for well CH-1565, with a median of 7.4 percent. The change was 10 percent or less for four of the six wells.

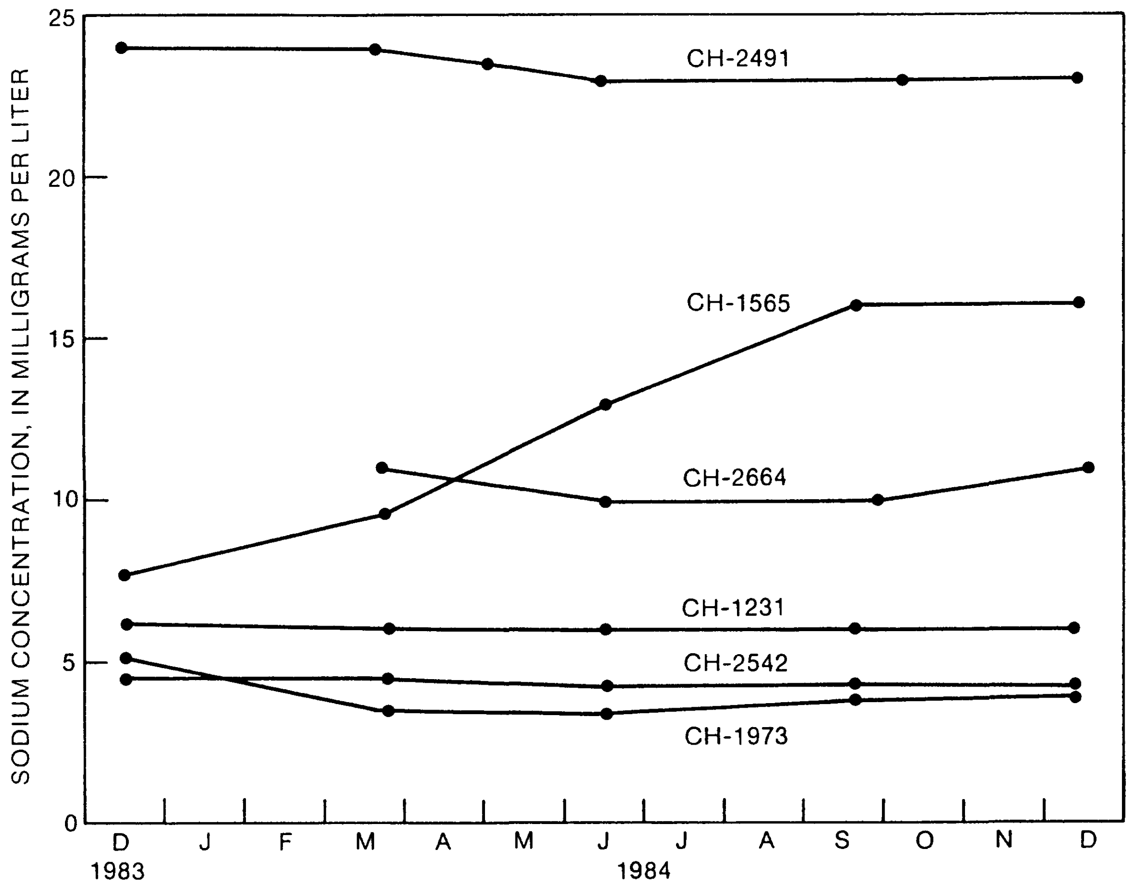


Figure 33.--Fluctuation of sodium concentration in water from six wells sampled quarterly from December 1983 to December 1984.

Data for early (1949-76) and later (1982-83) sodium concentrations were available for 33 wells. The median concentration for early samples was 6.4 mg/L; the median concentration for later samples was 9.7 mg/L. Water from 26 wells increased in sodium concentration, with a median increase of 2.4 mg/L.

Water from seven wells decreased in sodium concentration, with a median decrease of 5 mg/L. The median change was an increase in sodium concentration of 1.9 mg/L. These changes are greater than the short-term fluctuation of 1.0 mg/L.

Changes in sodium concentration were evaluated based on whether an area where a well was located was sewered or unsewered, and on land use. As with chloride, the greatest increase in the sodium concentration was in water from wells in sewered areas. Seven wells were in sewered areas. Water from six wells increased in sodium concentration, with a median increase of 2.7 mg/L. The median change for wells in sewered areas was an increase of 2.3 mg/L. Twenty-six wells were in unsewered areas. Water from 21 wells increased in sodium concentration, with a median increase of 2.0 mg/L. Water from five wells decreased in sodium concentration, with a median decrease of 0.9 mg/L. The median change for wells in unsewered areas was an increase of 1.3 mg/L.

As with chloride, the greatest increase in the concentration of sodium was in water from wells in commercial areas. Sodium concentrations in water from wells in commercial, single family residential, and agricultural areas were compared. Six wells were in commercial areas. Water from four wells increased in sodium concentration, whereas water from two wells decreased in sodium concentration. The median change for wells in commercial areas was an increase of 30 mg/L. Water from all eight wells in single family residential areas increased in sodium concentration, with a median increase of 1.2 mg/L. Eighteen wells were in agricultural areas. Water from 15 wells increased in sodium concentration, with a median increase of 2.1 mg/L. Water from three wells decreased in sodium concentration. The median change for wells in agricultural areas was an increase of 2.0 mg/L.

Long-term increases in both sodium and chloride concentrations in ground water were greater than short-term fluctuations, indicating that the source of these constituents probably is deicing salt (sodium chloride). The change in sodium concentration correlated well with the change in chloride concentration (correlation coefficient = 0.76). Greater increases in both sodium and chloride concentrations occurred in sewered areas where population density generally is greater than in unsewered areas. Greater increases in both sodium and chloride concentrations also occurred in commercial areas, where the area of paved surfaces generally is greater than in residential or agricultural areas.

Sulfate

Sulfur is not abundant in the earth's crust, but is widely distributed in both igneous and sedimentary rocks as metallic sulfides such as pyrite (FeS_2), and in sedimentary rocks as gypsum ($CaSO_4 \cdot 2H_2O$) anhydrite ($CaSO_4$). Sulfate (SO_4) is a common constitutent of ground water.

Water samples from six wells were analyzed quarterly for sulfate (fig. 34). The range and mean values for sulfate concentrations are given in table 22. The range of fluctuation in sulfate concentration was from 4 mg/L for well CH-2542 to 21 mg/L for well CH-2491, with a median fluctuation of 10 mg/L. Expressed as a percentage of the lowest measured value, the change in sulfate concentration ranged from six percent for well CH-2542 to 135 percent for well CH-2664, with a median of 45 percent.

Data for early (1949-76) and later (1982-83) sulfate concentrations were available for 41 wells. The median sulfate concentration for both the early and the later samples was 22 mg/L. Water from 26 wells increased in sulfate concentration, with a median increase of 7.5 mg/L. Water from 14 wells decreased in sulfate concentration, with a median decrease of 8 mg/L. The sulfate concentration in water from one well remained the same. The median change was an increase in sulfate concentration of 2.7. mg/L. These changes are less than the median short-term fluctuation of 10 mg/L.

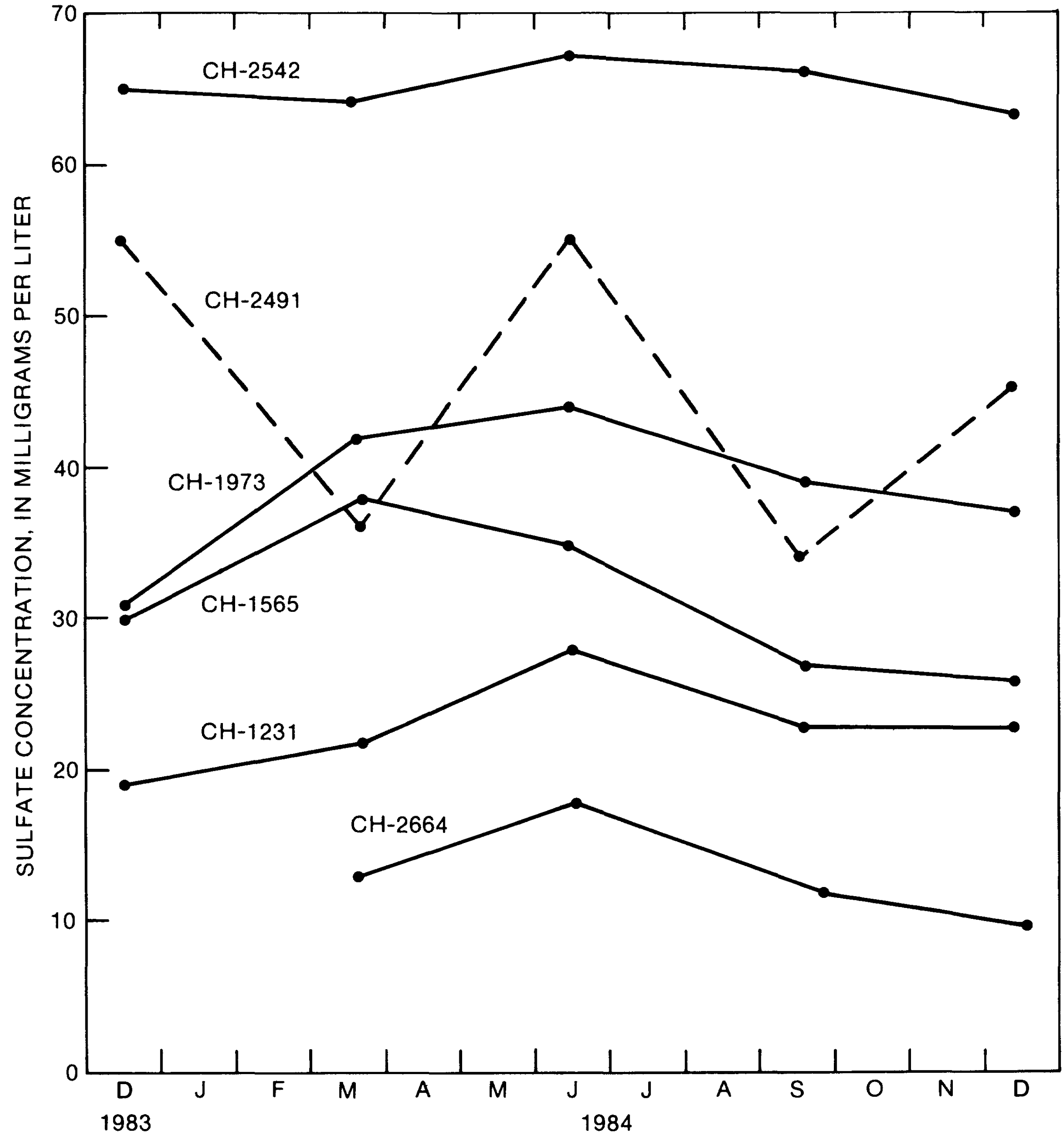


Figure 34.--Fluctuation of sulfate concentration in water from six wells sampled quarterly from December 1983 to December 1984.

Radionuclides

Even though they are naturally occurring, radionuclides in ground water may present a potential health problem. Preliminary sampling of wells in the Chickies Formation has shown elevated concentrations of radium-226, radium-228, and alpha particle activity. The USEPA has set a maximum contaminant level of 5 pCi/L (picocuries per liter) for radium (combined radium-226 and radium-228) and 15 pCi/L for gross alpha activity (Code of Federal Regulations, 1983, p. 236). Two wells in the Chickies Formation were sampled for radionuclides. Water from well CH-2197 had a radium-226 concentration of 1.8 pCi/L, a radium-228 concentration of 13 pCi/L, and a gross alpha activity of 7.2 pCi/L. The gross beta activity was 15 and 13 pCi/L for gross beta activity as cesium-137 and yttrium-90, respectively. Water from well CH-2436 had a radium-226 concentration of 5.4 pCi/L, a radium-228 concentration of 9 pCi/L, and a gross alpha activity of 7.6 pCi/L. The gross beta activity was 24 and 20 pCi/L for gross beta activity as cesium-137 and yttrium-90, respectively.

Four water samples from three wells in the Chickies Formation in other parts of Chester County not included in this study were analyzed for radionuclides. The concentration of radium-226 ranged from 0.7 to 11 pCi/L, the concentration of radium-228 ranged from 6 to 76 pCi/L, and the gross alpha activity ranged from 1 to 55 pCi/L. Gross beta activity as cesium-137 ranged from 5.5 to 120 pCi/L, and as yttrium-90 ranged from 5 to 100 pCi/L.

Radioactivity is the release of energy and energetic particles by changes in the atomic 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, which is electromagnetic waves (Hem, 1985, p. 146-151).

Radioactivity in water is produced by dissolved constituents, mostly caused by the decay of uranium-238 and thorium-232. They decay in steps, forming a series of radionuclide daughter products until a stable lead isotope is produced. Uranium-238 produces the greatest part of radioactivity in natural water. Alpha-emitting constituents in water are mainly isotopes of radium and radon, which are members of the uranium and thorium decay series. Beta emissions are also given off by members of these series.

Radium-226 and radium-228 are the principle radium isotope decay products. Radium-226 is an alpha emitter; radium-228 is a beta emitter. Radium-226 decays to produce radon-222, a gas that is soluble in water. Radon-222 subsequently decays through a series of short-lived daughter products to the stable isotope lead-206. Radium-228 decays to the stable isotope lead-208.

Organochlorine Insecticides and PCB in Stream-Bottom Material

One of the greatest effects of human activity on the surface-water system has been the accumulation of organic compounds, particularly pesticides and PCB, in stream-bottom material. Organic molecules are generally hydrophobic and are adsorbed onto sediment and deposited in stream channels. Persistent compounds, such as DDT or PCBs, may remain in the sediment for years.

Bottom material from eight streams (fig. 35) was analyzed for organochlorine insecticides and PCB in 1978-79 and 1985 (table 24). PCB, DDE, and dieldrin were found in the bottom materials of all of the streams sampled. Chlorodane was found in the bottom material of all the streams sampled except Pickering Creek. Lindane was found in bottom material from only Ridley and Chester Creeks. The higher concentration of lindane in bottom material from Chester Creek may be the result of use of this insecticide by the mushroom industry, which was prevelant in the Chester Creek basin. Aldrin, methoxychlor, and toxaphene were not detected in any of the stream sediments sampled.

Metals and Other Trace Constituents

Twenty-nine surface-water sites were sampled annually at base flow for dissolved metals and other trace constituents from 1973-84 (fig. 36). Site numbers are those used by Lium (1976 and 1977) and Moore (1987). Data for dissolved aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, and zinc are presented for 1973-83 in the U.S. Geological Survey Water Resources Data reports for Pennsylvania for 1974-84 (U.S. Geological Survey, 1974-84). Metals and other trace constituents were generally not a water-quality problem except for iron and manganese in some streams. However, lead concentrations exceeded 50 μg/L in three samples from site B16 on French Creek, and in one sample each from sites B3, B6, and B21. Mercury concentrations exceeded 0.2 μg/L in one sample each from sites B16, B24, and B25. The mercury concentration at site B25 on Goose Creek, a tributary to East Branch Chester Creek below two sewage treatment plants, was 83 μg/L on October 10, 1981. The concentration of nickel exceeded 13.4 μg/L in one sample from site B22.

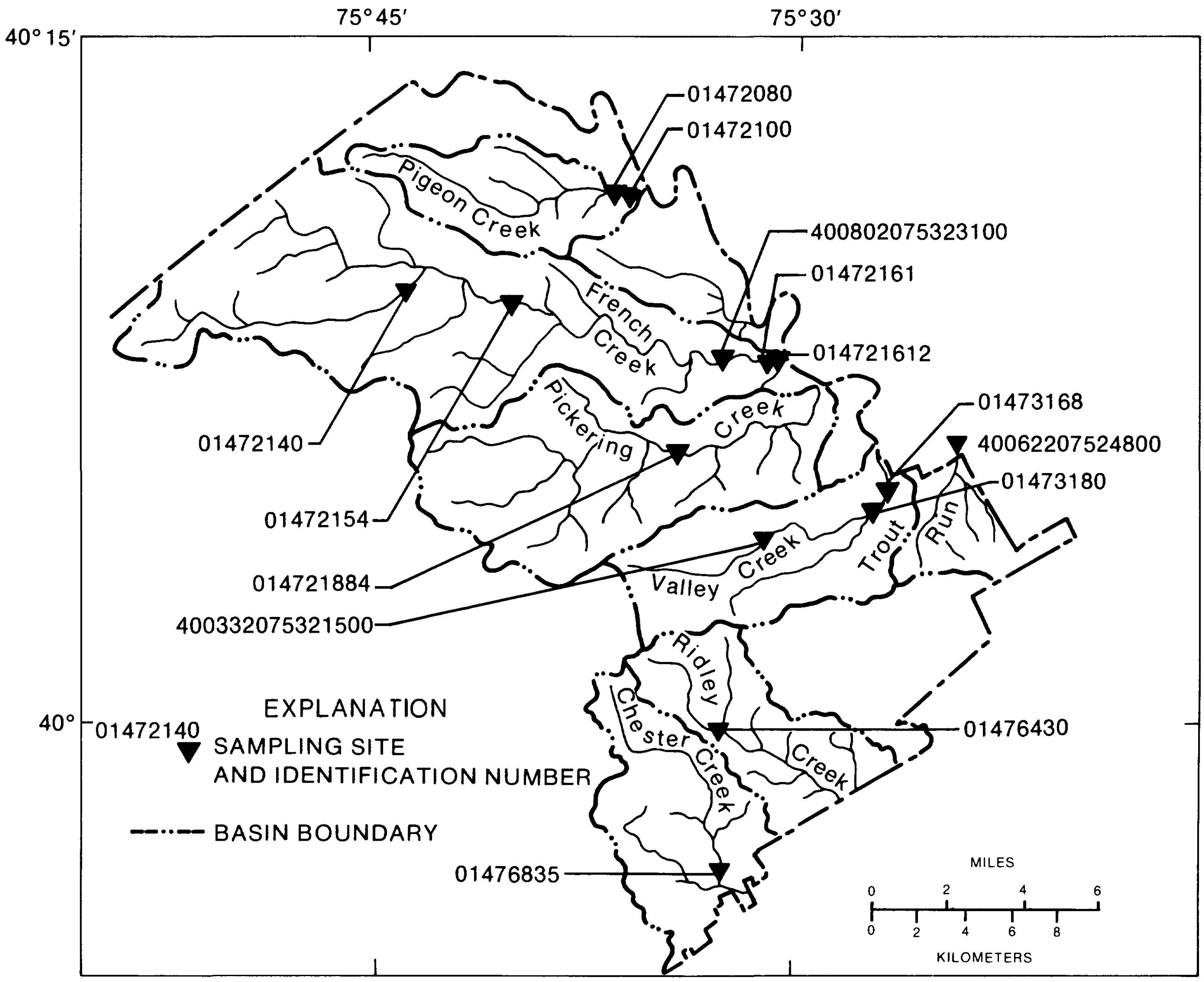


Figure 35.--Sampling sites for organochlorine insecticides and PCB in stream-bottom material.

Table 24.-- Chemical analyses of stream-bottom material for organochlorine insecticides and PCB from selected streams

[Results are in micrograms per kilogram; a dash indicates no data]

STATION NUMBER	STATION NAME (BIOLOGICAL SAMPLING SITE)	DATE OF SAMPLE	ALDRIN, TOTAL IN BOTTOM MATERIAL	CHLORDANE, TOTAL IN BOTTOM MATERIAL	DDD, TOTAL IN BOTTOM MATERIAL	DDE, TOTAL IN BOTTOM MATERIAL
01472080	PIGEON CREEK NEAR PARKER FORD (B10)	10-11-85	<.1	<1.0	<.1	.1
01472100	PIGEON CREEK AT PARKER FORD	11-16-79	.0	4.0	.4	.5
01472140	S BR FRENCH CR AT COVENTRYVILLE (B12)	10-10-85	<.1	<1.0	.3	.4
01472154	FRENCH CREEK NEAR PUGHTOWN (B14)	10-11-85	<.1	6.0	<.1	.6
400802075323100	FRENCH CR AT NUTT RD NR PHOENIXVILLE	12-06-79	.0	3.0	.0	.0
01472161	FRENCH CR AT MAIN ST. BRDG. AT PHOENIXVILLE	12-06-79	.0	61	2.8	3.0
014721612	FRENCH CREEK AT RR BRIDGE AT PHOENIXVILLE (B16)	10-09-85	<.1	5.0	<.1	<.1
014721884	PICKERING CR AT CHLSTWN RD BR. AT CHLSTWN (B4)	10-07-85	<.1	<1.0	<.1	--
400332075321500	VALLEY CR NR DEVAULT	11-13-79	.0	9.0	1.3	5.1
01473168	VALLEY CREEK NR VALLEY FORGE	10-09-85	<.1	5.0	1.7	1.7
01473180	VALLEY CR AT VALLEY FORGE (B50)	12-28-78	.0	2.0	.0	.0
		11-13-79	.0	2.0	.0	1.1
400622075242800	TROUT CR NR VALLEY FORGE	11-15-79	.0	34	.0	4.7
01476430	RIDLEY CREEK AT GOSHENVILLE (B20)	10-15-85	<.1	7.0	.6	.6
01476835	EAST BRANCH CHESTER CR AT WESTTOWN SCHOOL (B24)	10-16-85	<.1	7.0	<.1	.3

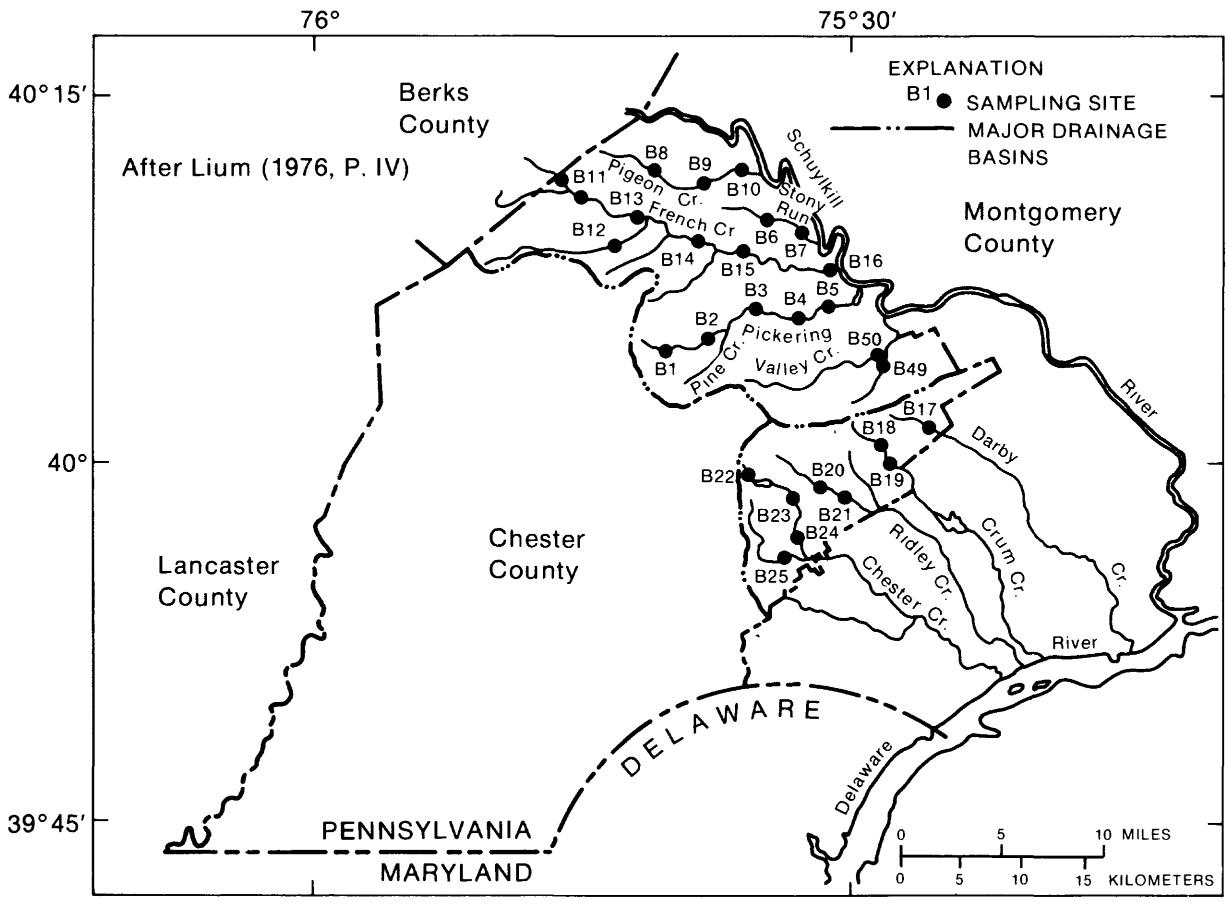


Figure 36.--Chemical and biological surface-water-sampling sites.

DDT, TOTAL IN BOTTOM MATERIAL	DIELDRIN, TOTAL IN BOTTOM MATERIAL	ENDRIN, TOTAL IN BOTTOM MATERIAL	HEPTACHLOR, TOTAL IN BOTTOM MATERIAL	HEPTACHLOR EPOXIDE TOT. IN BOTTOM MATL.	LINDANE TOTAL IN BOTTOM MATERIAL	METHOXYCHLOR, TOT. IN BOTTOM MATL.	TOXAPHENE, TOTAL IN BOTTOM MATERIAL	PCB, TOTAL IN BOTTOM MATERIAL	STATION NUMBER	DATE OF SAMPLE
<.1	<.1	<.1	<.1	<.1	<.1	<.1	<10	<1	01472080	10-11-85
.0	1.1	.0	.0	.0	.0	.0	.00	3	01472100	11-16-79
.4	4.8	.1	<.1	.4	<.1	<.1	<10	<1	01472140	10-10-85
<.1	.1	<.1	<.1	.1	<.1	<.1	<10	12	01472154	10-11-85
.0	.9	.0	.0	.0	.0	.0	.00	10	400802075323100	12-06-79
3.2	3.5	.0	.0	.0	.0	.0	.00	68	01472161	12-06-79
<.1	.2	<.1	<.1	.1	<.1	<.1	<10	5	014721612	10-09-85
<.1	.1	<.1	<.1	<.1	<.1	<.1	<10	9	014721884	10-07-85
1.0	1.3	.0	.0	.0	.0	.0	.00	47	400332075321500	11-13-79
3.2	.1	<.1	.1	.1	<.1	<.1	<10	18	01473168	10-09-85
1.2	1.8	.0	.0	.0	.0	--	.00	8	01473180	12-28-78
2.2	.7	.0	.0	.0	.0	.0	.00	110		11-13-79
7.5	3.0	.0	.0	1.1	.0	.0	.00	100	400622075242800	11-15-79
<.1	.3	<.1	<.1	.4	.1	<.1	<10	5	01476430	10-15-85
<.1	.1	<.1	<.1	.1	.4	<.1	<10	2	01476835	10-16-85

Inorganic Constituents

Discharge from sewage-treatment plants generally has a greater effect on surface-water quality than does land use. Four surface-water sites on Goose Creek were sampled at base flow (fig. 37) on October 22, 1982. Site S1 drains a highly urbanized residential and industrial area. Site S2 drains an area of single-family dwellings, open space, and an area used for mushroom growing and composting mushroom-growing medium. Site S3 drains a residential and agricultural area. Surface-water-sampling site 01476840 receives inflow from these three tributaries and adjoining areas and is below two sewage treatment plants.

Water quality among sites S1, S2, and S3 is similar except for the concentrations of dissolved nitrogen and organic nitrogen, which are higher at site S2 (table 25), probably as the result of heavy use of manure in mushroom-growing media. Site S3 has a lower concentration of total dissolved solids, chloride, sodium, and sulfate.

The difference in water quality between sites S1, S2, and S3 and site 01476840 is substantial and is due to discharge from the sewage treatment plants. Water sampled at site 01476840 had substantially higher concentrations of ammonia, nitrogen, phosphorous, orthophosphorous, total dissolved solids, chloride, sulfate, sodium, and potassium.

Table 25.-- Concentrations of selected dissolved constituents at four sites in the Goose Creek basin, October 22, 1982
Sampling site locations are shown on figure 37
[MG/L, milligrams per liter]

STATION NAME	DATE OF SAMPLE	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	NITRO-GEN DIS-SOLVED (MG/L AS N)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SULFATE DIS-SOLVED (MG/L AS SO4)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
GOOSE CREEK TRIBUTARY SITE S1	82-10-22	3.0	0.040	0.090	0.90	3.9	0.110	0.110	0.19	280	53	40	29	3.3
GOOSE CREEK TRIBUTARY SITE S2	82-10-22	5.6	.030	.040	2.5	8.1	.010	<.010	.18	271	46	43	16	1.9
GOOSE CREEK TRIBUTARY SITE S3	82-10-22	5.2	.010	.080	.60	5.8	.050	.060	.04	198	22	23	9.4	2.4
GOOSE CREEK STATION NUMBER 01476840	82-10-22	7.3	.200	23.0	28	36	5.40	5.20	.42	586	160	130	110	43

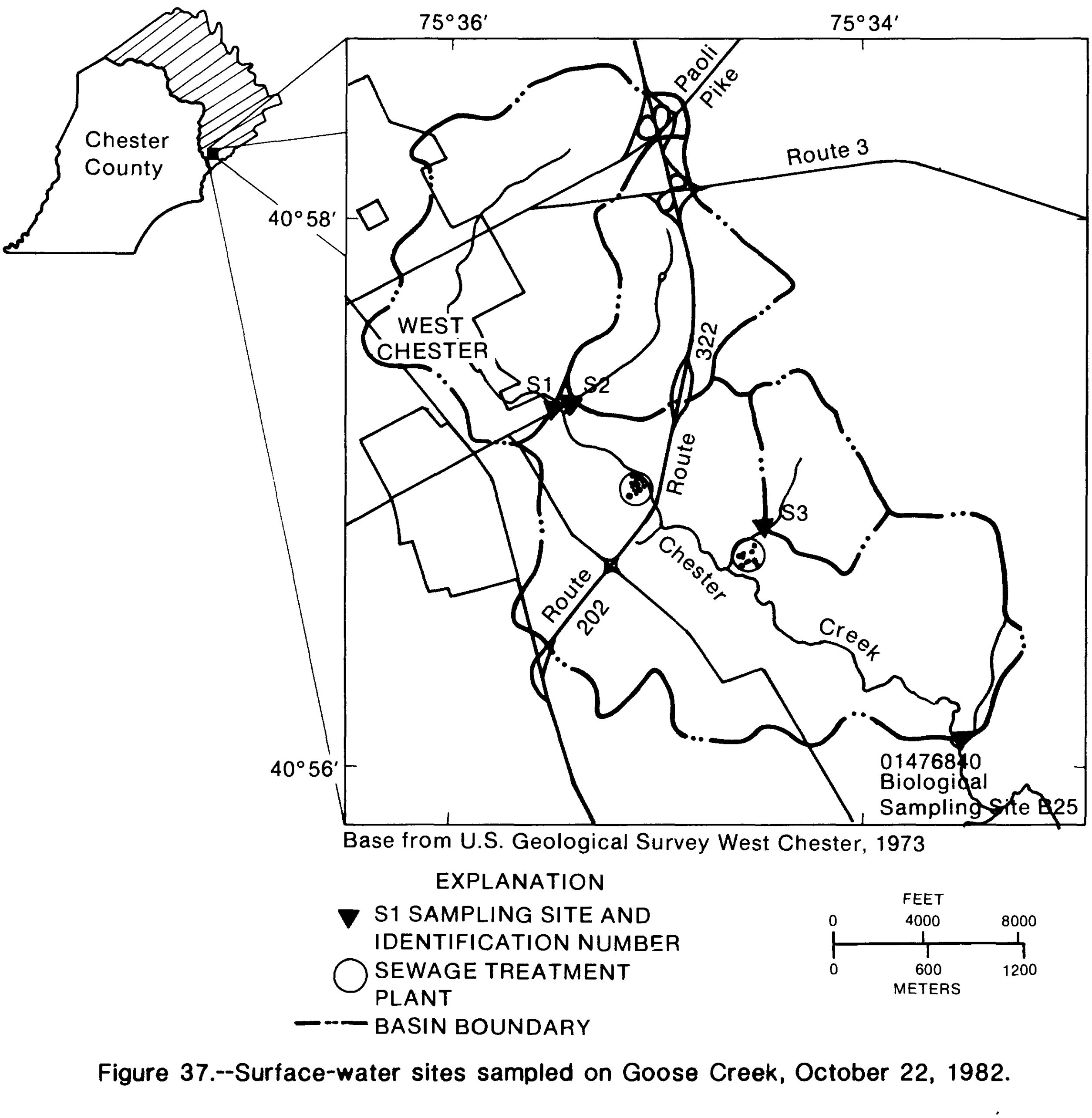


Figure 37.--Surface-water sites sampled on Goose Creek, October 22, 1982.

EFFECT OF URBANIZATION ON BENTHIC-INVERTEBRATE INDICES

Moore (1987) evaluated trends in diversity index of stream benthic invertebrates for 46 sites in Chester County. Twenty-five of those sites are in eastern Chester County (fig. 36). Benthic invertebrates are organisms inhabiting the bottoms of streams, such as aquatic insects, crustaceans, snails, clams, and worms. Common examples are crayfish, dragonfly nymphs, and caddisfly larvae. The relevant quantitative information about a benthic invertebrate or other biological community consists of: (1) the number of different kinds of organisms (taxa), and (2) their relative abundances. These two properties are commonly summed up in a descriptive statistic called a diversity index. Of the many measures of diversity that have been proposed, Brillouin's diversity index (Brillouin, 1962), which is based on information theory, has been adopted for use by the U.S. Geological Survey (Slack, J. R., U.S. Geological Survey, written commun., 1985).

Moore (1987) calculated Brillouin's diversity index for each site and used a modified form of the seasonal Kendall test (Hirsh and others, 1982) to test for trend. The seasonal Kendall test is a nonparametric, distribution-free statistical test for monotonic trend with time. Moore applied a second statistical technique, the Kendall slope estimator (Thiel, 1950; Sen, 1980), to estimate the direction and magnitude of trends. The Kendall slope estimator is an unbiased estimator of the slope of linear trends. Moore found that diversity index exhibited an upward trend at 44 sites and a downward trend at 2 sites. The upward trend was statistically significant at 27 sites.

For this study, trends in diversity index and changes in land use were compared. Diversity indices for 1970-80 were obtained from Moore (1987). Additional diversity indices for 1981-84 were provided by Moore (U.S. Geological Survey, written commun., 1985). Land-use changes in 10 selected subbasins were quantified. Land use was lumped into two categories: (1) agricultural and undeveloped, which included row crops, pasture, orchards, forests, parks, open space, and lakes; and (2) residential and commercial, which included single and multiple residential housing, trailer parks, commercial areas, and industrial areas. Land use was determined from aerial photographs for 1968 and 1980. Land use was transferred to topographic maps and planimetered to determine the area of each land use. The percentage of each type of land use in each subbasin was calculated. Changes in land use from agricultural and undeveloped to residential and commercial in the 10 subbasins ranged from 0 to 37.3 percent (table 26). Site numbers are the same as those used by Moore (1987) and are shown on figure 36. Diversity index and the Kendall slope estimator were plotted for four sites with different percentage changes in land use: site B1 (no change), site B20 (10.5 percent change), site B50 (23 percent change), and site B24 (37.3 percent change). The Kendall slope estimators (fig. 38) show that diversity index increased at all four sites; however, the slope is greater for sites with a greater percentage of land-use change. For all 10 subbasins, the percentage of change in land-use correlated well with the slope of the Kendall slope estimator (correlation coefficient = 0.72) and is statistically significant at the 98 percent level of confidence.

Generally, the greater the change in land use, the steeper the Kendall slope estimator and the greater the rate of increase in the diversity index. Sites with greater changes in land use generally had a lower diversity index in the early 1970's (fig. 39). Decreasing use of pesticides in subbasins changing from rural to suburban may, in part, account for the steeper slope of the Kendall slope estimator (fig. 38) at sites in those subbasins. Although upward trends in diversity index found by Moore can be related to changes in land use, the diversity index at sites in subbasins where land use has not changed also showed an upward trend. The generally upward trend in diversity index for all sites may be due to the banning of certain very persistent pesticides such as DDT, which was banned in 1971. Pesticides such as DDT are persistent, hydrophobic, and are usually adsorbed onto stream sediments. Analysis of stream-bottom materials (table 24) has shown pesticides in the sediment of all eight streams sampled. In time, these pesticides may either break down or be flushed downstream by storms. Subbasins with more rapidly changing land use may produce temporary increases in runoff and peak flow, either flushing pesticide-contaminated sediment downstream or burying it under more recent, uncontaminated sediments. Sediment eroded from farm fields may be the major transport mechanism for the movement of pesticides into stream sediments. A change in land use from rural to urban could result in a decrease in transport.

Data for the early 1970's show much more variability in diversity index among stations than data for the late 1970's. The diversity indices in figure 39 appear to be converging in the late 1970's. A plot of mean diversity index for the 25 biological sampling sites in eastern Chester County shows a similar trend (fig. 40). Figure 40 also shows the minimum, maximum, and mean diversity index increasing with time. The highest peak discharges for 1970-80 for streams in northern Chester County occurred in 1972 and 1973. Increased variability in the early data may be, in part, caused by the hydraulic effects (shear and scouring) of Hurricane Agnes in 1972 and another large storm in 1973. However, diversity index did not correlate well with peak discharge for 1970-80 at three biological sampling sites at continuous-record surface-water stations (fig.36): site B2 (correlation coefficient = 0.05), site B15 (correlation coefficient = 0.32), and site B17 (correlation coefficient = -0.39).

Point-source discharges also affect diversity index. Sewage-treatment plants on Valley Creek and Little Valley Creek were abandoned in 1977 when the Valley Forge Sewer Authority sewage treatment plant began operation. The diversity index at both site B50 on Valley Creek and site B49 on Little Valley Creek (fig. 36) increased and remained higher after 1977 (fig. 41). The zero diversity index at site B49 in 1974 was probably the result of a cyanide spill into Little Valley Creek.

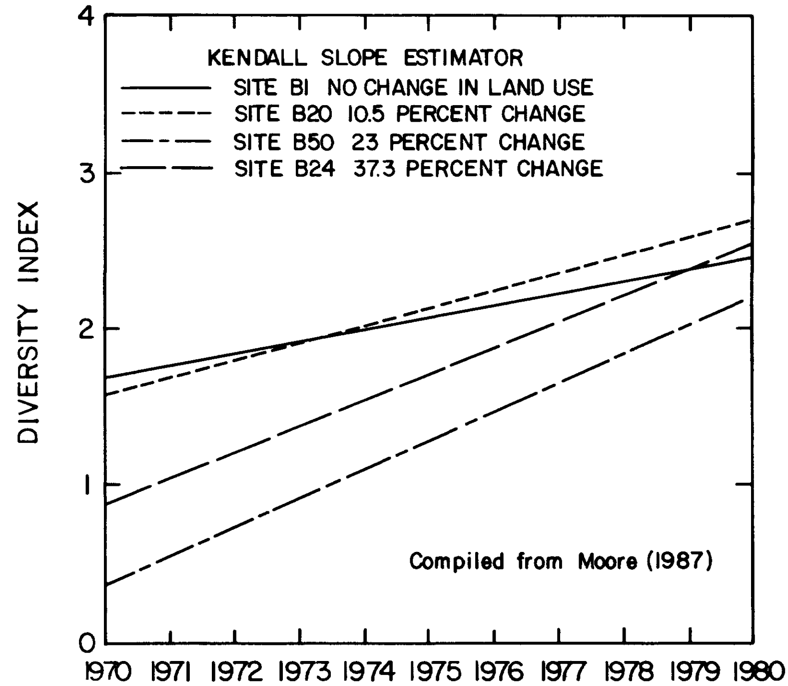


Figure 38.--Kendall slope estimator for trend in diversity index at biological sampling sites B1, B20, B24, and B50.

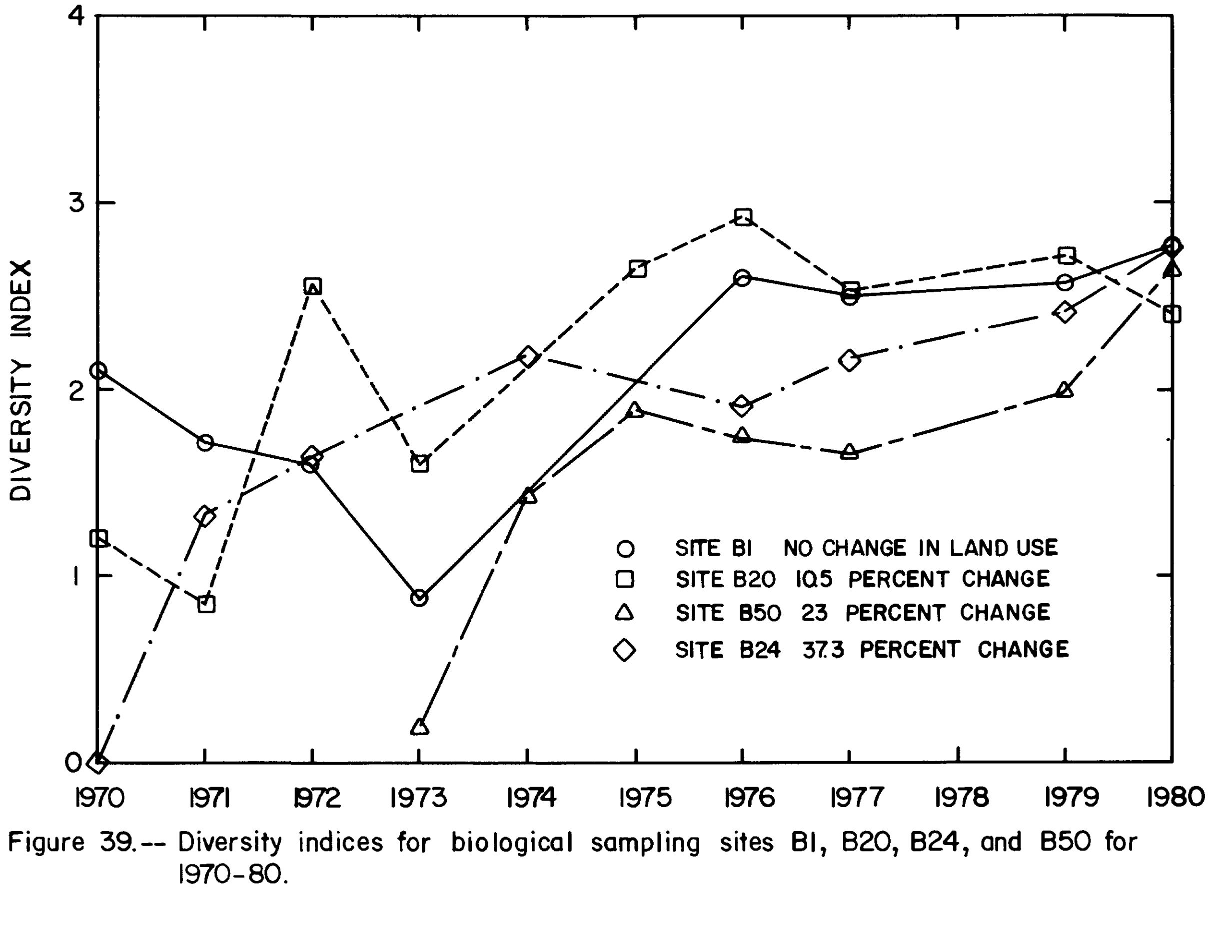


Figure 39.-- Diversity indices for biological sampling sites B1, B20, B24, and B50 for 1970-80.

Table 26.--Land-use changes in 10 selected subbasins

[mi^2, square miles]

Site number	Station number	Station name	Drainage area (mi^2)	1968 Land use: Agricultural and undeveloped (percent)	1968 Land use: Residential and commercial (percent)	1980 Land use: Agricultural and undeveloped (percent)	1980 Land use: Residential and commercial (percent)	Percent of land changed from agricultural and undeveloped to residential and commercial
B1	01472170	Pickering Creek near Eagle	3.09	96	4	96	4	0
B2	01472174	Pickering Creek near Chester Springs	5.98	93	7	90.4	9.6	2.6
B8	01472054	Pigeon Run near Bucktown	4.20	93.3	6.7	89.1	10.9	4.2
B9	0147065	Pigeon Run at Porter's Mill	6.97	96.2	3.8	86.7	13.3	9.5
B20	01476430	Ridley Creek at Goshenville	4.22	45.1	54.9	34.6	65.4	10.5
B21	01476435	Ridley Creek at Dutton Mill near West Chester	9.71	87.5	12.5	68.6	31.4	18.9
B23	01476830	East Branch Chester Creek at Milltown	5.77	79.8	20.2	54.5	45.5	25.3
B24	01476835	East Branch Chester Creek at Westtown School	10.4	73	27	35.7	64.3	37.3
B49	01473167	Little Valley Creek at Howellville	6.45	51.4	48.6	36.1	63.9	15.3
B50	01473168	Valley Creek near Valley Forge	12.7	88.4	11.6	65.4	34.6	23

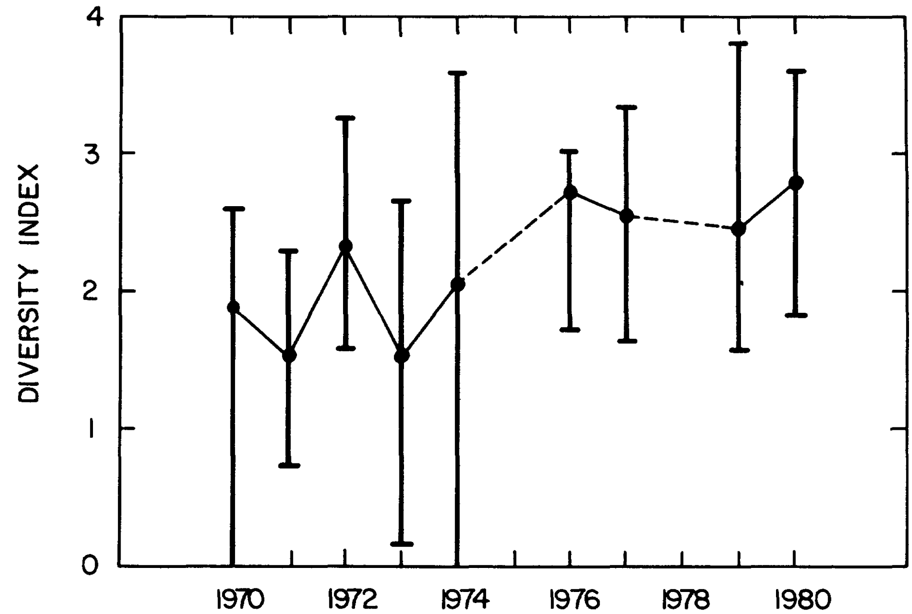


Figure 40.--Minimum, maximum, and mean diversity index for 25 biological sampling sites, 1970-80.

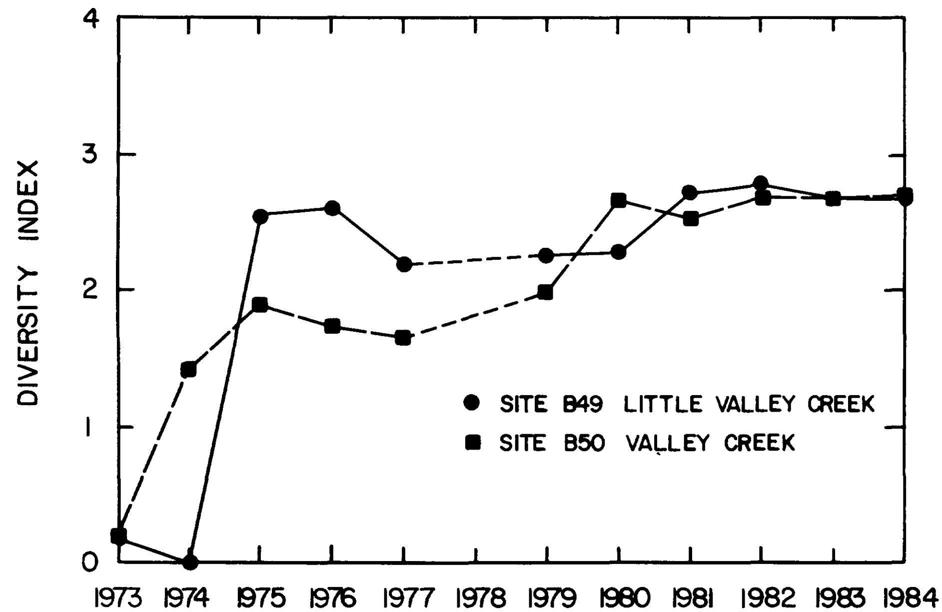


Figure 41.--Diversity index at site B49 on Little Valley Creek and site B50 on Valley Creek, 1973-84.

SUMMARY

The effect of human activity on the water resources of eastern Chester County were evaluated. The 207-mi^2 study area is that part of Chester County drained by Pigeon Creek, Stony Run, French Creek, Pickering Creek, Valley Creek, Trout Run, Darby Creek, Crum Creek, Ridley Creek, and Chester Creek. Continuing urbanization has caused a decrease in agricultural land and open space, and a corresponding increase in residential, commercial, and industrial land uses.

Before urbanization, domestic wells and springs served as the source of water supply. Wastewater was eliminated through onsite septic systems. As eastern Chester County became urbanized, these were replaced by public water and sewer systems, which now serve the more densely populated areas. In 1984, public water purveyors supplied an average of 17 Mgal/d of water to approximately 95,000 people, or about 47 percent of the population of eastern Chester County.

Public water and sewer systems have created an interbasin transfer of water. Estimates of interbasin transfer for 1984 ranged from a net loss of 630 Mgal in the Valley Creek basin to a net gain of 783 Mgal in the Chester Creek basin. The Crum Creek basin had an estimated net loss of 97 Mgal, the Pickering Creek basin a net loss of 47 Mgal, the Ridley Creek basin a net loss of 24 Mgal, and the French Creek basin a net loss of 3 Mgal. In the highly urbanized Darby Creek and Trout Run basins, all of the public water is imported, and all of the wastewater is exported, resulting in no net interbasin transfer. In the rural Pigeon Creek and Stony Run basins, no interbasin transfer of water occurs.

The quantity of wastewater discharged from treatment plants generally correlates well with the altitude of the water table observed in wells, but does not correlate with water use in the same area. Wastewater discharge also does not correlate with precipitation, indicating that the source of additional inflow to sewer systems is ground-water infiltration rather than storm water. In older municipal systems, water use may be higher than the wastewater return flow because of leakage from distribution pipes. In newer systems, wastewater return flow may be higher than water use because of ground-water infiltration. Estimated average ground-water infiltration to the West Goshen sewer system for 1980-84 was 0.5 Mgal/d or 0.8 $(ft^3/s)/mi^2$ of sewered area. This infiltration is about 15 percent of the long-term average base flow of Chester Creek in the sewered area. Ground-water infiltration to the Valley Forge sewer system for 1980-84 was estimated to be 1.2 Mgal/d. The highest estimated ground-water infiltration, 4.9 Mgal/d, occurred in April 1984, and contributed a greater percentage of flow to the Valley Forge treatment plant than did wastewater.

Quarry dewatering in Chester Valley has lowered water levels locally and increased the range of water-table fluctuation. The spread of the cone of depression caused by quarry dewatering is limited by geologic and hydrologic controls. Ground-water discharge from the Cedar Hollow Quarry averaged about 5 Mgal/d in the summer of 1984.

The pumping of public-supply wells in Chester Valley has caused local cones of depression about 1,000 feet in diameter in the Ledger and Elbrook Formations. Streamflow measurements indicate that these wells may affect Valley Creek and its tributaries at a distance, causing stream reaches to lose water. The affected stream reaches are 1,100 to 2,700 feet west of the walls.

Urbanization has resulted in the contamination of ground water by organic chemicals, metals, and chloride. The most serious problem is contamination by volatile organic compounds (VOCs).

Sampling for VOCs generally was biased towards wells in areas that had the greatest potential for the presence of VOCs. VOCs were detected in 39 percent of the 70 wells sampled. As many as nine VOCs were detected in one water sample, and total VOC concentration was as high as 17,400 µg/L. The most commonly detected VOCs were trichloroethylene (24 percent of wells sampled), 1,1,1-trichoroethane (16 percent), 1,2-trans-dichloroethylene (14 percent), benzene (11 percent), and tetrachloroethylene (10 percent).

VOCs are moving through the ground-water system in Chester Valley under the influence of the hydraulic gradient caused by quarry pumping. Movement through the quarries, however, reduces the concentrations of the VOCs, except trichloroethylene, to below detection limits.

Water from 15 wells was analyzed for 46 base-neutral organic compounds. Three compounds were detected in low concentrations: bis(2-ethylhexyl) phthalate, di-n-butyl phthalate, and 1,2-dichlorobenzene. No acid organic compounds were detected in water samples from five wells.

Pesticides generally are not a problem in ground water. Where present, concentrations are low. Water from 48 wells was analyzed for organochlorine insecticides. Four compounds were detected: aldrin, dieldrin, DDD, and DDT. Water from 11 wells was analyzed for organophosphorous insecticides; diazinon and methyl parathion were detected.

Sampling for herbicides was biased towards areas where herbicides are used. Sampled wells were located in or near cropland, orchards, and golf courses. Triazine herbicides were not detected in water samples from seven wells and one spring. Water from six wells and one spring was analyzed for alachlor; water from one well in a cornfield had a concentration of 0.18 µg/L of alachlor. Water from nine wells and one spring was analyzed for phenoxy acid herbicides, dicamba, and picloram. 2,4-D was detected in water from one well.

Fifty-four wells were sampled for total phenol. Phenol was found in 28 percent of the wells sampled. Concentrations of total phenol ranged from less than 1 to 7 µg/L. Fifty-one wells were sampled for PCB and PCN. PCB was found at the detection limit of 1 µg/L in one water sample; however, followup testing failed to confirm the presence of PCB in water from that well. PCN was not detected.

Metals, except for iron and manganese, and other trace constituents generally are not a water-quality problem. However, ground water and surface water in an area in Chester Valley contains elevated concentrations of boron and lithium. The boron and lithium that originate from processing wastes are moving through the ground-water system, and are being discharged to Valley Creek approximately 1.5 miles northeast of the processing plant. Concentrations of boron and lithium are as high as 20,000 µg/L and 13,000 µg/L, respectively, in ground water. Concentrations of boron and lithium as high as 130 µg/L and 800 µg/L, respectively, were found in Valley Creek. The concentration of lithium in surface water was inversely related to flow, and concentrations of boron and lithium were directly related to each other.

Forty-four wells sampled in 1949-76 were sampled again in 1982-83 to determine if long-term changes in water chemistry had occurred. Six wells were sampled monthly for 12-13 months for selected constituents to determine short-term fluctuations. Median long-term changes in pH, total dissolved solids, nitrate, and sulfate were less than median short-term fluctuations.

Median long-term increases in sodium and chloride concentrations were greater than median short-term fluctuations. Changes in sodium and chloride concentrations were evaluated based on whether a well was located in a sewered or unsewered area and on land use. A greater increase in the concentration of both constituents occurred for wells in sewered areas, which generally have a higher density of population and roads than unsewered areas. Greater increases in the concentration of both constituents occurred in commercial areas, where the area of paved surfaces is generally greater than in residential or agricultural areas. The increase in sodium correlated well with the increase in chloride. The source of these constituents is probably deicing salt.

Concentrations of chloride as high as 2,100 mg/L were found in ground water at a former highway deicing salt storage site. Concentrations of chloride in wells downgradient from the Pennsylvania Turnpike in carbonate rocks were as high as 350 mg/L, probably as a result of using deicing salt.

One of the greatest effects of human activity on the surface-water system has been the accumulation of organic compounds, particularly PCB and pesticides, in stream-bottom material. PCB, DDE, and dieldrin were found in bottom material from all eight streams sampled.

Land-use changes in 10 selected subbasins were quantified and related to stream benthic-invertebrate diversity index. A comparison of sites with land use changes of 0, 10.5, 23, and 37.3 percent from undeveloped and agricultural to residential and commercial showed an increasing diversity index at all sites from 1970-80. The subbasins that had greater changes in land use had a greater increase in diversity index. This may be due to: (1) the banning of certain pesticides such as DDT, (2) a decreasing use of pesticides in basins with a greater change from agricultural to residential, or (3) burial or flushing of older pesticide-contaminated sediment by increased storm runoff and peak flows caused by urbanization.

REFERENCES CITED

Bascom, Florence, Clark, W. B., Darton, N. H., Kummel, H. B., Salsbury, R. D., Miller, B. L., and Knapp, G. M., 1909, Description of the Philadelphia district (Pennsylvania-New Jersey-Delaware): U.S. Geological Survey Geological Atlas, Folio 162, 24 p.

Bascom, Florence, and Stose, G. W., 1932, Description of the Coatesville and West Chester quadrangles (Pennsylvania and Delaware): U.S. Geological Survey Geological Atlas, Folio 223, 15 p.

_____1938, Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania: U.S. Geological Survey Bulletin 891, 145 p.

Berg, T. M., and Dodge, C. M., 1981, Atlas of preliminary geologic quadrangle maps of Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Map 61, 636 p.

Berg, T. M., McInerney, M. K., Way, J. H., and MacLachlan, D. B., 1986, Stratigraphic correlation chart of Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., General Geology Report 75.

Biesecker, J. E., Lescinsky, J. B., and Wood, C. R., 1968, Water resources of the Schuylkill River basin: Pennsylvania Department of Forests and Waters Water Resources Bulletin 3, 198 p.

Brillouin, L., 1962, Science and information theory (2d ed.): New York, Academic Press, 347 p.

Chester County Planning Commission, 1973, Chester County Geology: West Chester, Pennsylvania, 95 p.

_____1982a, Eastern Chester County Region Water Resources Inventory Update (1980): West Chester, Pennsylvania, 123 p.

_____1982b, Population density 1980, Chester County, Pennsylvania: West Chester, Pennsylvania, Data Series 80, Map 2-7.

_____1983, Census highlights: West Chester, Pennsylvania, Planning Bulletin No. 11, 14 p.

_____1985, Community facilities inventory, Chester County, Pennsylvania, Volume 1, Sewer facilities: West Chester, Pennsylvania, 253 p.

Council on Environmental Quality, 1981, Contamination of ground water by toxic organic chemicals: Washington, U.S. Government Printing Office, 84 p.

Crawford, M. L., and Crawford, W. A., 1980, Metamorphic and tectonic history of the Pennsylvania piedmont: Journal of the Geological Society of London, V. 137, p. 311-320.

Delaware Valley Regional Planning Commission, 1984, Land use in the Delaware Valley 1970 and 1980, municipal data in 12 categories: Philadelphia, 25 p.

Flecher, W. W., 1974, The pest war: New York, John Wiley and Sons, 218 p.

Greenman, D. W., 1955, Ground water resources of Bucks County, Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resources Report 11, 67 p.

Hall, G. M., 1934, Ground water in southeastern Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resources Report 2, 255 p.

Hartwig, N. L., Gesell, S. G., and Dum, S. A., 1980, Pesticide use survey for agronomic crops in Pennsylvania: State College, Pennsylvania State University, 36 p.

Hem, J. D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 264 p.

Hirsch, R. M., Slack, J. R., and Smith, R. A., 1982, Techniques of trend analysis for monthly water-quality data: Water Resources Research, v. 18, no. 1, p. 107-121.

Lietman, P. L., Ward, J. R., and Behrendt, T. E., 1983, Effects of specific land uses on non-point sources of suspended sediment, nutrients, and herbicides--Pequea Creek Basin, Pennsylvania 1979-80: U.S. Geological Survey Water-Resources Investigations Report 83-4113, 88 p.

Lium, B. W., 1976, Limnological data for the major streams in Chester County, Pennsylvania: U.S. Geological Survey Open-File Report, 219 p.

_____1977, Limnological studies of the major streams in Chester County, Pennsylvania: U.S. Geological Survey Open-File Report 77-462, 37 p.

Longwill, S. W., and Wood, C. R., 1965, Ground-water resources of the Brunswick Formation in Montgomery and Berks Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resources Report 22, 59 p.

Mahan, I., and Mahan, E., 1977, Mercury retention in untreated water samples in the parts-per billion level: Analytical Chemistry, V. 49, p. 662-664.

McGreevy, L. J., and Sloto, R. A., 1976, Selected hydrologic data, Chester County, Pennsylvania: U.S. Geological Survey Open-File Report, 138 p.

_____1977, Ground-water resources of Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 77-67, 76 p.

_____1980, Development of a digital model of ground-water flow in deeply weathered crystalline rock, Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 80-2, 42 p.

Miller, R. A., Troxell, John, and Leopold, L. B., 1971, Hydrology of two small river basins in Pennsylvania before urbanization: U.S. Geological Survey Professional Paper 701-A, 57 p.

Moore, C. R., 1987, Determination of benthic-invertebrate indices and water-quality trends of selected streams in Chester County, Pennsylvania 1969-80: U.S. Geological Survey Water-Resources Investigations Report 85-4177, 62 p.

Moorshead-Siddiqui and Associates, 1982, An investigation of water supply alternatives for Devault and Cedar Hollow, Chester County, Pennsylvania: West Chester, Pennsylvania, Earth Data Incorporated.

National Oceanic and Atmospheric Administration, 1982, Monthly normals of temperature, precipitation, and heating and cooling degree days, 1951-80, Pennsylvania: Climatography of the United States No. 81, National Climatic Center, Asheville, North Carolina.

Newton, J. G., 1976, Early detection and correction of sinkhole problems in Alabama, with a preliminary evaluation of remote sensing applications: Alabama Highway Department, Bureau of Research and Development Research Report No. HPR-76, 83 p.

Newton, J. G., and Hyde, L. W., 1971, Sinkhole problem in and near Roberts Industrial Subdivision, Birmingham, Alabama--a reconnaissance: Alabama Geological Survey Circular 68, 42 p.

O'Brien, R. D., 1967, Insecticides, action and metabolism: New York, Academy Press, 332 p.

Office of the Federal Register, 1983, Code of Federal regulations, protection of environment: Washington, U.S. Government Printing Office, v. 40.

Parker, G. C., Hely, A. G., Keighton, W. B., Olmsted, F. H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p.

Parsons, F., Wood, P. R., and DeMarco, J., 1984, Transformation of tetrachloroethene in microcoms and ground water: Journal American Water Works Association, v. 56, no. 2, p. 56-59.

Peters, N. E., Schroeder, R. A., and Troutman, D. E., 1982, Temporal trends in the acidicy of precipitation and surface waters of New York: U.S. Geological Survey Water Supply Paper 2188, 35 p.

Petura, J. C., 1980, TCE in ground water--a problem assessment: The Weston Way, v. 6, no. 2.

Poth, C. W., 1968, Hydrology of the metamorphic and igneous rocks of central Chester County, Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resources Report 25, 84 p.

Reith, J. G., Brinton, E. G., and Stern, J. R., 1978, Water Resources Inventory Study, Vol. 1, Delaware subbasin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 97 p.

_____1979, Water resources inventory study, Vol. 2, Schuylkill subbasin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 115 p.

Rima, D. R., Meisler, Harold, and Longwill, S. M., 1962, Geology and hydrology of the Stockton Formation in southeastern Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resources Report 14, 111 p.

Sen, P. K., 1968, Estimates of the regression coefficient based on Kendall's tau: Journal American Statisticians Association, v. 63, p. 1379-1389.

Sloto, R. A., and Davis, D. K., 1982, Effect of urbanization on the water resources of Warminster Township, Bucks County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 82-4020, 72 p.

Tabak, H. H., Quave, S. A., Mashni, C. I., and Barth, E. F., 1981, Biodegradability studies with organic priority pollutant compounds: Journal Water Pollution Control Federation, v. 53, no. 10, p. 1503-1518.

Tetrault, R. C., and Wuest, P. J., 1979, Pennsylvania grower's guide to mushroom pest control: University Park, Cooperative Extension Service, Pennsylvania State University.

Theil, H., 1950, A rank-invariant method of linear and polynomial regression analysis: Akademie Nederlandse Van Wetenschappen Proceedings, v. 53, p. 386-392, p. 521-525, and p. 1397-1412.

U.S. Environmental Protection Agency, 1977, National secondary drinking water regulations: Federal Register, March 31, 1977, v. 42, no. 62, Part 143, p. 17145-17147.

_____1980, Water quality criteria documents; availability: Federal Register, November 28, 1980, p. 79318-79379.

U.S. Geological Survey, 1973-84, Water resources data for Pennsylvania Water years 1973-84, Volume 1, Delaware River basin: U.S. Geological Survey water data reports (published annually).

Windholz, Martha, Budavari, Susan, Stroumtses, L. Y., and Fertig, M. N., editors, 1976, The Merck Index: Ninth edition, Rahway, N. J., Merck and Company, Incorporated.

Wood, C. R., 1980, Ground-water resources of The Gettysburg and Hammer Creek Formations, Southeastern Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resources Report 49, 87 p.

Table 27.--Valley Creek streamflow measurements, October 11-18, 1984
Measurement sites are shown on figure 15

[A dash indicates no data; ft^3/s, cubic feet per second]

Valley Creek from headwaters to Mill Lane, October 11, 1984

Site number	Stream	Location	Discharge (ft^3/s)				
			Tributary	Main stream	Gain or loss in tributary and/or measurement error	Gain or loss in Valley Creek and/or measurement error	Total gain or loss in Valley Creek and/or measurement error
1	Tributary to Valley Creek	at State Route 401	0.09	----	-----	-----	-----
2	Tributary to Valley Creek	at trailer park	.12	----	+0.3	-----	-----
3	Tributary to Valley Creek	at State Route 401	Dry	----	- .12	-----	-----
4	Tributary to Valley Creek	at State Route 401	.16	----	+ .16	-----	-----
5	Tributary to Valley Creek	at State Route 401	.22	----	+ .06	-----	-----
8	Valley Creek	30 feet above railroad bridge	----	0.07	-----	-----	-----
9	Valley Creek	below bridge on Phoenixville Pike	----	.20	-----	+0.13	+0.13
10	Valley Creek	at Swedesford Road	----	.23	-----	+ .03	+ .16
11	Valley Creek	below U.S. Route 202	----	Dry	-----	- .23	- .23
12	Tributary to Valley Creek	above Immaculata College sewage treatment plant	.01	----	-----	-----	-----
13	Tributary to Valley Creek	below Immaculata College sewage treatment plant	.17	----	+ .16	-----	-----
14	Tributary to Valley Creek	20 feet below U.S. Route 30	.08	----	- .08	-----	-----
15	Tributary to Valley Creek	at Swedesford Road	.70	----	+ .62	-----	
16	Valley Creek	at Church Road	----	.89	-----	+ .27	+ .89
17	Valley Creek	at State Route 401	----	.87	-----	- .02	+ .87
18	Valley Creek	at Mill Lane	----	2.93	-----	+2.06	+2.93

Table 27.--Valley Creek streamflow measurements, October 11-18, 1984--Continued

[A dash indicates no data; ft^3/s, cubic feet per second]

Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary and/or measurement error	Gain or loss in Valley Creek and/or measurement error	Total gain or loss in Valley Creek and/or measurement error
Valley Creek from Mill Lane to Creek Road, October 12, 1984							
5	Tributary to Valley Creek	at State Route 401	0.21	----	+0.07	-----	-----
6	Tributary to Valley Creek	650 feet west of Moores Road	.28	----	-----	-----	-----
7	Tibutary to Valley Creek	at Moores Road	.32	----	+ .04	-----	-----
18	Valley Creek	at Mill Lane	----	3.07	-----	-----	-----
19	Tributary to Valley Creek	30 feet above railroad bridge	.12	----	-----	-----	-----
20	Tributary to Valley Creek	50 feet below U.S. Route 30	.25	----	+ .13	-----	-----
21	Tributary to Valley Creek	at Swedesford Road	.40	----	+ .15	-----	-----
22	Valley Creek	above U.S. Route 202	----	2.88	-----	-0.19	-0.19
23	Valley Creek	at State Route 29	----	4.82	-----	+1.94	+1.75
24	Tributary to Valley Creek	50 feet above confluence with Valley Creek	.30	----	-----	-----	-----
25	Valley Creek	at Church Road	----	5.19	-----	+ .37	+2.12

Table 27.--Valley Creek streamflow measurements, October 11-18, 1984--Continued

[A dash indicates no data; ft^3/s, cubic feet per second]

Valley Creek from Church Road to Mill Road, October 16, 1984

Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary and/or measurement error	Gain or loss in Valley Creek and/or measurement error	Total gain or loss in Valley Creek and/or measurement error
25	Valley Creek	at Church Road	----	5.24	-----	-----	-----
26	Cedar Hollow Quarry discharge	100 feet below discharge point	8.21	----	-----	-----	-----
27	Tributary to Valley Creek	above confluence with Valley Creek	8.39	----	+0.18	-----	-----
28	Valley Creek	1000 feet east of railroad bridge	----	14.3	-----	+9.08	+9.08
29	Tributary to Valley Creek	before confluence with Valley Creek	0.37	----	-----	-----	-----
30	Valley Creek	at North Valley Road	----	12.6	-----	-1.68	+7.40
31	Tributary to Valley Creek	at Yellow Springs Rosd	.04	----	-----	-----	-----
32	Tributary to Valley Creek	before confluence with Valley Creek	.12	----	+ .08	-----	-----
33	Valley Creek	at Leboutillier Road	----	13.9	-----	+1.21	+8.61
34	Tributary to Valley Creek	at Leboutillier Road	Dry	----	-----	-----	-----
35	Valley Creek	at Mill Road	----	12.6	-----	-1.25	+7.36

Table 27.--Valley Creek streamflow measurements, October 11-18, 1984--Continued

[A dash indicates no data; ft^3/s, cubic feet per second]

Little Valley Creek, October 16, 1984

Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary and/or measurement error	Gain or loss in Little Valley Creek and/or measurement error	Total gain or loss in Little Valley Creek and/or measurement error
36	Little Valley Creek	500 feet north of Amtrak railroad	----	0.11	-----	-----	-----
37	Little Valley Creek	300 feet north of U.S. Route 30	----	.31	-----	+0.20	+0.20
38	Tributary to Little Valley Creek	at Lantern Road	0.16	-----	-----	-----	-----
39	Tributary to Little Valley Creek	at U.S. Route 30 and State Route 29	.39	-----	+0.23	-----	-----
40	Tributary to Little Valley Creek	at State Route 29	----	.79	-----	+ .48	+ .68
41	Tributary to Little Valley Creek	at State Route 30	.09	-----	-----	-----	-----
42	Tributary to Little Valley Creek.	below Conrail railroad bridge	.33	-----	+ .24	-----	-----
43	Little Valley Creek	at Church Road	----	1.52	-----	+ .73	+1.41
44	Tributary to Little Valley	above Jacqueline and North Cedar Hollow Road	.04	-----	-----	-----	-----
45	Tributary to Little Valley Creek	below Hawthorne Place	Dry	-----	- .04	-----	-----
46	Tributary to Little Valley Creek	below railroad bridge	Dry	-----	-----	-----	-----
47	Tributary to Little Valley Creek	35 feet above railroad bridge	.30	-----	-----	-----	-----
48	Little Valley Creek	at North Valley Road	----	2.71	-----	+1.19	+2.60
49	Tributary to Little Valley Creek	at Hawthorne Place	Dry	-----	-----	-----	-----
50	Tributary to Little Valley Creek	at Conrail railroad bridge	Dry	-----	-----	-----	-----

Table 27.--Valley Creek streamflow measurements, October 11-18, 1984--Continued

[A dash indicates no data; ft^3/s, cubic feet per second]

Little Valley Creek, October 16, 1984

Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary and/or measurement error	Gain or loss in Little Valley Creek and/or measurement error	Total gain or loss in Little Valley Creek and/or measurement error
51	Tributary to Little Valley Creek	at North Valley Road	Dry	-----	-----	-----	-----
52	Tributary to Little Valley Creek	100 feet above railroad bridge	0.17	-----	-----	-----	-----
53	Tributary to Little Valley Creek	100 feet below railroad bridge	.25	-----	+0.08	-----	-----
54	Tributary to Little Valley Creek	50 feet above railroad culvert	.38	-----	+ .13	-----	-----
55	Little Valley Creek	above Swedesford Road	----	3.24	-----	+0.53	+3.13
56	Tributary to Little Valley Creek	above Penn Central railroad	.52	-----	-----	-----	-----
57	Tributary to Little Valley Creek	at Howellville	.46	-----	- .06	-----	-----
58	Tributary to Little Valley Creek	at Swedesford and Mill Roads	1.23	-----	+ .77	-----	-----
59	Little Valley	at Mill Road	----	3.30	-----	+ .06	+3.19

Table 27.--Valley Creek streamflow measurements, October 11-18, 1984--Continued

[A dash indicates no data; ft^3/s, cubic feet per second]

Site number	Stream	Location	Discharge (ft^3/s): Tributary	Main stream	Gain or loss in tributary and/or measurement error	Gain or loss in Valley Creek and/or measurement error	Total gain or loss in Valley Creek and/or measurement error
			Valley Creek at Mill Road to Gaging Station, October 17, 1984				
34	Valley Creek	at Mill Road	----	13.0	-----	-----	-----
59	Little Valley Creek	at Mill Road	4.52	----	-----	-----	-----
60	Tributary to Valley Creek	at Yellow Springs Road	0.05	----	-----	-----	-----
62	Valley Creek	at gaging station	----	26.2a/	-----	-----	+8.68
			Valley Creek from Wilson Road to Schuylkill River, October 18, 1984				
63	Tributary to Valley Creek	at Fairfax Road	.05	-----	-----	-----	-----
64	Tributary to Valley Creek	at Wilson Road	Dry	-----	-0.05	-----	-----
65	Valley Creek	600 feet east of Wilson Road	----	20.1	-----	-----	-----
66	Valley Creek	above covered bridge	----	19.3	-----	-0.66	-0.66
67	Valley Creek	750 feet below covered bridge	----	21.2	-----	+1.75	+1.09
68	Tributary to Valley Creek	above confluence with Valley Creek	.13	-----	-----	-----	-----
69	Valley Creek	above confluence with Schuylkill River	----	22.8	-----	+1.66	+2.75

a/ Discharge from stage and rating table

page 102 follows

Table 28.-- Chemical analyses of volatile organic compounds
[Results in micrograms per liter; ND means not detected; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TOTAL VOLATILE ORGANIC COMPOUNDS	BENZENE TOTAL	BROMOFORM TOTAL	CARBON-TETRA-CHLORIDE TOTAL	CHLORO-BENZENE TOTAL	CHLORO-DI-BROMO-METHANE TOTAL	CHLORO-ETHANE TOTAL	2-CHLORO-ETHYL-VINYL-ETHER TOTAL	CHLORO-FORM TOTAL
CH-151	82-07-19	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
154	82-07-19	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
155	83-06-07	ND	<1.0	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
164	83-06-13	ND	<1.0	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
165	83-06-13	ND	<1.0	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
206	83-05-17	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
207	84-08-27	15	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
	85-06-18	12	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
251	81-08-19	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
293	81-08-19	6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
1585	81-06-10	290	.00	.00	.00	.00	.00	.00	.00	0
1969	83-06-21	130	3.0	<1.0	<1.0	2.0	<1.0	—	<1.0	49
1973	84-08-31	ND	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
1976	84-06-04	ND	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
1978	84-08-30	ND	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
1983	80-06-04	ND	.00	.00	.00	.00	.00	.00	.00	0
2046	81-05-29	1150	20	.00	.00	.00	.00	.00	.00	0
	83-06-27	1380	16	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
2089	84-06-04	300	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
2136	81-08-19	200	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-06-22	223	3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2148	84-06-01	ND	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
2149	83-06-09	ND	<1.0	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
2197	83-06-01	ND	<1.0	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
2198	83-06-01	ND	<1.0	<1.0	<1.0	<1.0	<1.0	—	<1.0	<1
2199	84-08-27	ND	<3.0	<3.0	<3.0	<3.0	<3.0	—	—	<3
2402	80-06-03	ND	.00	.00	.00	.00	.00	.00	.00	0
2405	80-06-04	ND	.00	.00	.00	.00	.00	.00	.00	0
2411	80-08-26	19	.00	.00	.00	.00	.00	.00	.00	0
	81-08-18	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-07-22	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2425	81-05-28	60	.00	.00	.00	.00	.00	.00	.00	0
2426	81-05-28	ND	.00	.00	.00	.00	.00	.00	.00	0
	82-10-04	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2427	81-05-28	ND	.00	.00	.00	.00	.00	.00	.00	0
2432	81-06-03	ND	.00	.00	.00	.00	.00	.00	.00	0
2434	81-06-10	80	.00	.00	.00	.00	.00	.00	.00	0
2435	81-06-10	1290	.00	.00	.00	.00	.00	.00	.00	0
2436	81-06-10	ND	.00	.00	.00	.00	.00	.00	.00	0
2438	81-06-11	22	.00	.00	.00	.00	.00	.00	.00	0
2441	81-08-17	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2443	81-10-21	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-08-03	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2444	81-08-18	180	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-08-03	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2445	81-08-18	1210	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2447	81-08-19	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-07-08	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2448	81-08-21	30	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-07-19	26	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2449	81-08-21	310	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	82-06-23	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2464	82-06-17	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2465	82-06-17	8	8.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2466	82-06-21	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1

1,2-TRANSDICHLORO-ETHYL-ENE TOTAL	DI-CHLORO-BROMO-METHANE TOTAL	DI-CHLORO-DI-FLUORO-METHANE TOTAL	1,1-DI-CHLORO-ETHANE TOTAL	1,2-DI-CHLORO-ETHANE TOTAL	1,1-DI-CHLORO-ETHYL-ENE TOTAL	1,2-DI-CHLORO-PROPANE TOTAL	1,3-DI-CHLORO-PROPENE TOTAL	ETHYL-BENZENE TOTAL	DATE OF SAMPLE	WELL NUMBER
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-07-19	CH-151
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-07-19	154
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-07	155
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-13	164
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-13	165
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-05-17	206
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-08-27	207
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-06-18	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-19	251
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-19	293
30	.00	.00	.00	.00	.00	.00	.00	.00	81-06-10	1585
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-21	1969
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-08-31	1973
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-06-04	1976
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-08-30	1978
.00	.00	.00	.00	.00	.00	.00	.00	.00	80-06-04	1983
500	.00	.00	.00	.00	.00	.00	.00	.00	81-05-29	2046
520	<1.0	—	62	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-27	
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-06-04	2089
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-19	2136
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-22	
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-06-01	2148
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-09	2149
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-01	2197
<1.0	<1.0	—	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-01	2198
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	—	<3.0	84-08-27	2199
.00	.00	.00	.00	.00	.00	.00	.00	.00	80-06-03	2402
.00	.00	.00	.00	.00	.00	.00	.00	.00	80-06-04	2405
9.0	.00	.00	.00	.00	.00	.00	.00	.00	80-08-26	2411
20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-18	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-07-22	
.00	.00	.00	.00	.00	.00	.00	.00	.00	81-05-28	2425
.00	.00	.00	.00	.00	.00	.00	.00	.00	81-05-28	2426
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-10-04	
.00	.00	.00	.00	.00	.00	.00	.00	.00	81-05-28	2427
.00	.00	.00	.00	.00	.00	.00	.00	.00	81-06-03	2432
20	.00	.00	.00	.00	.00	.00	.00	.00	81-06-10	2434
8.0	.00	.00	.00	.00	.00	.00	.00	.00	81-06-10	2435
.00	.00	.00	.00	.00	.00	.00	.00	.00	81-06-10	2436
.00	.00	.00	.00	.00	.00	.00	.00	.00	81-06-11	2438
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-17	2441
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-10-21	2443
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-08-03	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-18	2444
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-08-03	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-18	2445
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-19	2447
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-07-08	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	81-08-21	2448
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-07-19	
50	<1.0	<1.0	<1.0	20	<1.0	<1.0	<1.0	<1.0	81-08-21	2449
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-23	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-17	2464
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-17	2465
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-21	2466

Table 28.-- Chemical analyses of volatile organic compounds--Continued
[Results in micrograms per liter; ND means not detected; a daah indicates no data]

WELL NUMBER	DATE OF SAMPLE	METHYL-BROMIDE TOTAL	METHYL-ENE CHLO-RIDE TOTAL	1,1,2,2 TETRA-CHLORO-ETHANE TOTAL	TETRA-CHLORO-ETHYL-ENE TOTAL	TOLUENE TOTAL	1,1,1-TRI-CHLORO-ETHANE TOTAL
CH-151	82-07-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
154	82-07-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
155	83-06-07	—	<1.0	<1.0	<1.0	<1.0	<1.0
164	83-06-13	—	<1.0	<1.0	<1.0	<1.0	<1.0
165	83-06-13	—	<1.0	<1.0	<1.0	<1.0	<1.0
206	83-05-17	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
207	84-08-27	—	<3.0	<3.0	7.0	<3.0	<3.0
	85-06-18	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
251	81-08-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
293	81-08-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1585	81-06-10	.00	.00	.00	.00	.00	.00
1969	83-06-21	—	<1.0	<1.0	<1.0	<1.0	76
1973	84-08-31	—	<3.0	<3.0	<3.0	<3.0	<3.0
1976	84-06-04	—	32	<3.0	<3.0	<3.0	<3.0
1978	84-08-30	—	<3.0	<3.0	<3.0	<3.0	<3.0
1983	80-06-04	.00	.00	.00	.00	.00	.00
2046	81-05-29	.00	.00	.00	30	.00	60
	83-06-27	—	<1.0	<1.0	10	4.0	69
2089	84-06-04	—	300	<3.0	<3.0	<3.0	<3.0
2136	81-08-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	82-06-22	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2148	84-06-01	—	<3.0	<3.0	<3.0	<3.0	<3.0
2149	83-06-09	—	<1.0	<1.0	<1.0	<1.0	<1.0
2197	83-06-01	—	<1.0	<1.0	<1.0	<1.0	<1.0
2198	83-06-01	—	<1.0	<1.0	<1.0	<1.0	<1.0
2199	84-08-27	—	<3.0	<3.0	<3.0	<3.0	<3.0
2402	80-06-03	.00	.00	.00	.00	.00	.00
2405	80-06-04	.00	.00	.00	.00	.00	.00
2411	80-08-26	.00	.00	.00	.00	2.0	.00
	81-08-18	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	82-07-22	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2425	81-05-28	.00	.00	.00	20	.00	.00
2426	81-05-28	.00	.00	.00	.00	.00	.00
	82-10-04	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2427	81-05-28	.00	.00	.00	.00	.00	.00
2432	81-06-03	.00	.00	.00	.00	.00	.00
2434	81-06-10	.00	.00	.00	.00	.00	60
2435	81-06-10	.00	.00	.00	.00	.00	.00
2436	81-06-10	.00	.00	.00	.00	.00	.00
2438	81-06-11	.00	.00	.00	.00	.00	20
2441	81-08-17	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2443	81-10-21	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	82-08-03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2444	81-08-18	<1.0	<1.0	<1.0	<1.0	<1.0	180
	82-08-03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2445	81-08-18	<1.0	<1.0	<1.0	250	<1.0	520
2447	81-08-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	82-07-08	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2448	81-08-21	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	82-07-19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2449	81-08-21	<1.0	200	<1.0	<1.0	20	<1.0
	82-06-23	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2464	82-06-17	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2465	82-06-17	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2466	82-06-21	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

1,1,2-TRI-CHLORO-ETHANE TOTAL	TRI-CHLORO-ETHYL-ENE TOTAL	TRI-CHLORO-FLOURO-METHANE TOTAL	VINYL CHLO-RIDE TOTAL	DATE OF SAMPLE	WELL NUMBER
<1.0	<1.0	<1.0	<1.0	82-07-19	CH-151
<1.0	<1.0	<1.0	<1.0	82-07-19	154
<1.0	<1.0	—	—	83-06-07	155
<1.0	<1.0	—	—	83-06-13	164
<1.0	<1.0	—	—	83-06-13	165
<1.0	<1.0	<1.0	<1.0	83-05-17	206
<3.0	18.0	<3.0	—	84-08-27	207
<3.0	12.0	<3.0	<3.0	85-06-18	
<1.0	20.0	<1.0	<1.0	81-08-19	251
<1.0	6.0	<1.0	<1.0	81-08-19	293
.00	260	.00	.00	81-06-10	1585
<1.0	<1.0	—	—	83-06-21	1969
<3.0	<3.0	<3.0	—	84-08-31	1973
<3.0	<3.0	<3.0	—	84-06-04	1976
<3.0	<3.0	<3.0	—	84-08-30	1978
.00	.0	.00	.00	80-06-04	1983
.00	540	.00	.00	81-05-29	2046
<1.0	700	—	—	83-06-27	
<3.0	<3.0	<3.0	—	84-06-04	2089
<1.0	200	<1.0	<1.0	81-08-19	2136
<1.0	220	<1.0	<1.0	82-06-22	
<3.0	<3.0	<3.0	—	84-06-01	2148
<1.0	<1.0	—	—	83-06-09	2149
<1.0	<1.0	—	—	83-06-01	2197
<1.0	<1.0	—	—	83-06-01	2198
<3.0	<3.0	<3.0	—	84-08-27	2199
.00	.0	.00	.00	80-06-03	2402
.00	.0	.00	.00	80-06-04	2405
.00	8.0	.00	.00	80-08-26	2411
<1.0	<1.0	<1.0	<1.0	81-08-18	
<1.0	<1.0	<1.0	<1.0	82-07-22	
.00	40.0	.00	.00	81-05-28	2425
.00	.0	.00	.00	81-05-28	2426
<1.0	<1.0	<1.0	<1.0	82-10-04	
.00	.0	.00	.00	81-05-28	2427
.00	.0	.00	.00	81-06-03	2432
.00	.0	.00	.00	81-06-10	2434
.00	1280	.00	.00	81-06-10	2435
.00	.0	.00	.00	81-06-10	2436
.00	20.0	.00	.00	81-06-11	2438
<1.0	<1.0	<1.0	<1.0	81-08-17	2441
<1.0	<1.0	<1.0	<1.0	81-10-21	2443
<1.0	<1.0	<1.0	<1.0	82-08-03	
<1.0	<1.0	<1.0	<1.0	81-08-18	2444
<1.0	<1.0	<1.0	<1.0	82-08-03	
<1.0	440	<1.0	<1.0	81-08-18	2445
<1.0	<1.0	<1.0	<1.0	81-08-19	2447
<1.0	<1.0	<1.0	<1.0	82-07-08	
<1.0	30.0	<1.0	<1.0	81-08-21	2448
<1.0	26.0	<1.0	<1.0	82-07-19	
<1.0	<1.0	<1.0	<1.0	81-08-21	2449
<1.0	<1.0	<1.0	<1.0	82-06-23	
<1.0	<1.0	<1.0	<1.0	82-06-17	2464
<1.0	<1.0	<1.0	<1.0	82-06-17	2465
<1.0	<1.0	<1.0	<1.0	82-06-21	2466

Table 28.-- Chemical analyses of volatile organic compounds--Continued
[Results in micrograms per liter; ND means not detected; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TOTAL VOLATILE ORGANIC COMPOUNDS	BENZENE TOTAL	BROM-OFORM TOTAL	CARBON-TETRA-CHLO-RIDE TOTAL	CHLORO-BENZENE TOTAL	CHLORO-DI-BROMO-METHANE TOTAL	CHLORO-ETHANE TOTAL	2-CHLORO-ETHYL-VINYL-ETHER TOTAL	CHLORO-FORM TOTAL
CH-2468	82-06-22	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2469	82-09-02	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	84-06-28	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2470	82-06-23	ND	3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2471	82-06-24	ND	3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2478	82-08-03	313	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
	83-07-07	241	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0	<1
2479	82-07-22	ND	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1
2494	83-06-21	ND	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0	<1
2502	83-06-29	ND	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0	<1
2535	84-06-01	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2545	84-08-30	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2549	85-04-30	53	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
2569	85-04-30	ND	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
2606	85-04-30	78	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
2613	84-06-04	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2664	84-08-28	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2672	85-05-13	17400	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	190
2676	84-06-07	680	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2677	84-06-05	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2680	84-06-14	11	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2681	84-06-26	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2748	84-06-28	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2749	84-06-29	24	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2750	84-06-05	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2751	84-06-06	10	<3.0	10	<3.0	<3.0	<3.0	--	--	<3
2801	84-08-29	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
2802	84-08-15	ND	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
CATANACH QUARRY NORTH	85-07-05	860	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	13
CATANACH QUARRY SOUTH	85-07-05	11	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
CATANACH QUARRY DISCHARGE	85-07-05	91	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
CEDAR HOLLOW QUARRY SOUTH	85-04-29	120	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
CEDAR HOLLOW QUARRY NORTH	85-04-29	32	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
CEDAR HOLLOW QUARRY DISCHRGE	85-04-29	24	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3
TRIBUTARY TO VALLEY CREEK	84-08-24	19	<3.0	<3.0	<3.0	<3.0	<3.0	--	--	<3
	85-04-29	13	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3

1,1,2-TRI-CHLORO-ETHANE TOTAL	TRI-CHLORO-ETHYL-ENE TOTAL	TRI-CHLORO-FLOURO-METHANE TOTAL	VINYL CHLO-RIDE TOTAL	DATE OF SAMPLE	WELL NUMBER
<1.0	<1.0	<1.0	<1.0	82-06-22	CH-2468
<1.0	<1.0	<1.0	<1.0	82-09-02	2469
<3.0	<3.0	<3.0	--	84-06-28	
<1.0	<1.0	<1.0	<1.0	82-06-23	2470
<1.0	<1.0	<1.0	<1.0	82-06-24	2471
<1.0	22.0	<1.0	<1.0	82-08-03	2478
<1.0	34.0	--	--	83-07-07	
<1.0	<1.0	<1.0	<1.0	82-07-22	2479
<1.0	<1.0	--	--	83-06-21	2494
<1.0	<1.0	--	--	83-06-29	2502
<3.0	<3.0	<3.0	--	84-06-01	2535
<3.0	<3.0	<3.0	--	84-08-30	2545
<3.0	19.0	<3.0	<3.0	85-04-30	2549
<3.0	<3.0	<3.0	<3.0	85-04-30	2569
<3.0	24.0	<3.0	<3.0	85-04-30	2606
<3.0	<3.0	<3.0	--	84-06-04	2613
<3.0	<3.0	<3.0	--	84-08-28	2664
<3.0	4400	<3.0	<3.0	85-05-13	2672
<3.0	470	<3.0	--	84-06-07	2676
<3.0	<3.0	<3.0	--	84-06-05	2677
<3.0	<3.0	<3.0	--	84-06-14	2680
<3.0	<3.0	<3.0	--	84-06-26	2681
<3.0	<3.0	<3.0	--	84-06-28	2748
<3.0	<3.0	<3.0	--	84-06-29	2749
<3.0	<3.0	<3.0	--	84-06-05	2750
<3.0	<3.0	<3.0	--	84-06-06	2751
<3.0	<3.0	<3.0	--	84-08-29	2801
<3.0	<3.0	<3.0	--	84-08-15	2802
<3.0	200	<3.0	<3.0	85-07-05	CATANACH QUARRY NORTH
<3.0	11.0	<3.0	<3.0	85-07-05	CATANACH QUARRY SOUTH
<3.0	30.0	<3.0	<3.0	85-07-05	CATANACH QUARRY DISCHARGE
<3.0	98.0	<3.0	<3.0	85-04-29	CEDAR HOLLOW QUARRY SOUTH
<3.0	21.0	<3.0	<3.0	85-04-29	CEDAR HOLLOW QUARRY NORTH
<3.0	24.0	<3.0	<3.0	85-04-29	CEDAR HOLLOW QUARRY DISCHARGE
<3.0	19.0	<3.0	--	84-08-24	TRIBUTARY TO VALLEY CREEK
<3.0	13.0	<3.0	<3.0	85-04-29	

Table 28.-- Chemical analyses of volatile organic compounds--Continued
[Results in microgrsms per liter; ND means not detected; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	METHYL-BROMIDE TOTAL	METHYL-ENE CHLO-RIDE TOTAL	1,1,2,2 TETRA-CHLORO-ETHANE TOTAL	TETRA-CHLORO-ETHYL-ENE TOTAL	TOLUENE TOTAL	1,1,1-TRI-CHLORO-ETHANE TOTAL
CH-2468	82-06-22	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2469	82-09-02	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	84-06-28	--	<3.0	<3.0	<3.0	<3.0	<3.0
2470	82-06-23	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2471	82-06-24	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2478	82-08-03	<1.0	<1.0	<1.0	<1.0	<1.0	260
	83-07-07	--	<1.0	<1.0	10	<1.0	190
2479	82-07-22	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2494	83-06-21	--	<1.0	<1.0	<1.0	<1.0	<1.0
2502	83-06-29	--	<1.0	<1.0	<1.0	<1.0	<1.0
2535	84-06-01	--	<3.0	<3.0	<3.0	<3.0	<3.0
2545	84-08-30	--	<3.0	<3.0	<3.0	<3.0	<3.0
2549	85-04-30	<3.0	<3.0	<3.0	<3.0	<3.0	34
2569	85-04-30	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
2606	85-04-30	<3.0	<3.0	<3.0	5.1	<3.0	34
2613	84-06-04	--	<3.0	<3.0	<3.0	<3.0	<3.0
2664	84-08-28	--	<3.0	<3.0	<3.0	<3.0	<3.0
2672	85-05-13	<3.0	49	<3.0	1200	<3.0	5400
2676	84-06-07	--	<3.0	<3.0	<3.0	<3.0	<3.0
2677	84-06-05	--	<3.0	<3.0	<3.0	<3.0	<3.0
2680	84-06-14	--	<3.0	<3.0	<3.0	<3.0	11
2681	84-06-26	--	<3.0	<3.0	<3.0	<3.0	<3.0
2748	84-06-28	--	<3.0	<3.0	<3.0	<3.0	<3.0
2749	84-06-29	--	<3.0	<3.0	<3.0	<3.0	<3.0
2750	84-06-05	--	<3.0	<3.0	<3.0	<3.0	<3.0
2751	84-06-06	--	<3.0	<3.0	<3.0	<3.0	<3.0
2801	84-08-29	--	<3.0	<3.0	<3.0	<3.0	<3.0
2802	84-08-15	--	<3.0	<3.0	<3.0	<3.0	<3.0
CATANACH QUARRY NORTH	85-07-05	<3.0	<3.0	<3.0	25	<3.0	300
CATANACH QUARRY SOUTH	85-07-05	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
CATANACH QUARRY DISCHARGE	85-07-05	<3.0	<3.0	<3.0	<3.0	<3.0	37
CEDAR HOLLOW QUARRY SOUTH	85-04-29	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
CEDAR HOLLOW QUARRY NORTH	85-04-29	<3.0	<3.0	<3.0	<3.0	<3.0	11
CEDAR HOLLOW QUARRY DISCHARGE	85-04-29	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
TRIBUTARY TO VALLEY CREEK	84-08-24	--	<3.0	<3.0	<3.0	<3.0	<3.0
	85-04-29	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

1,2-TRANSDI CHLORO-ETHYL-ENE TOTAL	DI-CHLORO-BROMO-METHANE TOTAL	DI-CHLORO-DI-FLUORO-METHANE TOTAL	1,1-DI-CHLORO-ETHANE TOTAL	1,2-DI-CHLORO-ETHANE TOTAL	1,1-DI-CHLORO-ETHYL-ENE TOTAL	1,2-DI-CHLORO-PROPANE TOTAL	1,3-DI-CHLORO-PROPENE TOTAL	ETHYL-BENZENE TOTAL	DATE OF SAMPLE	WELL NUMBER
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-22	CH-2468
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-09-02	2469
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-28	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-23	2470
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-06-24	2471
<1.0	<1.0	<1.0	<1.0	<1.0	31	<1.0	<1.0	<1.0	82-08-03	2478
<1.0	<1.0	--	<1.0	<1.0	7.0	<1.0	<1.0	<1.0	83-07-07	
<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	82-07-22	2479
<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-21	2494
<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	83-06-29	2502
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-01	2535
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-08-30	2545
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-30	2549
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-30	2569
15	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-30	2606
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-04	2613
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-08-28	2664
560	<3.0	<3.0	39	140	5400	<3.0	<3.0	<3.0	85-05-13	2672
210	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-07	2676
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-05	2677
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-14	2680
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-26	2681
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-28	2748
24	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-29	2749
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-05	2750
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-06-06	2751
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-08-29	2801
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-08-15	2802
140	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-07-05	CATANACH QUARRY NORTH
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-07-05	CATANACH QUARRY SOUTH
24	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-07-05	CATANACH QUARRY DISCHARGE
25	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-29	CEDAR HOLLOW QUARRY SOUTH
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-29	CEDAR HOLLOW QUARRY NORTH
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-29	CEDAR HOLLOW QUARRY DISCHRGE
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	84-08-24	TRIBUTARY TO VALLEY CREEK
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	85-04-29	

Table 29.-- Chemical analyses of polychlorinated biphenyls, polychlorinated napthalenes, phenols, and organic carbon in ground water

[UG/L, micrograms per liter; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	PCB, TOTAL (UG/L)	NAPH-THA-LENES, POLY-CHLOR. TOTAL (UG/L)	PHENOLS TOTAL (UG/L)	PHENOL (C6H-5OH) TOTAL (UG/L)	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C)	CARBON, ORGANIC SUS-PENDED TOTAL (MG/L AS C)
CH-151	82-07-19	--	--	<1	--	.40	--	--
154	82-07-19	<.1	<.10	<1	--	.20	--	--
164	83-06-13	--	--	1	--	--	--	--
165	83-06-13	--	--	1	--	--	--	--
207	84-08-27	--	--	<1	--	--	--	--
251	81-08-19	<.1	<.10	<1	--	2.6	--	--
293	81-08-19	<.1	<.10	<1	--	2.3	--	--
1585	81-06-10	<.1	<.10	1	--	.10	--	--
1600	83-06-16	<.1	<.10	--	--	--	--	--
1969	83-06-21	--	--	<1	--	--	--	--
1973	84-06-14	<.1	<.10	<1	--	--	--	--
1976	84-06-04	<.1	<.10	<1	--	--	--	--
1978	83-07-13	--	--	<1	--	--	--	--
	83-09-06	<.1	<.10	--	--	--	--	--
	84-08-30	<.1	<.10	--	--	--	--	--
	84-08-30	--	--	<1	--	--	--	--
1983	80-06-04	.0	.00	0	--	2.2	--	--
2046	81-05-29	<.1	<.10	4	--	1.1	--	--
	83-06-27	--	--	<1	<1.0	--	3.3	.20
2089	84-06-04	--	--	<1	--	--	--	--
2136	81-08-19	.1	<.10	<1	--	4.4	--	--
	82-06-22	<.1	<.10	<1	--	.60	--	--
2199	84-08-27	<.1	<.10	<1	--	--	--	--
2402	80-06-03	.0	.00	0	--	.30	--	--
2405	80-06-04	.0	.00	0	--	.90	--	--
2411	80-08-26	.0	.00	0	--	3.6	--	--
	81-08-18	<.1	<.10	<1	--	3.0	--	--
	82-07-22	--	--	<1	--	1.4	--	--
2425	81-05-28	<.1	<.10	0	--	.10	--	--
2426	81-05-28	<.1	<.10	2	--	.30	--	--
	82-06-16	<.1	<.10	<1	--	--	--	--
	82-06-17	--	--	--	--	.30	--	--
2427	81-05-28	<.1	<.10	0	--	.40	--	--
2432	81-06-03	<.1	<.10	0	--	.90	--	--
2434	81-06-10	<.1	<.10	2	--	.10	--	--
2435	81-06-10	<.1	<.10	5	--	--	--	--
2436	81-06-10	<.1	<.10	4	--	.60	--	--
2438	81-06-11	<.1	<.10	2	--	.30	--	--
2441	81-08-17	<.1	<.10	<1	--	1.7	--	--
2443	81-08-18	<.1	<.10	<1	--	2.2	--	--
	82-08-03	--	--	<1	--	.40	--	--
2444	81-08-18	<.1	<.10	<1	--	.60	--	--
	82-08-03	<.1	<.10	<1	<1.0	.90	--	--
2445	81-08-18	<.1	<.10	<1	--	.60	--	--
2447	81-08-19	<.1	<.10	<1	--	.00	--	--
	82-07-08	<.1	<.10	<1	--	<.10	--	--
2448	81-08-21	<.1	<.10	<1	--	4.3	--	--
	82-07-19	--	--	7	--	1.5	--	--
2449	81-08-21	<.1	<.10	<1	--	1.0	--	--
	82-06-23	--	<1.0	1	--	.60	--	--
2463	82-06-16	--	--	--	--	.90	--	--
	82-06-17	<.1	<.10	<1	--	--	--	--
2464	82-06-17	<.1	<.10	<1	--	.20	--	--
2465	82-06-17	<.1	<.10	<1	--	2.6	--	--
2466	82-06-21	<.1	<.10	<1	--	--	--	--
2468	82-06-02	--	--	--	--	.50	--	--
	82-06-22	<.1	<.10	<1	--	--	--	--
2469	82-06-23	<.1	<.10	3	--	.40	--	--
	83-06-30	<.1	<.10	<1	<1.0	--	--	--
	84-06-28	<.1	<.10	<1	--	--	--	--
2470	82-06-23	<.1	<1.0	1	--	.30	--	--
2471	82-06-24	<.1	<.10	1	--	.30	--	--
2477	82-08-03	--	--	<1	--	.50	--	--
2478	82-08-03	<.1	<.10	<1	--	1.5	--	--
	83-07-07	--	--	<1	--	--	--	--
2479	82-07-22	<.1	<.10	<1	--	--	--	--
2494	83-06-21	--	--	<1	--	--	--	--
2499	83-06-23	<.1	<.10	<1	--	--	1.8	.40
2502	83-06-29	<.1	<.10	<1	--	--	--	--
2545	84-08-30	--	--	<1	--	--	--	--
2664	84-08-28	<.1	<.10	<1	--	--	--	--
2681	84-06-26	<.1	<.10	<1	--	--	--	--
2748	84-06-28	<.1	<.10	<1	--	--	--	--
2749	84-06-29	<.1	<.10	5	--	--	--	--
2750	84-06-05	--	--	<1	--	--	--	--
2751	84-06-06	<.1	<.10	--	--	--	--	--
2801	84-08-29	<.1	<.10	<1	<1.0	--	--	--
2802	84-08-15	--	--	<1	--	--	--	--

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Table 30.-- Chemical analyses of metals and other trace constituents in ground water
[UG/L, micrograms per liter; ND means not detected]

WELL NUMBER	DATE OF SAMPLE	ALUMINUM, DISSOLVED (UG/L AS AL)	ARSENIC DISSOLVED (UG/L AS AS)	BARIUM, DISSOLVED (UG/L AS BA)	BERYLLIUM, DISSOLVED (UG/L AS BE)	BISMUTH DISSOLVED (UG/L AS BI)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	CHROMIUM, DISSOLVED (UG/L AS CR)	COBALT, DISSOLVED (UG/L AS CO)	COPPER, DISSOLVED (UG/L AS CU)	GALLIUM DISSOLVED (UG/L AS GA)	GERMANIUM, DISSOLVED (UG/L AS GE)
CH-16	72-05-23	--	--	--	--	--	--	--	--	--	--	--	--
147	75-01-06	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-09	--	4	--	--	--	--	<1	<10	--	3	--	--
151	82-07-19	--	6	--	--	--	--	<1	<1	--	2	--	--
152	57-09-18	--	--	--	--	--	--	--	--	--	--	--	--
	57-10-24	--	--	--	--	--	--	--	--	--	--	--	--
	73-11-20	--	--	--	--	--	--	--	--	--	--	--	--
	73-11-20	0	--	66	<2.0	<0	30	<3	<3	<6	<2	<3	<6
	74-05-29	--	--	--	--	--	--	--	--	--	--	--	--
	74-05-29	40	--	68	<2.0	<0	20	<3	<3	<5	2	<3	<5
	74-10-17	--	--	--	--	--	--	--	--	--	--	--	--
	74-10-17	0	--	71	<10	<0	30	<6	<2	<2	<2	0	<2
	75-05-28	30	6	<100	--	--	30	ND	<20	ND	ND	--	--
	75-05-28	0	--	65	<10	<0	20	<4	<2	<2	<2	<1	<2
	75-12-09	10	6	<100	--	--	<20	<2	<20	2	<20	--	--
153	56-06-07	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-07	--	6	--	--	--	--	<1	10	--	1	--	--
154	56-06-07	--	--	--	--	--	--	--	--	--	--	--	--
	82-07-19	--	8	--	--	--	--	<1	<1	--	8	--	--
155	56-06-07	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-07	--	2	--	--	--	--	<1	10	--	17	--	--
157	56-06-07	--	--	--	--	--	--	--	--	--	--	--	--
164	83-06-13	--	6	--	--	--	--	<1	<10	--	11	--	--
165	83-06-13	--	5	--	--	--	--	<1	10	--	11	--	--
181	63-04-12	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-09	--	6	--	--	--	--	<1	30	--	3	--	--
182	49-04-20	--	--	--	--	--	--	--	--	--	--	--	--
	83-09-07	--	3	--	--	--	--	1	10	--	67	--	--
201	64-05-22	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-14	--	2	--	--	--	--	<1	20	--	9	--	--
202	64-05-22	--	--	--	--	--	--	--	--	--	--	--	--
	83-05-09	--	1	--	--	--	--	<1	1	--	19	--	--
205	64-05-20	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-06	--	1	--	--	--	--	<1	10	--	23	--	--
206	64-05-20	--	--	--	--	--	--	--	--	--	--	--	--
	83-05-17	--	5	--	--	--	--	<1	<10	--	11	--	--
207	84-08-27	20	<1	33	--	--	200	<1	10	--	4	--	--
	85-06-18	<10	<1	<100	--	--	--	<1	30	--	2	--	--
251	81-08-19	--	1	--	--	--	--	1	<1	--	--	--	--
252	65-04-08	--	--	--	--	--	--	--	--	--	--	--	--
	83-05-18	--	1	--	--	--	--	<1	10	--	20	--	--
253	65-04-08	--	--	--	--	--	--	--	--	--	--	--	--
	83-05-10	--	1	--	--	--	--	<1	<1	--	1	--	--
257	65-04-08	--	--	--	--	--	--	--	--	--	--	--	--
293	81-08-19	--	1	--	--	--	--	1	<1	--	--	--	--
619	63-05-15	--	--	--	--	--	--	--	--	--	--	--	--
	83-05-25	--	<1	--	--	--	--	<1	10	--	110	--	--
634	63-05-22	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-17	--	<1	--	--	--	--	1	<10	--	18	--	--
644	73-06-13	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-14	--	1	--	--	--	--	<1	10	--	11	--	--
1083	66-09-07	--	--	--	--	--	--	--	--	--	--	--	--
1084	66-09-07	--	--	--	--	--	--	--	--	--	--	--	--
1107	61-10-24	--	--	--	--	--	--	--	--	--	--	--	--
	67-02-14	--	--	--	--	--	--	--	--	--	--	--	--

IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	LITHIUM DIS- SOLVED (UG/L AS LI)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)	MERCURY DIS- SOLVED (UG/L AS HG)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO)	NICKEL, DIS- SOLVED (UG/L AS NI)	SELE- NIUM, DIS- SOLVED (UG/L AS SE)	SILVER, DIS- SOLVED (UG/L AS AG)	STRON- TIUM, DIS- SOLVED (UG/L AS SR)	TIN DIS- SOLVED (UG/L AS SN) (A.A.S. DIRECT)	TI- TANIUM, DIS- SOLVED (UG/L AS TI)	VANA- DIUM, DIS- SOLVED (UG/L AS V)	ZINC, DIS- SOLVED (UG/L AS ZN)	ZIR- CONIUM, DIS- SOLVED (UG/L AS ZR)
0	--	--	0	--	--	--	--	--	--	--	--	--	--	--
110	--	--	<10	--	--	--	--	--	--	--	--	--	--	--
5	<1	--	2	<.1	--	1	--	--	--	--	--	--	20	--
18	2	--	5	<.1	--	2	4	--	--	--	--	--	<4	--
100	--	--	50	--	--	--	--	--	--	--	--	--	--	--
110	--	--	140	--	--	--	--	--	--	--	--	--	--	--
50	--	--	30	--	--	--	--	--	--	--	--	--	--	--
35	<6	4	30	--	100	<6	--	<2	850	<0	<4	6	<6	<7
40	--	--	70	--	--	--	--	--	--	--	--	--	--	--
60	<6	4	100	--	110	<6	--	ND	750	<0	<5	<3	130	<9
40	--	--	80	--	--	--	--	--	--	--	--	--	--	--
40	<2	4	97	--	120	<2	--	ND	780	<0	<2	<2	<5	<3
50	2	<10	70	<.5	--	<2	1	ND	--	--	--	--	<20	--
50	<2	4	75	--	100	<2	--	ND	630	<0	<1	<2	<5	<5
50	3	<10	40	<.5	--	ND	1	ND	850	--	--	--	ND	--
140	--	--	--	--	--	--	--	--	--	--	--	--	--	--
42	1	--	230	<.1	--	1	--	--	--	--	--	--	9	--
520	--	--	--	--	--	--	--	--	--	--	--	--	--	--
360	2	--	71	<.1	--	3	<1	--	--	--	--	--	<4	--
100	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	<1	--	5	<.1	--	<1	--	--	--	--	--	--	1100	--
120	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7	1	--	1	<.1	--	<1	--	--	--	--	--	--	23	--
7	2	--	180	<.1	--	2	--	--	--	--	--	--	21	--
60	--	--	20	--	--	--	--	--	--	--	--	--	--	--
11	<1	--	3	<.1	--	1	--	--	--	--	--	--	15	--
330	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<10	4	--	10	<.1	--	4	--	--	--	--	--	--	20	--
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--
4	2	--	2	<.1	--	2	--	--	--	--	--	--	33	--
50	--	--	0	--	--	--	--	--	--	--	--	--	--	--
<3	7	--	<1	<.1	--	3	--	--	--	--	--	--	<3	--
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--
<3	1	--	1	<.1	--	3	--	--	--	--	--	--	11	--
50	--	--	0	--	--	--	--	--	--	--	--	--	--	--
24	6	--	6	<.1	--	6	--	--	--	--	--	--	110	--
<3	2	850	<1	.1	--	<1	--	--	--	--	--	--	6	--
<10	<1	930	10	.2	--	<1	--	--	--	--	--	--	20	--
30	1	--	7	<.1	--	3	--	--	--	--	--	--	--	--
170	--	--	0	--	--	--	--	--	--	--	--	--	--	--
19	5	--	4	<.1	--	3	--	--	--	--	--	--	16	--
40	--	--	0	--	--	--	--	--	--	--	--	--	--	--
18	12	--	8	<.1	--	5	--	--	--	--	--	--	30	--
40	--	--	0	--	--	--	--	--	--	--	--	--	--	--
40	3	--	10	<.1	--	3	--	--	--	--	--	--	--	--
160	--	--	20	--	--	--	--	--	--	--	--	--	--	--
29	1	--	42	<.1	--	6	--	--	--	--	--	--	20	--
630	--	--	20	--	--	--	--	--	--	--	--	--	--	--
<3	<1	--	2	<.1	--	3	--	--	--	--	--	--	13	--
150	--	--	30	--	--	--	--	--	--	--	--	--	--	--
<3	1	--	<1	<.1	--	4	--	--	--	--	--	--	14	--
20	--	--	0	--	--	--	--	--	--	--	--	--	--	--
4000	--	--	150	--	--	--	--	--	--	--	--	--	--	--
770	--	--	0	--	--	--	--	--	--	--	--	--	--	--
60	--	--	0	--	--	--	--	--	--	--	--	--	--	--

Table 30.-- Chemical analyses of metals and other trace constituents in ground water--Continued
[UG/L, micrograms per liter; ND means not detected]

WELL NUMBER	DATE OF SAMPLE	ALUMINUM, DISSOLVED (UG/L AS AL)	ARSENIC DISSOLVED (UG/L AS AS)	BARIUM, DISSOLVED (UG/L AS BA)	BERYLLIUM, DISSOLVED (UG/L AS BE)	BISMUTH DISSOLVED (UG/L AS BI)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	CHROMIUM, DISSOLVED (UG/L AS CR)	COBALT, DISSOLVED (UG/L AS CO)	COPPER, DISSOLVED (UG/L AS CU)	GALLIUM DISSOLVED (UG/L AS GA)	GERMANIUM, DISSOLVED (UG/L AS GE)
CH-1231	74-10-29	0	<1	<100	--	--	<20	<2	ND	ND	50	--	--
	83-05-17	--	1	--	--	--	--	<1	10	--	17	--	--
	84-03-22	<100	--	--	--	--	--	--	--	--	--	--	--
	84-06-13	--	--	--	--	--	--	--	--	--	--	--	--
	84-09-19	--	--	--	--	--	<20	--	--	--	--	--	--
	84-12-12	--	--	--	--	--	--	--	--	--	--	--	--
1451	73-06-13	--	--	--	--	--	--	--	--	--	--	--	--
1452	73-06-13	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-14	--	1	--	--	--	--	<1	20	--	6	--	--
1454	73-06-13	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-14	--	1	--	--	--	--	<1	<10	--	13	--	--
1459	75-03-31	10	<1	<100	--	--	<20	ND	ND	ND	ND	--	--
1460	73-06-13	--	--	--	--	--	--	--	--	--	--	--	--
1481	74-10-24	0	<0	<100	--	--	<20	ND	<20	ND	120	--	--
	83-05-24	--	<1	--	--	--	--	1	10	--	40	--	--
1483	74-10-25	0	0	<100	--	--	<20	ND	<20	ND	<20	--	--
	83-06-03	--	1	--	--	--	--	1	10	--	3	--	--
1496	76-05-10	10	1	<100	--	--	<20	ND	<20	<2	90	--	--
	83-05-24	--	<1	--	--	--	--	1	10	--	19	--	--
1528	74-10-31	0	2	<100	--	--	<20	ND	ND	ND	<20	--	--
	83-09-07	--	4	--	--	--	--	1	10	--	12	--	--
1547	74-10-30	0	3	300	--	--	<20	ND	<20	ND	50	--	--
	83-05-23	--	2	--	--	--	--	<1	20	--	26	--	--
1565	74-10-29	0	2	200	--	--	80	<2	<20	ND	ND	--	--
	83-05-06	--	1	--	--	--	--	1	<1	--	5	--	--
	84-03-23	100	--	--	--	--	--	--	--	--	--	--	--
	84-06-13	--	--	--	--	--	--	--	--	--	--	--	--
	84-09-19	--	--	--	--	--	50	--	--	--	--	--	--
	84-12-12	--	--	--	--	--	--	--	--	--	--	--	--
1568	76-05-10	<100	2	<100	--	--	<20	<2	<20	ND	20	--	--
	83-05-23	--	3	--	--	--	--	1	10	--	11	--	--
1577	74-10-29	0	<1	<100	--	--	<20	ND	ND	ND	60	--	--
	83-05-17	--	1	--	--	--	--	<1	10	--	82	--	--
1585	81-06-10	--	0	--	--	--	--	3	.00	--	--	--	--
1595	74-10-30	0	5	500	--	--	30	<2	<20	ND	ND	--	--
	83-06-06	--	5	--	--	--	--	1	10	--	6	--	--
1600	83-06-16	--	1	--	--	--	--	<1	<10	--	<1	--	--
1613	74-10-30	0	<1	<100	--	--	<20	ND	<20	ND	140	--	--
	83-05-17	--	1	--	--	--	--	<1	20	--	11	--	--
1616	74-10-30	130	<1	<100	--	--	<20	<2	ND	2	<20	--	--
	83-05-13	--	1	--	--	--	--	1	10	--	120	--	--
1631	74-10-30	0	4	<100	--	--	<20	ND	<20	ND	20	--	--
	83-06-08	--	1	--	--	--	--	<1	10	--	15	--	--
1969	83-06-21	--	1	--	--	--	--	<1	3	--	2	--	--
1973	84-03-20	100	--	--	--	--	--	--	--	--	--	--	--
	84-06-14	--	1	--	--	--	--	2	<1	--	8	--	--
	84-09-19	--	--	--	--	--	<20	--	--	--	--	--	--
	84-12-12	--	--	--	--	--	--	--	--	--	--	--	--
1976	75-04-01	20	1	<100	--	--	<20	<2	ND	<2	ND	--	--
	83-05-31	--	1	--	--	--	--	<1	10	--	3	--	--
1978	83-07-13	--	1	--	--	--	--	<1	<1	--	2	--	--
	84-08-30	10	<1	<100	--	--	<20	2	<10	--	4	--	--
1983	80-06-04	--	1	--	--	--	--	0	1	--	--	--	--
2046	81-05-29	--	0	--	--	--	--	2	.00	--	--	--	--
	83-06-27	--	1	--	--	--	--	<1	<1	--	23	--	--

IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	LITHIUM DIS- SOLVED (UG/L AS LI)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)	MERCURY DIS- SOLVED (UG/L AS HG)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO)	NICKEL, DIS- SOLVED (UG/L AS NI)	SELE- NIUM, DIS- SOLVED (UG/L AS SE)	SILVER, DIS- SOLVED (UG/L AS AG)	STRON- TIUM, DIS- SOLVED (UG/L AS SR)	TIN DIS- SOLVED (UG/L AS SN) (A.A.S. DIRECT)	TI- TANIUM, DIS- SOLVED (UG/L AS TI)	VANA- DIUM, DIS- SOLVED (UG/L AS V)	ZINC, DIS- SOLVED (UG/L AS ZN)	ZIR- CONIUM, DIS- SOLVED (UG/L AS ZR)
<10	ND	<10	<10	<.5	--	3	0	ND	--	--	--	--	20	--
19	6	--	6	<.1	--	2	--	--	--	--	--	--	6	--
5	--	6	4	--	--	--	--	--	--	--	--	--	--	--
8	--	--	6	--	--	--	--	--	--	--	--	--	--	--
<3	--	--	2	--	--	--	--	--	--	--	--	--	--	--
5	--	--	3	--	--	--	--	--	--	--	--	--	--	--
<10	--	--	<10	--	--	--	--	--	--	--	--	--	--	--
<10	--	--	20	--	--	--	--	--	--	--	--	--	--	--
9	<1	--	3	<.1	--	4	--	--	--	--	--	--	14	--
<10	--	--	<10	--	--	--	--	--	--	--	--	--	--	--
<3	<1	--	<1	<.1	--	1	--	--	--	--	--	--	18	--
1600	<2	<10	180	<.5	--	3	<1	ND	--	--	--	--	<20	--
820	--	--	130	--	--	--	--	--	--	--	--	--	--	--
<10	7	<10	<10	<.5	--	6	<1	ND	--	--	--	--	140	--
32	2	--	15	<.1	--	5	--	--	--	--	--	--	140	--
<10	ND	<10	<10	<.5	--	3	0	ND	--	--	--	--	20	--
10	1	--	3	<.1	--	2	--	--	--	--	--	--	17	--
60	5	<10	<10	<.5	--	5	<1	ND	40	--	--	--	30	--
15	3	--	7	.1	--	3	--	--	--	--	--	--	9	--
90	3	<10	<10	<.5	--	2	0	ND	--	--	--	--	500	--
10	6	--	10	<.1	--	3	--	--	--	--	--	--	110	--
<10	<2	<10	<10	<.5	--	2	0	ND	--	--	--	--	60	--
19	1	--	3	<.1	--	<1	--	--	--	--	--	--	110	--
<10	<2	<10	<10	<.5	--	3	<1	ND	--	--	--	--	<20	--
<3	10	--	3	--	--	2	--	--	--	--	--	--	<3	--
<3	--	7	2	--	--	--	--	--	--	--	--	--	--	--
<3	--	--	4	--	--	--	--	--	--	--	--	--	--	--
<3	--	--	2	--	--	--	--	--	--	--	--	--	--	--
5	--	--	<1	--	--	--	--	--	--	--	--	--	--	--
<10	2	20	<10	<.5	--	ND	<1	ND	150	--	--	--	<20	--
12	2	--	<1	.1	--	<1	--	--	--	--	--	--	4	--
<10	2	<10	<10	<.5	--	<2	0	ND	--	--	--	--	40	--
<3	4	--	2	<.1	--	2	--	--	--	--	--	--	16	--
<10	0	--	30	.2	--	6	--	--	--	--	--	--	--	--
<10	2	<10	<10	<.5	--	2	0	ND	--	--	--	--	370	--
3	1	--	1	<.1	--	1	--	--	--	--	--	--	220	--
1400	<1	--	210	<.1	--	12	--	--	--	--	--	--	480	--
40	2	<10	20	<.5	--	5	0	ND	--	--	--	--	40	--
30	5	--	2	<.1	--	3	--	--	--	--	--	--	11	--
1000	8	<10	1500	<.5	--	4	1	ND	--	--	--	--	800	--
240	7	--	56	.2	--	5	--	--	--	--	--	--	11	--
<10	2	<10	20	<.5	--	4	3	ND	--	--	--	--	440	--
16	<1	--	19	<.1	--	1	--	--	--	--	--	--	31	--
<3	1	--	1	<.1	--	1	<1	--	--	--	--	--	19	--
<3	--	6	2	--	--	--	--	--	--	--	--	--	--	--
<10	<1	<10	<10	.1	--	2	1	--	--	--	--	--	20	--
<3	--	--	2	--	--	--	--	--	--	--	--	--	--	--
5	--	--	1	--	--	--	--	--	--	--	--	--	--	--
20	2	<10	<10	<.5	--	<2	1	ND	--	--	--	--	ND	--
10	2	--	<1	<.1	--	1	--	--	--	--	--	--	5	--
6	3	--	1	<.1	--	2	1	--	--	--	--	--	<3	--
20	3	<10	10	<.1	--	4	--	--	--	--	--	--	10	--
0	0	--	0	<.1	--	0	--	--	--	--	--	--	--	--
1200	0	--	20	<.1	--	4	--	--	--	--	--	--	--	--
1400	3	--	48	.1	--	5	<1	--	--	--	--	--	79	--

Table 30.-- Chemical analyses of metals and other trace constituents in ground water--Continued
[UG/L, micrograms per liter; ND means not detected]

WELL NUMBER	DATE OF SAMPLE	ALUMINUM, DISSOLVED (UG/L AS AL)	ARSENIC DISSOLVED (UG/L AS AS)	BARIUM, DISSOLVED (UG/L AS BA)	BERYLLIUM, DISSOLVED (UG/L AS BE)	BISMUTH DISSOLVED (UG/L AS BI)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	CHROMIUM, DISSOLVED (UG/L AS CR)	COBALT, DISSOLVED (UG/L AS CO)	COPPER, DISSOLVED (UG/L AS CU)	GALLIUM DISSOLVED (UG/L AS GA)	GERMANIUM, DISSOLVED (UG/L AS GE)
CH-2087	75-04-01	20	<1	<100	--	--	<20	ND	<20	<2	ND	--	--
	83-05-11	--	1	--	--	--	--	<1	10	--	3	--	--
2089	84-06-04	--	1	--	--	--	--	4	2	--	1	--	--
2100	74-11-01	0	<1	<100	--	--	<20	<2	ND	ND	30	--	--
	83-06-08	--	1	--	--	--	--	1	<10	--	40	--	--
2107	75-04-01	10	<1	<100	--	--	<20	<2	<20	<2	40	--	--
	83-05-13	--	1	--	--	--	--	<1	<10	--	84	--	--
2134	75-04-02	20	1	200	--	--	<20	ND	<20	<2	ND	--	--
	83-05-11	--	1	--	--	--	--	<1	2	--	290	--	--
2136	81-08-19	--	1	--	--	--	--	1	<1	--	--	--	--
	82-06-22	--	1	--	--	--	--	<1	<1	--	6	--	--
2148	84-06-01	--	2	--	--	--	--	<1	<10	--	1	--	--
2149	72-04-20	--	--	--	--	--	--	3	20	--	5	--	--
	83-06-09	--	5	--	--	--	--	<1	10	--	7	--	--
2153	72-08-11	--	--	--	--	--	--	--	--	--	--	--	--
	83-09-06	--	3	--	--	--	--	1	30	--	4	--	--
2197	61-10-24	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-01	--	1	--	--	--	--	<1	10	--	13	--	--
2198	61-10-02	--	--	--	--	--	--	--	--	--	--	--	--
	83-06-01	--	1	--	--	--	--	<1	10	--	12	--	--
2199	84-08-27	20	1	13	--	--	<20	<1	<10	--	110	--	--
2240	76-05-10	10	<1	<100	--	--	<20	ND	<20	2	80	--	--
	83-05-23	--	<1	--	--	--	--	1	10	--	41	--	--
2321	75-04-01	20	<1	<100	--	--	<20	2	ND	<2	30	--	--
	83-09-08	--	3	--	--	--	--	1	<10	--	80	--	--
2322	75-04-02	20	<1	<100	--	--	<20	<2	<20	<2	250	--	--
	83-05-13	--	1	--	--	--	--	<1	<10	--	57	--	--
2402	80-06-03	--	1	--	--	--	--	4	1	--	--	--	--
2405	80-06-04	--	0	--	--	--	--	0	.00	--	--	--	--
2411	80-08-26	--	1	--	--	--	--	0	6	--	--	--	--
	81-08-18	--	1	--	--	--	--	2	<1	--	--	--	--
	82-07-22	--	1	--	--	--	--	<1	<1	--	10	--	--
2425	81-05-28	--	0	--	--	--	--	2	1	--	--	--	--
2426	81-05-28	--	6	--	--	--	--	1	1	--	--	--	--
	82-06-16	--	1	--	--	--	--	<1	<1	--	43	--	--
2427	81-05-28	--	0	--	--	--	--	2	2	--	--	--	--
2432	81-06-03	--	1	--	--	--	--	1	.00	--	--	--	--
2434	81-06-10	--	0	--	--	--	--	1	.00	--	--	--	--
2435	81-06-10	--	0	--	--	--	--	2	.00	--	--	--	--
2436	81-06-10	--	1	--	--	--	--	3	.00	--	--	--	--
2438	81-06-11	--	0	--	--	--	--	3	.00	--	--	--	--
2441	81-08-17	--	0	--	--	--	--	1	1	--	--	--	--
2443	81-08-18	--	1	--	--	--	--	1	<1	--	--	--	--
	82-08-03	--	2	--	--	--	--	<1	<1	--	6	--	--
2444	81-08-18	--	1	--	--	--	--	2	<1	--	--	--	--
	82-08-03	--	2	--	--	--	--	1	<1	--	430	--	--
2445	81-08-18	--	1	--	--	--	--	1	<1	--	--	--	--
2447	81-08-19	--	1	--	--	--	--	1	<1	--	--	--	--
	82-07-08	--	<1	--	--	--	--	<1	4	--	16	--	--
2448	81-08-21	--	6	--	--	--	--	1	<1	--	--	--	--
2448	82-07-19	--	4	--	--	--	--	<1	<1	--	6	--	--
2449	81-08-21	--	1	--	--	--	--	2	3	--	--	--	--
	82-06-23	--	1	--	--	--	--	<1	<1	--	<1	--	--
2463	82-06-17	--	8	--	--	--	--	<1	<1	--	63	--	--
2464	82-06-17	--	1	--	--	--	--	<1	<1	--	5	--	--

IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	LITHIUM DIS- SOLVED (UG/L AS LI)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)	MERCURY DIS- SOLVED (UG/L AS HG)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO)	NICKEL, DIS- SOLVED (UG/L AS NI)	SELE- NIUM, DIS- SOLVED (UG/L AS SE)	SILVER, DIS- SOLVED (UG/L AS AG)	STRON- TIUM, DIS- SOLVED (UG/L AS SR)	TIN DIS- SOLVED (UG/L AS SN) (A.A.S. DIRECT)	TI- TANIUM, DIS- SOLVED (UG/L AS TI)	VANA- DIUM, DIS- SOLVED (UG/L AS V)	ZINC, DIS- SOLVED (UG/L AS ZN)	ZIR- CONIUM, DIS- SOLVED (UG/L AS ZR)
<10	ND	<10	<10	<.5	--	2	<1	ND	--	--	--	--	ND	--
<3	4	--	<1	<.1	--	5	--	--	--	--	--	--	<3	--
590	1	--	3100	<.1	--	4	<1	--	--	--	--	--	30	--
30	6	<10	<10	<.5	--	3	1	ND	--	--	--	--	260	--
21	2	--	2	<.1	--	2	--	--	--	--	--	--	430	--
20	4	<10	<10	<.5	--	3	<1	ND	--	--	--	--	ND	--
<3	2	--	10	<.1	--	3	--	--	--	--	--	--	9	--
<10	<2	<10	<10	<.5	--	<2	2	ND	--	--	--	--	60	--
<3	11	--	1	--	--	9	--	--	--	--	--	--	20	--
10	1	--	1	<.1	--	4	--	--	--	--	--	--	--	--
<3	2	--	4	<.1	--	2	<1	--	--	--	--	--	<4	--
210	1	34	9	<.1	--	--	--	--	--	--	--	--	--	--
440	--	--	30	--	--	--	--	--	--	--	--	--	50	--
5	1	--	<1	<.1	--	1	--	--	--	--	--	--	29	--
2900	--	--	140	--	--	--	--	--	--	--	--	--	--	--
2100	5	--	120	<.1	--	3	--	--	--	--	--	--	60	--
1400	--	--	90	--	--	--	--	--	--	--	--	--	--	--
60	4	--	35	<.1	--	1	--	--	--	--	--	--	28	--
20	--	--	20	--	--	--	--	--	--	--	--	--	--	--
<3	1	--	2	<.1	--	2	--	--	--	--	--	--	190	--
34	20	6	3	<.1	--	<1	--	--	--	--	--	--	16	--
50	5	<10	<10	<.5	--	7	<1	ND	60	--	--	--	20	--
4	1	--	8	.1	--	9	--	--	--	--	--	--	26	--
110	2	<10	30	<.5	--	<2	<1	ND	--	--	--	--	1400	--
<10	7	--	10	<.1	--	3	--	--	--	--	--	--	180	--
50	2	<10	<10	<.5	--	3	1	ND	--	--	--	--	20	--
46	5	--	3	<.1	--	5	--	--	--	--	--	--	60	--
20	0	--	2	.3	--	0	--	--	--	--	--	--	--	--
3600	0	--	80	<.1	--	3	--	--	--	--	--	--	--	--
10	0	--	10	.5	--	1	--	--	--	--	--	--	--	--
10	<1	--	30	.1	--	4	--	--	--	--	--	--	--	--
17	2	--	2	.2	--	4	<1	--	--	--	--	--	<4	--
<10	0	--	<1	<.1	--	2	--	--	--	--	--	--	--	--
10	0	--	2	<.1	--	1	--	--	--	--	--	--	--	--
<3	1	--	<1	<.1	--	<1	<1	--	--	--	--	--	23	--
<10	0	--	<1	<.1	--	5	--	--	--	--	--	--	--	--
10	1	--	1	.3	--	8	--	--	--	--	--	--	--	--
10	0	--	10	.1	--	5	--	--	--	--	--	--	--	--
870	0	--	60	.1	--	7	--	--	--	--	--	--	--	--
<10	0	--	20	.2	--	4	--	--	--	--	--	--	--	--
<10	0	--	1	.1	--	3	--	--	--	--	--	--	--	--
340	<1	--	80	<.1	--	3	--	--	--	--	--	--	--	--
50	<1	--	3	.1	--	1	--	--	--	--	--	--	--	--
14	8	--	3	<.1	--	1	<1	--	--	--	--	--	4	--
40	2	--	20	.2	--	3	--	--	--	--	--	--	--	--
42	3	--	140	.1	--	4	1	--	--	--	--	--	31	--
10	<1	--	1	.1	--	4	--	--	--	--	--	--	--	--
6100	5	--	160	.1	--	17	--	--	--	--	--	--	--	--
5900	3	--	150	<.1	--	19	<1	--	--	--	--	--	190	--
50	1	--	430	<.1	--	11	--	--	--	--	--	--	--	--
24	1	--	410	<.1	--	5	<1	--	--	--	--	--	230	--
380	3	--	90	<.1	--	<1	--	--	--	--	--	--	--	--
430	<1	--	89	<.1	--	<1	<1	--	--	--	--	--	180	--
<3	2	--	8	<.1	--	1	<1	--	--	--	--	--	150	--
<3	2	--	15	<.1	--	2	<1	--	--	--	--	--	16	--

Table 30.-- Chemical analyses of metals and other trace constituents in ground water--Continued
[UG/L, micrograms per liter; ND means not detected]

WELL NUMBER	DATE OF SAMPLE	ALUM-INUM, DIS-SOLVED (UG/L AS AL)	ARSENIC DIS-SOLVED (UG/L AS AS)	BARIUM, DIS-SOLVED (UG/L AS BA)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE)	BISMUTH DIS-SOLVED (UG/L AS BI)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COBALT, DIS-SOLVED (UG/L AS CO)	COPPER, DIS-SOLVED (UG/L AS CU)	GALLIUM DIS-SOLVED (UG/L AS GA)	GER-MANIUM, DIS-SOLVED (UG/L AS GE)
CH-2465	82-06-17	--	1	--	--	--	--	<1	<1	--	5	--	--
2466	82-06-21	--	1	--	--	--	--	<1	1	--	16	--	--
2468	82-06-22	--	1	--	--	--	--	<1	<1	--	15	--	--
2469	82-06-23	--	1	--	--	--	--	<1	<1	--	<1	--	--
2470	82-06-23	--	1	--	--	--	--	<1	3	--	6	--	--
2471	82-06-24	--	1	--	--	--	--	<1	<1	--	58	--	--
2478	82-08-03	--	1	--	--	--	--	5	<1	--	47	--	--
	83-07-07	--	<1	--	--	--	--	2	<1	--	67	--	--
2479	82-07-22	--	1	--	--	--	--	<1	<1	--	5	--	--
2487	83-06-10	--	1	--	--	--	--	<1	10	--	2	--	--
2488	83-06-16	--	<1	--	--	--	--	<1	<10	--	59	--	--
2489	83-06-15	--	1	--	--	--	--	<1	<10	--	4	--	--
2490	83-06-16	--	2	--	--	--	--	<1	<10	--	6	--	--
2491	84-03-22	200	--	--	--	--	--	--	--	--	--	--	--
	84-06-14	--	<1	--	--	--	--	<1	10	--	51	--	--
	84-09-19	--	--	--	--	--	40	--	--	--	--	--	--
	84-12-12	--	--	--	--	--	--	--	--	--	--	--	--
2494	83-06-21	--	1	--	--	--	--	<1	2	--	11	--	--
2499	83-06-23	--	1	--	--	--	--	<1	<1	--	110	--	--
2502	83-06-29	--	1	--	--	--	--	<1	<1	--	17	--	--
2535	84-06-01	--	--	--	--	--	--	--	--	--	--	--	--
	84-06-26	20	1	59	--	--	9300	<1	50	--	3	--	--
	85-08-22	<10	<1	<100	<10	--	18000	<1	60	--	2	--	--
	85-10-01	--	--	--	--	--	20000	--	--	--	--	--	--
2542	84-03-20	<100	--	--	--	--	--	--	--	--	--	--	--
	84-06-14	100	--	--	--	--	--	--	--	--	--	--	--
	84-09-19	--	--	--	--	--	<20	--	--	--	--	--	--
	84-12-12	--	--	--	--	--	--	--	--	--	--	--	--
2545	84-08-30	10	<1	<100	--	--	60	2	<10	--	5	--	--
2613	84-06-04	--	--	--	--	--	--	--	--	--	--	--	--
2664	84-03-22	<100	--	--	--	--	--	--	--	--	--	--	--
	84-06-13	--	<1	--	--	--	--	<1	10	--	<1	--	--
	84-08-28	--	<1	--	--	--	--	<1	<1	--	1	--	--
	84-09-27	--	--	--	--	--	<20	--	--	--	--	--	--
	84-12-18	--	--	--	--	--	--	--	--	--	--	--	--
2676	84-06-07	--	--	--	--	--	--	--	--	--	--	--	--
2677	84-06-05	--	--	--	--	--	--	--	--	--	--	--	--
2680	84-06-14	--	1	--	--	--	--	<1	<10	--	6	--	--
2681	84-06-26	--	1	--	--	--	--	1	<1	--	8	--	--
2748	84-06-28	--	<1	--	--	--	--	1	<1	--	7	--	--
2749	84-06-29	--	<1	--	--	--	--	1	<1	--	1	--	--
2750	84-06-05	--	<1	--	--	--	--	<1	--	--	87	--	--
2801	84-08-29	--	2	--	--	--	--	<1	<1	--	1	--	--
2802	84-08-15	--	<1	--	--	--	--	<1	2	--	320	--	--

IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	LITHIUM DIS- SOLVED (UG/L AS LI)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)	MERCURY DIS- SOLVED (UG/L AS HG)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO)	NICKEL, DIS- SOLVED (UG/L AS NI)	SELE- NIUM, DIS- SOLVED (UG/L AS SE)	SILVER, DIS- SOLVED (UG/L AS AG)	STRON- TIUM, DIS- SOLVED (UG/L AS SR)	TIN DIS- SOLVED (UG/L AS SN) (A.A.S. DIRECT)	TI- TANIUM, DIS- SOLVED (UG/L AS TI)	VANA- DIUM, DIS- SOLVED (UG/L AS V)	ZINC, DIS- SOLVED (UG/L AS ZN)	ZIR- CONIUM, DIS- SOLVED (UG/L AS ZR)
<3	1	--	<1	<.1	--	<1	<1	--	--	--	--	--	6	--
22	3	--	4	<.1	--	<1	<1	--	--	--	--	--	22	--
<3	1	--	35	<.1	--	1	<1	--	--	--	--	--	<4	--
6	<1	--	3	<.1	--	<1	<1	--	--	--	--	--	10	--
<3	2	--	6	<.1	--	<1	<1	--	--	--	--	--	120	--
860	<1	--	60	<.1	--	<1	<1	--	--	--	--	--	86	--
50	9	--	70	.2	--	51	1	--	--	--	--	--	50	--
130	5	--	90	1.1	--	43	1	--	--	--	--	--	40	--
10	4	--	<1	<.1	--	3	<1	--	--	--	--	--	<4	--
1200	<1	--	210	.1	--	1	--	--	--	--	--	--	7	--
9	<1	--	9	<.1	--	4	--	--	--	--	--	--	15	--
17	<1	--	<1	<.1	--	2	--	--	--	--	--	--	12	--
<3	<1	--	<1	<.1	--	2	--	--	--	--	--	--	<3	--
88	--	<4	68	--	--	--	--	--	--	--	--	--	--	--
120	4	--	120	.1	--	--	--	--	--	--	--	--	--	--
1600	--	--	260	--	--	--	--	--	--	--	--	--	--	--
24	--	--	62	--	--	--	--	--	--	--	--	--	--	--
4	1	--	<1	<.1	--	1	1	--	--	--	--	--	20	--
4	1	--	9	<.1	--	2	3	--	--	--	--	--	74	--
<3	6	--	3	.1	--	1	<1	--	--	--	--	--	30	--
--	--	8900	--	--	--	--	--	--	--	--	--	--	--	--
13	1	9800	7	2.0	--	1	--	--	--	--	--	--	66	--
20	<1	12000	10	--	--	1	--	--	--	--	--	--	120	--
--	--	13000	--	--	--	--	--	--	--	--	--	--	--	--
6	--	10	2	--	--	--	--	--	--	--	--	--	--	--
9	--	12	3	--	--	--	--	--	--	--	--	--	--	--
8	--	--	2	--	--	--	--	--	--	--	--	--	--	--
9	--	--	3	--	--	--	--	--	--	--	--	--	--	--
10	2	120	<10	<.1	--	<1	--	--	--	--	--	--	10	--
--	--	<10	--	--	--	--	--	--	--	--	--	--	--	--
5	--	5	3	--	--	--	--	--	--	--	--	--	--	--
9	5	--	29	.1	--	--	--	--	--	--	--	--	--	--
10	1	--	<10	<.1	--	4	<1	--	--	--	--	--	<10	--
10	--	--	35	--	--	--	--	--	--	--	--	--	--	--
11	--	--	60	--	--	--	--	--	--	--	--	--	--	--
--	--	10	--	--	--	--	--	--	--	--	--	--	--	--
--	--	<10	--	--	--	--	--	--	--	--	--	--	--	--
21	3	<4	8	.1	--	--	--	--	--	--	--	--	--	--
320	8	--	20	<.1	--	1	<1	--	--	--	--	--	10	--
20	1	--	140	<.1	--	3	<1	--	--	--	--	--	60	--
2000	1	10	1500	<.1	--	17	<1	--	--	--	--	--	70	--
4	1	--	7	.1	--	2	1	--	--	--	--	--	19	--
2900	2	--	1000	<.1	--	5	<1	--	--	--	--	--	13	--
10	5	--	20	<.1	--	13	1	--	--	--	--	--	<10	--

Table 31.-- Chemical analyses of selected common ions in ground water
[DEG C, degrees Celcius; US/CM, microsiemens per centimeter at 25 degrees Celcius; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TEMPER-ATURE (DEG C)	PH (STAND-ARD UNITS)	SPE-CIFIC CON-DUCT-ANCE (US/CM)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SILICA, DIS-SOLVED (MG/L AS SIO2)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
CH-16	72-05-23	--	6.5	--	--	--	--	--
147	75-01-06	--	7.1	--	--	--	--	--
	83-06-09	13.0	6.9	535	68	16	25	.80
151	82-07-19	14.5	7.6	500	52	19	24	.30
152	57-09-18	13.5	7.3	542	59	23	22	1.1
	57-10-24	13.5	7.3	549	59	23	23	1.1
	73-11-20	--	7.9	431	45	20	15	.80
	73-11-20	--	--	--	--	--	--	--
	74-05-29	14.5	7.3	470	46	21	18	.80
	74-10-17	15.0	7.5	460	46	23	17	.50
	75-05-28	15.0	7.4	460	50	21	18	.60
	75-12-09	14.5	7.8	440	44	22	18	.70
	82-07-19	15.0	7.7	420	42	21	19	.50
153	56-06-07	14.0	8.1	489	45	24	26	--
	83-06-07	--	--	--	74	26	21	.90
	83-06-07	14.0	7.3	695	--	--	--	--
154	56-06-07	14.0	7.9	773	110	19	26	--
	82-07-19	14.5	7.6	900	160	17	20	.40
155	56-06-07	12.0	8.3	280	29	11	26	--
	83-06-07	15.0	7.0	375	40	13	26	1.1
157	56-06-07	12.0	8.0	479	48	20	21	--
164	83-06-13	--	7.6	740	63	37	24	1.8
165	83-06-13	--	7.6	875	140	13	19	1.2
181	63-04-12	--	7.7	361	42	13	22	.20
	83-06-09	13.0	7.4	595	75	21	25	.70
182	49-04-20	--	6.3	215	20	9.0	18	4.0
	83-09-07	12.5	6.1	330	28	12	20	2.2
201	64-05-22	12.0	7.1	643	97	19	7.7	.60
	83-06-14	15.0	7.2	700	72	25	9.9	1.5
202	64-05-22	--	7.3	248	70	39	6.0	2.0
	83-05-09	13.0	6.8	695	<64	<36	<7.0	2.0
205	64-05-20	--	6.2	75	7.2	1.9	21	.20
	83-06-06	12.0	6.0	105	8.4	2.6	24	.80
206	64-05-20	--	6.2	163	14	5.6	21	1.0
	83-05-17	13.0	6.4	310	28	11	26	2.0
207	84-08-27	15.0	7.1	690	56	24	7.7	2.1
	85-06-18	14.0	8.0	525	54	25	--	--
251	81-08-19	13.0	6.8	1200	--	--	--	--
252	65-04-08	--	6.8	157	15	5.4	25	2.0
	83-05-18	12.5	6.3	350	17	7.0	25	1.9
253	65-04-08	13.0	7.4	554	58	36	9.2	2.5
	83-05-10	13.0	7.1	770	77	48	10	3.6
257	65-04-08	--	5.8	119	5.6	4.9	9.2	.80
293	81-08-19	12.0	6.5	320	--	--	--	--
619	63-05-15	--	6.3	145	10	3.6	25	3.1
	83-05-25	13.0	5.9	210	14	5.5	22	3.8
634	63-05-22	14.0	6.4	122	8.0	3.4	26	1.1
	83-06-17	--	6.0	320	26	10	26	2.1
644	73-06-13	--	7.1	--	--	--	--	--
	83-06-14	12.5	6.2	325	24	9.7	28	1.9
1083	66-09-07	--	6.9	250	33	9.8	10	1.1
1084	66-09-07	--	7.3	237	7.5	23	1.3	2.9
1107	61-10-24	--	6.4	249	24	7.3	31	2.5
	67-02-14	3.5	6.8	228	27	8.2	27	3.0

SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, DIS- SOLVED (MG/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)
56	33	230	--	4.8	--	--	--	--
86	21	292	--	4.9	--	--	--	.160
56	33	362	.010	4.3	4.3	.010	.060	.060
38	36	354	<.010	--	7.8	.020	.030	.030
66	24	343	--	2.7	--	--	--	--
70	26	354	--	3.2	--	--	--	--
78	6.8	291	.011	.51	.52	--	--	.001
--	--	418	--	--	--	--	--	--
69	12	287	.010	1.2	1.2	--	--	.010
72	12	285	.010	.99	1.0	--	--	.010
70	12	302	.010	.99	1.0	<.010	--	.010
78	9.1	280	.010	.59	.60	.050	--	.010
53	14	323	<.010	--	.68	.030	.020	.020
120	9.5	388	--	.61	--	--	--	--
110	45	418	--	--	--	--	--	--
--	--	--	.070	1.8	1.9	.010	.010	.010
300	8.0	--	--	.47	--	--	--	--
330	10	715	<.010	--	<.10	.140	.010	.010
26	7.0	--	--	1.9	--	--	--	--
21	23	242	.010	2.7	2.7	.010	.070	.060
110	10	--	--	.75	--	--	--	--
33	65	424	.010	6.6	6.6	.020	.040	.030
140	55	497	.040	.20	.24	.070	.010	.010
32	8.4	238	--	1.8	--	--	--	--
92	22	396	.010	7.6	7.6	.010	.050	.040
22	6.4	136	--	1.7	--	--	--	--
30	32	231	<.010	--	5.3	.050	.070	.070
52	19	406	--	2.0	--	--	--	--
43	34	380	.010	.17	.18	.010	.050	.010
51	120	557	--	.88	--	--	--	--
31	40	310	.020	2.7	2.7	<.010	<.010	<.010
10	2.5	64	--	.38	--	--	--	--
15	5.4	79	<.010	--	.31	<.010	.030	.030
23	8.9	125	--	2.9	--	--	--	--
30	48	222	<.010	--	4.5	<.010	.010	<.010
48	.00	390	<.010	--	2.7	<.010	<.010	<.010
43	64	409	--	--	--	--	--	--
--	--	--	<.010	--	1.8	.010	--	--
29	3.6	112	--	.04	--	--	--	.030
34	46	206	<.010	--	2.1	<.010	.010	<.010
54	5.2	336	--	2.7	--	--	--	.000
47	63	436	<.010	--	4.6	<.010	<.010	<.010
3.1	9.8	83	--	5.6	--	--	--	.000
--	--	--	<.010	--	1.5	<.010	--	--
22	9.7	108	--	.00	--	--	--	--
2.7	18	139	.020	.94	.96	.010	<.010	<.010
3.8	4.8	101	--	2.1	--	--	--	--
17	49	259	<.010	--	7.7	<.010	.030	.030
15	7.5	240	--	7.3	--	--	--	.030
31	17	216	.010	6.4	6.4	.010	.030	.010
25	6.8	150	--	1.4	--	--	--	--
17	5.6	124	--	.02	--	--	--	--
33	24	171	--	3.4	--	--	--	--
34	7.4	153	--	1.4	--	--	--	--

Table 31.-- Chemical analyses of selected common ions in ground water--Continued
[DEG C, degrees Celcius; US/CM, microsiemens per centimeter at 25 degrees Celcius; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TEMPER- ATURE (DEG C)	PH (STAND- ARD UNITS)	SPE- CIFIC CON- DUCT- ANCE (US/CM)	CALCIUM DIS- SOLVED (MG/L AS CA)	MAGNE- SIUM, DIS- SOLVED (MG/L AS MG)	SILICA, DIS- SOLVED (MG/L AS SIO2)	POTAS- SIUM, DIS- SOLVED (MG/L AS K)
CH-1231	74-10-29	--	6.4	175	17	5.1	28	1.0
	83-05-17	11.5	6.6	135	16	4.7	32	1.2
	83-12-16	12.0	6.1	150	--	--	--	--
	84-01-26	10.5	6.3	165	--	--	--	--
	84-02-23	10.0	6.3	170	--	--	--	--
	84-03-22	10.5	6.2	160	15	4.8	--	1.5
	84-04-25	11.0	6.4	145	--	--	--	--
	84-05-24	14.0	6.6	155	--	--	--	--
	84-06-13	14.0	6.3	155	16	4.8	--	1.2
	84-07-19	14.0	6.3	165	--	--	--	--
	84-08-24	14.5	6.3	160	--	--	--	--
	84-09-19	13.0	6.1	155	17	5.0	--	1.2
	84-10-05	--	--	--	--	--	--	--
	84-11-26	11.5	6.4	160	--	--	--	--
	84-12-12	11.0	>6.5	160	17	5.0	--	1.3
1451	73-06-13	--	7.1	--	--	--	--	--
	83-06-14	12.0	5.9	340	--	--	--	--
1452	73-06-13	--	6.4	--	--	--	--	--
	83-06-14	13.0	6.0	230	18	6.0	12	.80
1454	73-06-13	--	7.3	--	--	--	--	--
	83-06-14	12.5	6.4	285	18	2.9	20	1.3
1459	75-03-31	--	7.3	240	28	5.9	23	4.0
1460	73-06-13	--	7.1	--	--	--	--	--
1481	74-10-24	--	5.8	195	13	6.5	24	2.4
	83-05-24	--	--	--	21	8.9	26	2.8
	83-05-24	12.0	5.6	265	--	--	--	--
1483	74-10-25	--	5.9	470	44	12	18	1.0
	83-06-03	13.5	6.1	455	43	14	21	.90
1496	76-05-10	13.0	5.4	--	.70	.80	10	.30
	83-05-24	11.5	5.2	25	.74	.75	11	.50
1528	74-10-31	--	7.0	220	15	6.1	21	.60
	83-09-07	14.0	6.5	235	--	--	--	--
	83-09-07	--	--	--	19	7.5	31	.90
1547	74-10-30	--	7.2	500	32	11	27	1.8
	83-05-23	--	--	--	37	13	30	1.0
	83-05-23	15.0	6.7	370	--	--	--	--
1565	74-10-29	--	7.7	420	41	14	16	.50
	83-05-06	--	7.8	342	41	16	13	1.0
	83-12-14	13.0	7.0	260	--	--	--	--
	84-01-25	11.5	7.4	365	--	--	--	--
	84-01-25	--	--	--	--	--	--	--
	84-02-23	12.5	6.9	310	--	--	--	--
	84-03-23	12.0	6.8	305	32	15	--	1.0
	84-04-25	13.0	7.1	340	--	--	--	--
	84-05-23	14.0	7.2	370	--	--	--	--
	84-06-13	14.0	7.4	405	39	17	--	.80
	84-07-19	14.5	7.1	410	--	--	--	--
	84-08-22	14.0	7.5	395	--	--	--	--
	84-09-19	14.5	7.7	400	40	18	--	.70
	84-10-05	14.0	7.5	390	--	--	--	--
	84-11-26	13.0	7.7	395	--	--	--	--
	84-12-12	--	--	--	41	19	--	.80
	84-12-12	13.0	7.5	390	--	--	--	--
1568	76-05-10	13.0	6.7	--	43	7.0	25	.80
	83-05-23	--	--	--	56	8.1	27	1.0
	83-05-23	13.5	6.8	415	--	--	--	--

SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, DIS- SOLVED (MG/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)
23	2.4	110	<.010	.64	.64	.010	--	.030
21	2.6	112	<.010	--	1.1	<.010	.030	.020
19	2.7	118	<.010	--	1.2	.020	--	<.010
--	1.5	109	<.010	--	1.1	.030	--	.020
--	2.9	114	.030	1.2	1.2	.220	--	.030
22	4.2	117	<.010	--	1.0	<.010	--	.010
--	2.8	142	<.010	--	1.2	.030	--	.020
--	2.8	129	.020	1.2	1.2	.140	--	.070
28	2.7	119	<.010	--	1.1	<.010	--	.050
--	2.9	131	<.010	--	1.1	.020	--	.050
--	2.7	113	<.010	--	1.1	.060	--	.030
23	2.9	119	<.010	--	1.2	<.010	--	.100
--	3.1	119	--	--	--	--	--	--
--	2.9	106	<.010	--	1.1	<.010	--	.020
23	2.6	114	.070	1.0	1.1	.030	--	.030
30	23	246	--	6.8	--	--	--	.030
--	--	--	.010	6.2	6.2	.010	.030	.010
6.0	12	178	--	4.3	--	--	--	.040
14	27	176	.010	4.2	4.2	.010	.030	.010
16	5.2	151	--	3.0	--	--	--	.060
5.1	5.4	112	.010	5.4	5.4	.010	.030	.010
44	7.1	185	<.010	.01	.01	.020	--	.060
36	8.0	161	--	1.5	--	--	--	.030
.8	7.2	142	<.010	11	11	<.010	--	.030
12	1.8	230	--	--	--	--	--	--
--	--	--	<.010	--	19	<.010	.020	.020
23	70	275	<.010	6.1	6.1	.010	--	.110
32	68	359	<.010	--	5.8	<.010	.130	.140
1.1	2.2	23	.010	.37	.38	.010	--	.010
.6	2.5	35	<.010	--	.42	<.010	.010	.020
13	3.1	132	<.010	1.2	1.2	<.010	--	.110
--	--	--	.010	2.2	2.2	.010	.110	.120
14	15	161	--	--	--	--	--	--
19	7.3	173	<.010	4.4	4.4	<.010	--	.120
25	20	254	--	--	--	--	--	--
--	--	--	<.010	--	6.3	<.010	.110	.120
22	4.2	228	<.010	1.0	1.0	<.010	--	.010
41	6.2	190	.020	1.8	1.8	<.010	.020	<.010
30	4.8	165	<.010	--	3.1	.040	--	<.010
--	--	--	<.010	--	2.9	<.010	--	.060
--	5.5	234	--	--	--	--	--	--
--	6.6	220	.020	3.6	3.6	.250	--	.040
38	7.2	195	<.010	--	3.4	.260	--	<.010
--	6.3	223	<.010	--	3.0	.030	--	<.010
--	6.2	263	.020	2.2	2.2	.100	--	<.010
35	6.1	256	<.010	--	1.9	<.010	--	.020
--	5.9	241	<.010	--	1.9	.030	--	.040
--	6.0	222	<.010	--	1.5	<.010	--	<.010
27	7.0	219	<.010	--	1.6	<.010	--	.010
--	7.4	218	<.010	--	2.0	<.010	--	.020
--	7.3	218	<.010	--	1.7	<.010	--	<.010
26	6.9	245	--	--	--	--	--	--
--	--	--	.040	2.3	2.3	<.010	--	<.010
9.2	24	232	.010	5.0	5.0	.010	--	.300
23	19	296	--	--	--	--	--	--
--	--	--	<.010	--	5.5	.010	.200	.210

Table 31.-- Chemical analyses of selected common ions in ground water--Continued
[DEG C, degrees Celcius; US/CM, microsiemens per centimeter at 25 degrees Celcius; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TEMPER-ATURE (DEG C)	PH (STAND-ARD UNITS)	SPE-CIFIC CON-DUCT-ANCE (US/CM)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SILICA, DIS-SOLVED (MG/L AS SIO2)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
CH-1577	74-10-29	--	6.0	65	4.7	1.2	17	.60
	83-05-17	--	--	--	4.3	1.2	19	.90
	83-05-18	12.5	5.8	70	--	--	--	--
1585	81-06-10	13.0	6.5	400	--	--	--	--
1595	74-10-30	--	7.9	500	50	20	17	1.3
	83-06-06	15.0	7.6	500	49	21	20	1.6
1600	83-06-16	17.5	6.8	345	30	7.3	29	2.9
1613	74-10-30	--	6.1	320	13	2.4	.3	2.0
	83-05-17	12.5	6.2	195	21	3.6	23	1.7
1616	74-10-30	--	5.4	160	4.0	5.0	6.1	1.0
	83-05-13	13.5	4.9	170	6.4	5.4	6.3	1.1
1631	74-10-30	--	6.4	185	21	4.8	22	1.8
	83-06-08	13.0	6.2	185	16	5.5	23	1.9
1969	83-06-21	14.0	7.0	750	110	16	12	2.1
1973	83-12-16	12.5	7.1	525	--	--	--	--
	84-01-25	11.0	7.0	495	--	--	--	--
	84-02-23	11.0	7.2	575	--	--	--	--
	84-03-20	12.0	7.3	560	62	41	--	.60
	84-04-25	12.0	7.2	605	--	--	--	--
	84-05-23	13.0	6.9	570	--	--	--	--
	84-06-14	14.0	7.1	565	62	40	6.5	.70
	84-07-19	13.0	7.0	570	--	--	--	--
	84-08-24	13.5	7.2	530	--	--	--	--
	84-09-19	13.0	7.2	550	57	37	--	.80
	84-10-05	13.0	7.4	515	--	--	--	--
	84-11-26	12.0	7.0	515	--	--	--	--
	84-12-12	12.0	7.3	570	57	36	--	.80
1976	75-04-01	--	7.6	495	56	30	7.9	2.5
	83-05-31	11.0	7.2	570	56	36	7.8	2.2
	84-06-04	14.0	7.1	635	--	--	--	--
1978	83-07-13	12.0	7.4	395	45	16	9.3	1.5
	84-08-30	15.0	7.6	420	--	--	--	--
1983	80-06-04	12.0	6.8	1300	--	--	--	--
2046	81-05-29	17.0	6.1	440	--	--	--	--
	83-06-27	17.0	6.3	525	41	19	31	2.9
2087	75-04-01	--	9.2	245	4.0	28	9.5	.90
	83-05-11	12.0	8.9	270	4.7	32	10	1.0
2089	84-06-04	17.0	6.4	255	--	--	--	--
2100	74-11-01	--	6.2	210	18	6.8	14	1.1
	83-06-08	12.5	6.1	275	26	9.7	28	1.7
2107	75-04-01	--	6.3	110	9.0	2.9	23	1.2
	83-05-13	12.0	6.1	120	11	3.6	25	1.3
2134	75-04-02	--	7.8	400	42	24	10	1.9
	83-05-11	12.5	·7.5	475	47	27	11	2.0
2136	81-08-19	14.0	7.1	650	--	--	--	--
	82-06-22	13.0	7.2	600	52	32	7.6	3.7
2148	84-06-01	12.5	7.4	680	71	40	8.1	6.9
2149	72-04-20	--	7.5	--	--	--	--	--
	83-06-09	--	--	--	64	14	26	.80
2153	72-08-11	--	7.3	--	--	--	--	--
	83-09-06	13.0	6.8	160	12	4.7	40	1.5
2197	61-10-24	--	5.5	31	1.2	.50	8.5	1.2
	83-06-01	12.0	4.7	43	.91	1.4	8.2	1.4
	85-06-18	14.0	4.9	41	.81	1.4	--	--
2198	61-10-02	--	7.3	783	82	45	10	4.0
	83-06-01	13.0	7.5	620	62	35	7.9	1.8

SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, DIS- SOLVED (MG/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)
2.2	3.3	59	<.010	.53	.53	<.010	--	.050
4.5	5.0	49	--	--	--	--	--	--
--	--	--	<.010	--	.50	<.010	.040	.020
--	--	--	<.010	--	1.5	.060	--	--
15	41	282	<.010	2.3	2.3	<.010	--	.060
17	27	308	<.010	--	2.1	<.010	.070	.060
44	11	188	<.010	--	<.10	.010	.010	<.010
15	5.0	85	<.010	2.5	2.5	<.010	--	<.010
15	20	145	<.010	--	3.4	<.010	.010	<.010
25	14	64	<.010	.55	.55	.010	--	<.010
28	22	99	<.010	--	1.7	<.010	<.010	<.010
23	8.7	102	<.010	2.2	2.2	<.010	--	.010
20	10	126	.010	3.0	3.0	.010	.010	.010
56	61	486	--	--	--	--	--	--
31	9.5	313	<.010	--	1.7	.010	--	<.010
--	8.5	327	<.010	--	2.3	<.010	--	.020
--	9.2	365	.030	1.3	1.3	.100	--	.010
42	48	348	<.010	--	1.4	<.010	--	<.010
--	9.7	413	<.010	--	2.9	.040	--	<.010
--	9.0	379	<.010	--	2.8	.050	--	<.010
44	8.8	383	<.010	--	2.8	.190	<.010	<.010
--	10	362	<.010	--	3.0	<.010	--	.020
--	9.6	298	<.010	--	2.7	<.010	--	.010
39	.00	307	<.010	--	2.8	<.010	--	.100
--	11	315	<.010	--	2.7	.020	--	<.010
--	10	288	<.010	--	3.0	<.010	--	<.010
37	11	305	--	--	--	--	--	--
35	8.4	307	.010	2.6	2.6	<.010	--	.010
38	22	319	<.010	--	.87	<.010	<.010	<.010
--	--	--	--	--	--	--	--	--
16	18	237	<.010	--	3.0	.030	.030	.010
--	--	--	--	--	--	--	--	--
--	--	--	.000	4.7	4.7	.000	--	--
--	--	--	.010	2.0	2.0	.020	--	--
24	56	293	.010	1.1	1.1	<.010	.080	<.010
1.7	8.2	139	<.010	2.5	2.5	.020	--	.010
3.2	8.8	145	<.010	--	2.7	<.010	<.010	<.010
--	--	--	<.010	--	.13	.080	<.010	<.010
26	5.4	129	<.010	3.8	3.8	<.010	--	.010
28	16	206	.010	8.9	8.9	.010	.020	.010
2.1	8.2	100	.010	2.4	2.4	.010	--	.010
4.3	8.5	79	<.010	--	2.2	<.010	<.010	<.010
24	11	250	.010	2.7	2.7	.010	--	.010
71	15	238	.010	3.7	3.7	.020	<.010	<.010
--	--	--	<.010	--	1.7	.010	--	--
31	23	329	<.010	--	1.8	.030	<.010	.010
180	3.5	562	<.010	--	<.10	.120	<.010	<.010
19	11	196	--	7.7	--	--	--	--
120	13	342	--	--	--	--	--	--
20	2.5	124	--	.10	--	--	--	.670
19	2.3	89	<.010	--	<.10	<.010	.050	.020
.8	3.2	26	--	.11	--	--	--	--
6.6	3.3	43	<.010	--	.62	<.010	<.010	<.010
5.5	3.9	28	--	--	--	--	--	--
32	25	474	--	21	--	--	--	--
26	5.9	350	<.010	--	4.4	.020	--	<.010

Table 31.-- Chemical analyses of selected common ions in ground water--Continued
[DEG C, degrees Celcius; US/CM, microsiemens per centimeter at 25 degrees Celcius; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TEMPER-ATURE (DEG C)	PH (STAND-ARD UNITS)	SPE-CIFIC CON-DUCT-ANCE (US/CM)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SILICA, DIS-SOLVED (MG/L AS SIO2)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
CH-2199	84-08-27	14.0	7.2	485	45	28	8.8	1.6
2240	76-05-10	12.0	5.8	--	9.2	1.7	11	.80
	83-05-23	12.0	5.4	70	4.4	2.4	10	1.1
2321	75-04-01	11.0	6.0	130	10	7.0	19	.10
	83-09-08	13.0	5.8	235	22	12	33	.50
2322	75-04-02	--	6.1	400	25	16	18	1.6
	83-05-13	11.0	6.3	350	20	11	16	1.0
2402	80-06-03	12.0	6.7	1200	--	--	--	--
2405	80-06-04	12.5	6.5	190	--	--	--	--
2411	80-08-26	13.0	7.8	950	--	--	--	--
	81-08-18	14.0	7.3	1100	--	--	--	--
	82-07-22	14.0	7.3	950	56	35	8.6	3.9
	83-07-14	16.0	7.0	1000	--	--	--	--
2425	81-05-28	13.5	5.4	190	--	--	--	--
2426	81-05-28	13.0	5.6	220	--	--	--	--
	82-06-16	14.0	6.4	195	19	4.0	24	.30
	82-06-17	14.0	6.4	195	--	--	--	--
	82-10-04	13.5	6.7	190	--	--	--	--
2427	81-05-28	14.0	5.3	260	--	--	--	--
2432	81-06-03	12.0	7.1	325	--	--	--	--
2434	81-06-10	15.0	5.4	220	--	--	--	--
2435	81-06-10	16.0	5.7	300	--	--	--	--
2436	81-06-10	12.0	4.5	85	--	--	--	--
2438	81-06-11	13.0	7.4	420	--	--	--	--
2441	81-08-17	18.0	6.6	125	--	--	--	--
2443	81-08-18	15.0	6.6	465	--	--	--	--
	81-10-21	12.0	6.6	500	--	--	--	--
	82-08-03	15.0	6.8	450	52	11	30	.80
2444	81-08-18	15.5	5.8	460	--	--	--	--
	82-08-03	13.0	5.7	445	28	12	6.7	3.0
2445	81-08-18	13.0	7.2	725	--	--	--	--
2447	81-08-19	17.5	6.8	155	--	--	--	--
	82-07-08	19.0	6.5	120	6.6	2.9	32	.80
2448	81-08-21	10.0	8.7	1000	--	--	--	--
	82-07-19	13.0	8.5	675	43	18	7.7	1.7
2449	81-08-21	12.5	7.7	455	--	--	--	--
	82-06-23	15.0	7.3	370	37	17	9.8	3.0
2463	82-06-16	19.0	7.2	390	--	--	--	--
	82-06-17	19.0	7.2	390	27	13	13	1.0
2464	82-06-17	16.0	7.2	510	65	8.5	15	.60
2465	82-06-17	14.0	7.2	480	56	14	16	.70
2466	82-06-21	12.5	5.7	155	10	7.5	6.9	2.4
2468	82-06-02	13.5	6.1	165	--	--	--	--
	82-06-22	13.5	6.1	165	--	--	--	--
2469	82-06-23	13.0	7.0	450	51	11	16	.90
	83-06-30	13.0	7.3	545	51	12	19	3.6
	84-06-28	16.0	7.3	520	--	--	--	--
2470	82-06-23	14.0	7.3	325	40	9.8	9.4	.80
2471	82-06-24	13.5	6.0	225	--	--	--	--
2478	82-08-03	16.0	5.6	6000	470	230	20	9.9
	83-07-07	14.5	5.2	5600	570	270	22	10
2479	82-07-22	13.5	7.1	750	72	47	10	.80
2486	83-06-08	13.5	6.6	185	--	--	--	--
2487	83-06-10	14.0	6.7	210	20	3.7	32	2.4
2488	83-06-16	15.0	6.1	435	38	11	28	2.5

SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, DIS- SOLVED (MG/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)
21	.00	274	<.010	--	2.4	<.010	<.010	<.010
7.8	2.0	60	.010	.19	.20	<.010	--	.060
.2	1.1	61	<.010	--	1.1	<.010	.050	.040
17	3.6	102	<.010	.18	.18	.030	--	<.010
24	13	203	.020	1.6	1.6	.020	.010	<.010
43	66	269	<.010	4.7	4.7	.020	--	.030
30	41	193	<.010	--	3.0	<.010	.060	.040
--	--	--	.000	6.6	6.6	.000	--	--
--	--	--	.010	.02	.03	.010	--	--
--	--	--	.010	.83	.84	1.10	--	--
--	--	--	.000	.76	.76	.930	--	--
38	120	540	<.010	--	1.1	.990	.020	.020
--	--	--	--	--	--	--	--	--
--	--	--	<.010	--	2.8	.040	--	--
--	--	--	<.010	--	4.8	.030	--	--
9.0	6.6	143	--	--	--	--	--	--
--	--	--	<.010	--	5.7	<.010	.140	.120
--	--	--	--	--	--	--	--	--
--	--	--	.010	6.5	6.5	.060	--	--
--	--	--	<.010	--	.14	.020	--	--
--	--	--	<.010	--	5.3	.050	--	--
--	--	--	.010	3.8	3.8	.060	--	--
--	--	--	.010	.81	.82	.040	--	--
--	--	--	.010	2.6	2.6	.030	--	--
--	--	--	.010	.37	.38	.010	--	--
--	--	--	.000	3.1	3.1	.010	--	--
--	--	--	--	--	--	--	--	--
18	30	276	<.010	--	3.2	.030	.150	.150
--	--	--	.010	7.0	7.0	.080	--	--
58	47	259	<.010	--	7.8	.040	<.010	.010
--	--	--	.000	2.1	2.1	.010	--	--
--	--	--	<.010	--	.02	<.010	--	--
17	1.2	92	<.010	--	<.10	.060	.120	.020
--	--	--	1.60	4.7	6.3	4.40	--	--
36	45	441	.670	4.9	5.6	3.30	.260	.250
--	--	--	.070	.01	.08	.180	--	--
19	9.3	193	<.010	--	<.10	.100	<.010	<.010
--	--	--	<.010	--	1.0	<.010	<.010	<.010
35	20	238	--	--	--	--	--	--
99	9.1	330	<.010	--	.22	<.010	.010	<.010
28	21	299	<.010	--	6.1	<.010	.050	.040
12	5.8	98	<.010	--	4.2	.040	<.010	.010
--	--	--	<.010	--	2.1	.030	--	--
--	--	--	--	--	--	--	--	--
20	35	251	<.010	--	4.6	.020	.050	.040
23	41	264	<.010	--	4.0	<.010	.080	.050
--	--	--	--	--	--	--	--	--
15	8.9	197	<.010	--	1.5	.050	.010	.020
--	--	--	<.010	--	.81	.040	--	--
72	1800	4050	<.010	--	.94	.200	.010	.010
36	2100	4370	--	--	--	--	--	--
32	12	415	--	--	--	--	--	--
--	7.4	106	.010	3.3	3.3	.010	.020	.010
24	12	124	.010	--	<.10	.020	.020	.010
29	26	361	<.010	--	27	.010	<.010	<.010

Table 31.-- Chemical analyses of selected common ions in ground water--Continued
[DEG C, degrees Celcius; US/CM, microsiemens per centimeter at 25 degrees Celcius; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TEMPER-ATURE (DEG C)	PH (STAND-ARD UNITS)	SPE-CIFIC CON-DUCT-ANCE (US/CM)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SILICA, DIS-SOLVED (MG/L AS SIO2)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
CH-2489	83-06-15	12.0	6.6	175	21	8.1	29	1.4
2490	83-06-16	14.0	7.6	235	19	8.9	29	.70
2491	82-02-23	--	--	--	--	--	--	--
	83-12-14	13.0	5.8	295	--	--	--	--
	84-01-18	11.0	5.4	285	--	--	--	--
	84-02-23	--	5.7	295	--	--	--	--
	84-03-22	12.5	6.0	290	20	8.3	--	1.7
	84-04-25	12.5	5.3	305	--	--	--	--
	84-05-23	15.0	5.2	310	--	--	--	--
	84-06-14	16.0	5.3	310	20	7.8	24	1.7
	84-07-19	15.0	5.7	305	--	--	--	--
	84-08-24	15.0	5.4	310	--	--	--	--
	84-09-19	15.0	5.8	295	22	8.0	--	1.7
	84-10-05	14.5	5.8	325	--	--	--	--
	84-11-26	13.0	5.7	310	--	--	--	--
	84-12-12	--	--	--	20	7.3	--	1.7
	84-12-12	13.0	5.5	290	--	--	--	--
2494	83-06-21	13.0	7.4	820	86	54	7.5	1.1
2499	83-06-23	15.0	6.4	270	30	6.4	32	1.0
2502	83-06-29	12.0	6.1	312	20	4.9	24	19
2535	84-06-01	13.5	7.0	1100	--	--	--	--
	84-06-26	14.0	7.1	1100	--	--	--	--
2542	83-12-16	13.0	7.4	515	--	--	--	--
	84-01-25	11.0	7.3	510	--	--	--	--
	84-02-23	11.0	7.2	515	--	--	--	--
	84-03-20	12.0	7.6	525	56	33	--	1.6
	84-04-25	12.0	7.2	570	--	--	--	--
	84-05-23	14.0	7.1	530	--	--	--	--
	84-06-14	15.0	7.2	535	59	32	--	1.6
	84-07-19	14.5	7.2	515	--	--	--	--
	84-08-27	15.0	7.0	515	--	--	--	--
	84-09-19	14.0	7.1	520	60	33	--	1.6
	84-10-05	14.0	7.3	505	--	--	--	--
	84-11-26	12.0	7.4	495	--	--	--	--
	84-12-12	12.0	7.2	520	58	32	--	1.6
2545	84-08-30	15.0	7.6	610	--	--	--	--
2549	84-10-31	15.0	7.4	580	--	--	--	--
	85-04-30	15.5	7.1	430	--	--	--	--
2556	84-10-31	17.0	6.3	1340	--	--	--	--
2558	84-10-31	18.0	7.2	875	--	--	--	--
2562	85-03-28	12.0	7.4	510	--	--	--	--
2563	84-10-31	14.0	6.2	840	--	--	--	--
2574	85-03-28	12.5	6.0	<1000	--	--	--	--
2606	85-04-30	17.5	7.4	360	--	--	--	--
2613	84-06-01	15.0	7.0	925	--	--	--	--
	84-06-04	15.0	7.0	925	--	--	--	--
	84-06-04	15.0	7.0	925	--	--	--	--
2664	84-01-31	13.0	5.8	190	--	--	--	--
	84-02-29	13.5	5.6	190	--	--	--	--
	84-03-22	13.0	6.2	190	15	5.8	--	.80
	84-04-25	14.0	5.8	190	--	--	--	--
	84-05-17	14.0	5.5	200	--	--	--	--
	84-06-13	15.5	5.2	205	15	5.6	11	.80
	84-07-24	15.0	5.9	190	--	--	--	--
	84-07-24	15.0	5.9	190	--	--	--	--

SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, DIS- SOLVED (MG/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)
27	12	199	.010	6.3	6.3	.010	.040	.020
8.4	5.2	144	<.010	--	1.9	<.010	.120	.110
--	22	210	--	--	--	--	--	--
55	24	202	<.010	--	7.4	<.010	--	<.010
--	24	221	.020	8.4	8.4	.130	--	.080
--	22	210	.030	7.0	7.0	.070	--	.020
36	22	180	<.010	--	5.0	.350	--	<.010
--	20	230	.020	8.4	8.4	.110	--	<.010
--	20	235	.020	2.6	2.6	.820	--	1.10
55	20	208	<.010	--	7.4	.100	<.010	<.010
--	22	211	<.010	--	4.8	.050	--	.030
--	20	192	<.010	--	9.8	<.010	--	<.010
34	21	187	<.010	--	4.3	<.010	--	<.010
--	21	184	<.010	--	6.5	.050	--	.060
--	23	195	<.010	--	7.0	<.010	--	.020
45	23	190	--	--	--	--	--	--
--	--	--	.040	8.0	8.0	.010	--	.030
82	9.4	531	--	--	--	--	--	--
18	20	153	<.010	--	2.2	<.010	.050	<.010
1.9	35	--	<.010	--	8.1	<.010	.060	<.010
--	--	--	<.010	--	3.0	.060	<.010	<.010
--	--	--	--	--	--	--	--	--
65	9.8	313	<.010	--	.16	<.010	--	<.010
--	8.1	310	<.010	--	.16	<.010	--	<.010
--	10	331	.020	.13	.15	.040	--	<.010
64	10	309	<.010	--	.10	<.010	--	<.010
--	10	348	.010	.23	.24	.060	--	.010
--	9.5	360	.010	.15	.16	.060	--	<.010
67	10	381	<.010	--	.16	<.010	--	.010
--	10	380	<.010	--	.19	<.010	--	<.010
--	9.4	303	<.010	--	.18	.030	--	<.010
66	9.6	318	<.010	--	.16	<.010	--	.160
--	10	313	<.010	--	.23	<.010	--	<.010
--	9.1	299	<.010	--	.20	<.010	--	<.010
63	8.6	315	.070	.10	.17	.020	--	.020
--	--	--	<.010	--	2.7	<.010	<.010	<.010
--	--	--	--	--	--	--	--	--
--	34	328	--	--	--	--	--	--
8.1	350	--	.010	3.2	3.2	--	--	--
4.9	160	--	<.010	--	.82	--	--	--
--	--	--	<.010	--	2.1	<.010	--	.020
5.2	200	--	<.010	--	.72	--	--	--
--	290	672	<.010	--	2.3	<.010	--	<.010
--	19	219	--	--	--	--	--	--
--	--	--	<.010	--	5.3	.050	<.010	<.010
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	17	130	<.010	--	7.3	<.010	--	<.010
--	18	139	<.010	--	5.6	.060	--	.020
13	18	129	<.010	--	6.7	<.010	--	<.010
--	16	159	<.010	--	8.4	<.010	--	<.010
--	16	151	<.010	--	6.1	.240	--	.020
18	17	148	<.010	--	6.5	.170	--	.020
--	--	--	<.010	--	6.2	.090	--	.040
--	15	145	--	--	--	--	--	--

Table 31.-- Chemical analyses of selected common ions in ground water--Continued
[DEG C, degrees Celcius; US/CM, microsiemens per centimeter at 25 degrees Celcius; MG/L, milligrams per liter; a dash indicates no data]

WELL NUMBER	DATE OF SAMPLE	TEMPER-ATURE (DEG C)	PH (STAND-ARD UNITS)	SPE-CIFIC CON-DUCT-ANCE (US/CM)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SILICA, DIS-SOLVED (MG/L AS SIO2)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
CH-2664	84-08-28	15.0	5.7	195	--	--	--	--
	84-08-28	15.5	5.7	200	--	--	--	--
	84-08-28	15.5	5.6	205	--	--	--	--
	84-09-27	13.0	5.7	185	16	5.5	--	.70
	84-10-24	--	--	--	--	--	--	--
	84-10-30	14.0	5.7	180	--	--	--	--
	84-11-28	--	--	--	--	--	--	--
	84-11-28	13.5	5.8	265	--	--	--	--
	84-12-18	14.0	5.5	190	16	5.6	--	.70
2671	85-03-28	9.5	7.0	124	--	--	--	--
2676	84-06-07	13.0	7.2	765	--	--	--	--
2677	84-06-05	13.0	7.1	620	--	--	--	--
2680	84-06-14	14.0	6.3	245	26	5.4	25	.70
2681	84-06-26	14.0	6.7	485	21	8.7	15	1.7
2748	84-06-28	20.0	6.8	300	--	--	--	--
2749	84-06-29	14.0	6.9	350	--	--	--	--
2750	84-06-05	14.0	6.3	500	--	--	--	--
2751	84-06-06	16.0	6.1	210	--	--	--	--
2801	84-08-29	15.0	6.2	570	--	--	--	--
2802	84-08-15	14.0	5.2	160	--	--	--	--
SP-23	84-05-25	14.0	5.9	170	--	--	--	--

SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, DIS- SOLVED (MG/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)
--	19	117	<.010	--	6.8	<.010	.010	.020
--	18	117	<.010	--	5.3	<.010	.020	.030
--	17	119	<.010	--	4.8	<.010	.010	.020
12	16	111	<.010	--	6.1	.080	--	.030
--	17	131	--	--	--	--	--	--
--	--	--	<.010	--	6.2	.040	--	.020
--	17	114	--	--	--	--	--	--
--	--	--	<.010	--	5.7	.070	--	.020
9.8	17	107	<.010	--	6.9	<.010	--	.020
--	2.1	73	<.010	--	.11	<.010	--	.060
--		--	<.010	--	.14	1.40	.050	<.010
--	--	--	<.010	--	3.1	.100	<.010	.010
39	13 --	179	<.010	--	3.0	<.010	.090	.100
19	20	164	<.010	--	2.2	<.010	.060	.060
--	--	--	<.010	--	.87	.200	.020	<.010
--	--	--	.010	.53	.54	.140	.030	<.010
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	.020	3.6	3.6	.210	.020	<.010
--	--	--	<.010	--	9.8	<.010	--	--
--	--	--	--	--	--	--	--	--