Effect of On-Site Wastewater Disposal on Quality of Ground Water and Base Flow—A Pilot Study in Chester County, Southeastern Pennsylvania, 2005

By Lisa A. Senior and Peter J. Cinotto

In cooperation with the
Chester County Water Resources Authority and
Chester County Health Department

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Contents

Abstract 1
Introduction 1
  Purpose and Scope 1
  Description of Study Area 2
    Hydrogeologic Setting 3
    Land Use and Wastewater Disposal 3
  Previous Studies.....3
Study Methods 3
  Selection of Sampling Locations 7
  Collection of Samples 10
  Analysis of Samples.....11
Ground-Water and Base-Flow Water Quality 11
  Inorganic Constituents 12
    General Water Quality.....13
    Nitrate and Other Nutrients 14
    Chloride 14
    Boron 16
  Organic Compounds 17
  Bacteria 20
  Seasonal Base-Flow Quality 24
  Effects of On-Site Wastewater Disposal 29
  Comparison to Results from Previous Studies 29
Summary and Conclusions 30
Acknowledgments 32
References Cited 32

Figures

1-3. Maps showing:
  1. Location of the Broad Run watershed, central Chester County, southeastern Pennsylvania.....2
  2. Bedrock geology in and near the Broad Run watershed, Chester County, Pennsylvania.....4
  3. Land use and location of streamflow-measurement station 01480638, observation well CH-12, and 2005 ground-water and base-flow sampling sites in and near the Broad Run watershed, Chester County, Pennsylvania 5
4. Graph showing streamflow at streamflow-measurement station 01480638, Broad Run at Northbrook, Pa., in 2005 and periods of base-flow and ground-water sample collection. . .6
5. Conceptual schematic showing predominant land use in tributaries selected for sampling in the Broad Run watershed, Chester County, Pennsylvania 7
6. Map showing location of stream sites and specific conductance and stream temperature measured during field survey in and near Broad Run watershed, Chester County, Pa., May 2005 8
7-16. Graphs showing:
  7. Nitrate concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005 15

8. Chloride concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005 16
9. Sodium and chloride concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005. 17
10. Boron concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005 18
11. Number of wastewater compounds detected in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005. 21
12. Bacteria concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005 22
13. Base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005 24
14. Boron concentrations in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005. 25
15. Concentrations of (A) enterococci and (B) fecal coliform bacteria in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005. 26
16. Number of organic wastewater compounds detected in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May-June and September 2005 28

Tables

1. Description of stream sites where base-flow samples were collected in and near the Broad Run watershed, Chester County, Pa., May-June and September 2005. 9
2. Description of ground-water sites where samples were collected in and near the Broad Run watershed, Chester County, Pa., June 2005. 10
3. Concentrations of chloride, boron, and nitrate in ground-water and base-flow samples collected May-June 2005 in and near the Broad Run watershed, Chester County, Pa., listed by land use for each tributary drainage area 12
4. Reported minimum, maximum, and average concentrations of selected constituents in septic-tank effluent 13
5. Organic wastewater compounds detected in samples from 10 surface-water and 10 ground-water sites, May-June and September 2005, Broad Run watershed and vicinity, Chester County, Pa., listed in order of the number of surface-water sites with detections 19
6. Results of laboratory analysis for nitrate, chloride, boron, and selected wastewater compounds in samples collected from 12 wells in summer 2000 or summer 2002 in areas possibly affected by on-site wastewater disposal, Chester County, Pennsylvania . . . 31
7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005 35
8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005. 45

Conversion Factors and Datum Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inches (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Mass	
microgram	35,270	ounce, avoirdupois (oz)
milligram	352.7	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature is given in degrees Celsius (°C) which may be converted to degrees Fahrenheit (°F) as follows:
°F = (1.8 x °C) + 32.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C = (°F - 32) / 1.8

Vertical coordinate information is referenced to the National Geodetic Datum of 1929 (NVGD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L), which are approximately equivalent to parts per million (ppm) or parts per billion (ppb), respectively.

Concentrations of bacteria in water are given in colonies per 100 milliliters (col/100 mL), which is the same as colony forming units per 100 milliliters (CFU/100 mL).

Effect of On-Site Wastewater Disposal on Quality of Ground Water and Base Flow—A Pilot Study in Chester County, Southeastern Pennsylvania, 2005

by Lisa A. Senior and Peter J. Cinotto

Abstract

On-site wastewater disposal has the potential to introduce contaminants into ground water and subsequently, by ground-water discharge, to streams. A pilot study was conducted during 2005 by the U.S. Geological Survey in cooperation with the Chester County Health Department and the Chester County Water Resources Authority to determine if wastewater components, including inorganic constituents and selected organic wastewater compounds, such as detergents, considered to be emerging contaminants, were present in ground water and stream base flow in areas with on-site wastewater disposal. The study area was a small watershed (about 7.1 square miles) of mixed land use drained by Broad Run in central Chester County, Pa. The area is underlain by fractured metamorphic rocks that form aquifers recharged by precipitation. Surface- and ground-water sampling was done in areas with and without on-site wastewater disposal for comparison, including a relatively densely populated village with cesspools and septic systems, a residential area with septic systems, a residential area served by sewers, and agricultural land. Samples were collected in May-June and September 2005 from eight headwater stream sites under base-flow conditions and in June 2005 from eight wells and two springs. Samples were analyzed for major ions, nutrients, boron, bacteria, and a suite of organic wastewater compounds. Several emerging contaminant wastewater compounds, including detergent components, insect repellents, and flame retardants, were detected in base-flow and ground-water samples. Stream base-flow samples generally contained more compounds and higher concentrations of those compounds than did ground-water samples, and of the ground-water samples, samples from springs contained more compounds and higher concentrations than samples from wells. Concentrations of nitrate, chloride, and boron (inorganic constituents associated with wastewater) generally were all elevated in base-flow and ground-water samples in areas with relatively high densities of on-site wastewater disposal (septic systems or cesspools) compared to other areas sampled. Results of this pilot study should be considered preliminary because of limited data.

Introduction

On-site wastewater disposal has the potential to introduce contaminants into ground water and subsequently, by ground-water discharge, to streams. In many rural to semi-rural areas, wastewater disposal through on-site systems is common. In these areas, water supply usually is from on-site wells or springs. Thus, the potential contamination of ground water by on-site wastewater disposal may affect those that use ground water for supply and also the quality of base flow (ground-water discharge to streams).

In Chester County, Pa., and other rural areas undergoing development, the change in land use consists of residential and commercial uses replacing forested or agricultural uses. In many of the areas being developed, residential wastewater is disposed of on-site rather than through sewers to a regional wastewater treatment plant. On-site disposal methods historically have included both septic systems and cesspools for individual residences. Cesspools are no longer permitted in Chester County and most cesspools have been removed from operation. In 2005, a pilot study of the effect of residential on-site wastewater disposal on ground-water and base-flow water quality was conducted by the U.S. Geological Survey (USGS), in cooperation with the Chester County Water Resources Authority and Chester County Health Department, to provide reconnaissance data that may assist in management of water resources in the county.

Purpose and Scope

This report presents and discusses the data collected for a pilot study of the effect of on-site wastewater disposal on ground-water and base-flow water quality in and near a small watershed in central Chester County, Pa., from May to September 2005. Ground-water and base-flow samples were collected in areas predominantly covered by a single land use and with different types of wastewater disposal, including areas with on-site disposal (septic systems and cesspools) and off-site disposal (area sewered). Base-flow samples were collected at 10 headwater stream sites in May 2005, and at 8 of those 10 sites in September 2005, representing different hydrologic conditions. Ground-water samples were collected from eight wells and two springs in June 2005. Water samples were analyzed for major ions, selected trace elements, nutrients, bacteria, and a suite of organic wastewater compounds considered to be emerging contaminants. Ground-water and base-flow water quality in the areas with different land uses are described. Nitrate, chloride, boron, and organic wastewater compounds were considered indicators of wastewater in the ground water and base flow. Differences and similarities in base-flow water quality in spring and fall 2005 are discussed.

Description of Study Area

The study area is approximately bounded by the 7.08 mi^2 Broad Run watershed, a tributary to West Branch Brandywine Creek in central Chester County, Pa. (fig. 1). The area is in the Piedmont Physiographic Province, southeastern Pennsylvania. The topography is characterized by rolling hills. The area has a humid temperate climate and receives an average total annual precipitation of about 48 in. [30-year normal (1971-2000) for meteorological station West Chester 2 NW about 8 mi east of the study area is 47.89 in.] (National Oceanic and Atmospheric Administration, 2005a), which is distributed nearly evenly throughout the year.

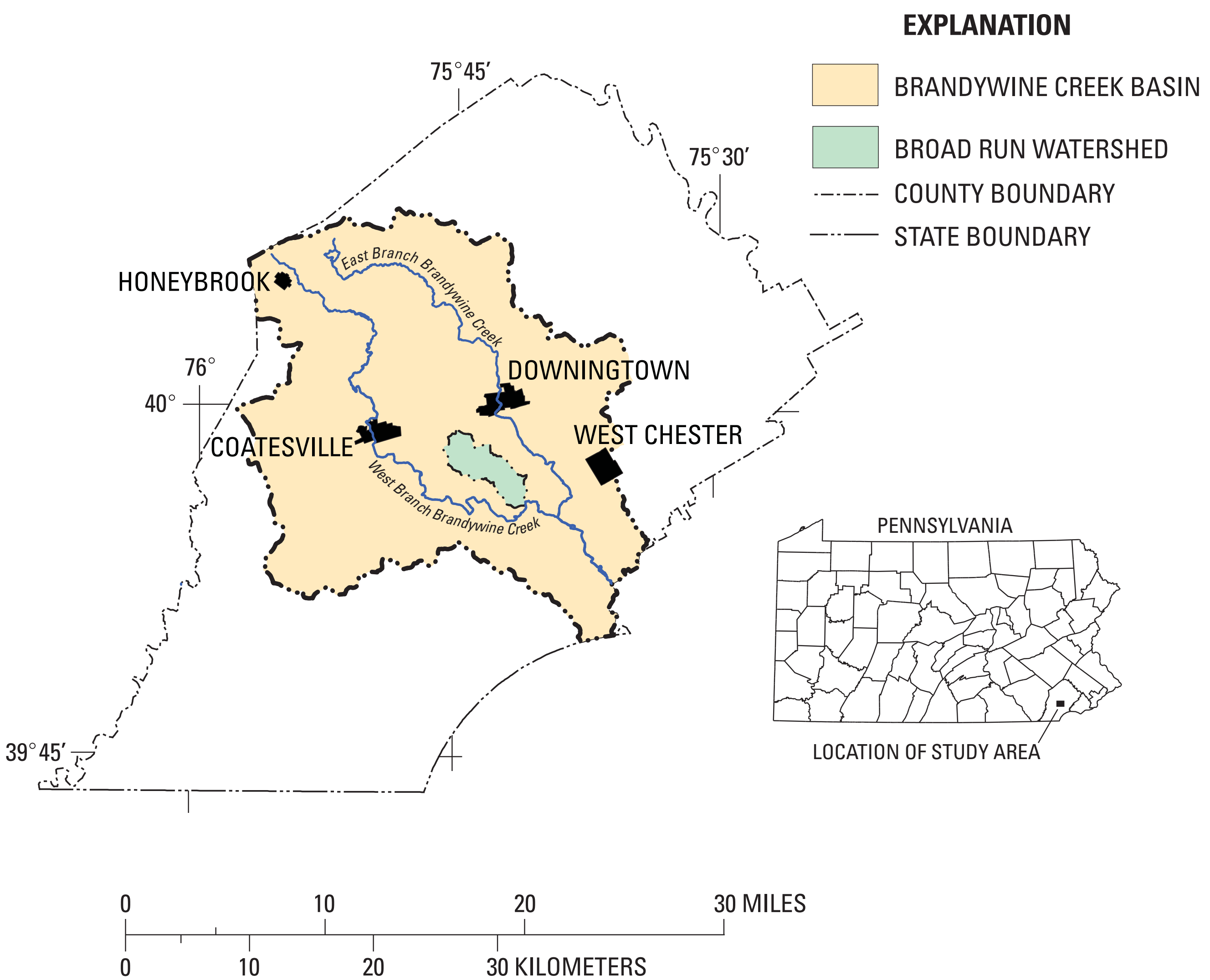


Figure 1. Location of the Broad Run watershed, central Chester County, southeastern Pennsylvania.

Hydrogeologic Setting

The area is underlain by Paleozoic and older metamorphic rocks, including phyllite, schist, marble, and gneiss (fig. 2). A more complete description of the geologic units in the study area is given by Cinotto and others (2005). The competent bedrock is overlain by weathered bedrock (saprolite) and soil. Thickness of the saprolite varies but commonly is 10 to 40 ft. Soils in most of the area are moderately deep and well drained (Cinotto and others, 2005).

The bedrock and overlying saprolite form an unconfined aquifer recharged by precipitation. Recharge infiltrates through soils and saprolite to bedrock and flows through fracture openings in the bedrock and also in the saturated part of the saprolite. Under natural conditions, ground water discharges to streams and springs. The water table generally is a subdued replica of the land surface, as shown by a map of ground-water levels in the area (Garges, 1988), such that ground-water flowpaths commonly follow topography. Base flow (supplied by ground-water discharge to streams) comprises about 82 percent of total annual streamflow in the Broad Run watershed (Cinotto and others, 2005, p. 21).

Depth to water typically varies by topography; depths to water are greater under hilltops than on slopes or in valleys. In a 2003-04 study of the Broad Run watershed, the depth to water in 14 wells ranged from less than 1 ft below land surface (bls) in the stream valley to about 86 ft bls below a hilltop; the magnitude of annual water-level fluctuations in these wells also differed by topographic setting, ranging from about 1 ft in the valley to about 10 ft under a hilltop. Ground-water levels fluctuate seasonally because of changes in net recharge rates; depth to water is greatest in the fall and least in the spring. Although precipitation is distributed nearly evenly throughout the year, net recharge generally is greater in the cooler months (October-April), when evapotranspiration is reduced, than in the warmer months (May-September). Long-term average ground-water levels and base flow are highest in spring and lowest in fall in Chester County, Pa.

Drilled wells generally are completed as open holes in the bedrock, with casing extending through the saprolite to the top of competent bedrock. Hand-dug wells generally are completed in the saprolite.

Land Use and Wastewater Disposal

Land use in the study area is mixed (fig. 3), consisting of agricultural (33 percent), wooded (29 percent), residential (27 percent), recreational (golf course) (8 percent), and other uses (schools, utilities, water) (about 3 percent) in the Broad Run watershed (Cinotto and others, 2005, p. 4). Agricultural products and uses include row crops, orchards, hay, and dairy cow and horse pasture. Residential areas can be characterized as relatively dense village (Marshallton), suburban (lot size of 1 to 2 acres or smaller), or rural suburban (lot size greater than 2 acres). The village of Marshallton has been settled since at least 1760. Most of the suburban residential development has occurred since 1970.

Wastewater disposal in most of the residential areas during the period of study (2005) was through on-site systems, largely consisting of septic systems but also including some cesspools in the village of Marshallton. In the northern part of the study area, a public wastewater system operated by the Utilities Inc. of Pennsylvania serves residential areas and there is little to no on-site wastewater disposal. Wastewater in this sewered area is exported out of the watershed, treated at the Broad Run sewer plant, and discharged to the East Branch Brandywine Creek. There is no in-stream discharge of treated wastewater within the study area. A municipal wastewater collection and land application system was under construction for some portions of the study area and that system has been in operation since the completion of this study.

Previous Studies

Data on stream-water quality in the Broad Run watershed were collected during recent studies by Senior and Koerkle (2003a; 2003b) and Cinotto and others (2005). Ground-water-quality data in areas with on-site wastewater disposal have been collected by USGS in cooperation with the Chester County Water Resources Authority and Chester County Health Department since 2000 as part of an ongoing Chester County ground-water-quality monitoring program. These data included analyses for emerging contaminant organic wastewater compounds such as detergent metabolites, selected antibiotics, hormones, and others, as well as analyses for inorganic constituents that are wastewater indicators such as nitrate, ammonia, chloride, and boron. Most of the data have been published (Durlin and Schaffstall, 2001, p. 429-433; 2003, p. 512-515), but some of the data on emerging contaminants collected in 2000 and on antibiotics collected in 2002 have not been published prior to this report.

Study Methods

Stream samples under base-flow conditions were collected twice and ground-water samples were collected once in the period from May to September 2005 to provide reconnaissance-level data for the pilot study (fig. 4). Data were collected for a preliminary assessment of potential effects of on-site wastewater disposal on ground-water and base-flow water quality and were not intended to support statistical analyses. The assessment was done by describing results and comparing results within this study to other studies. Because of limited data and lack of statistical analysis to evaluate differences in water quality among land uses, conclusions should be considered preliminary and results should be interpreted with caution. Comparisons of concentrations in samples from various land uses were not tested statistically and are presented as being higher or lower in a relative sense.

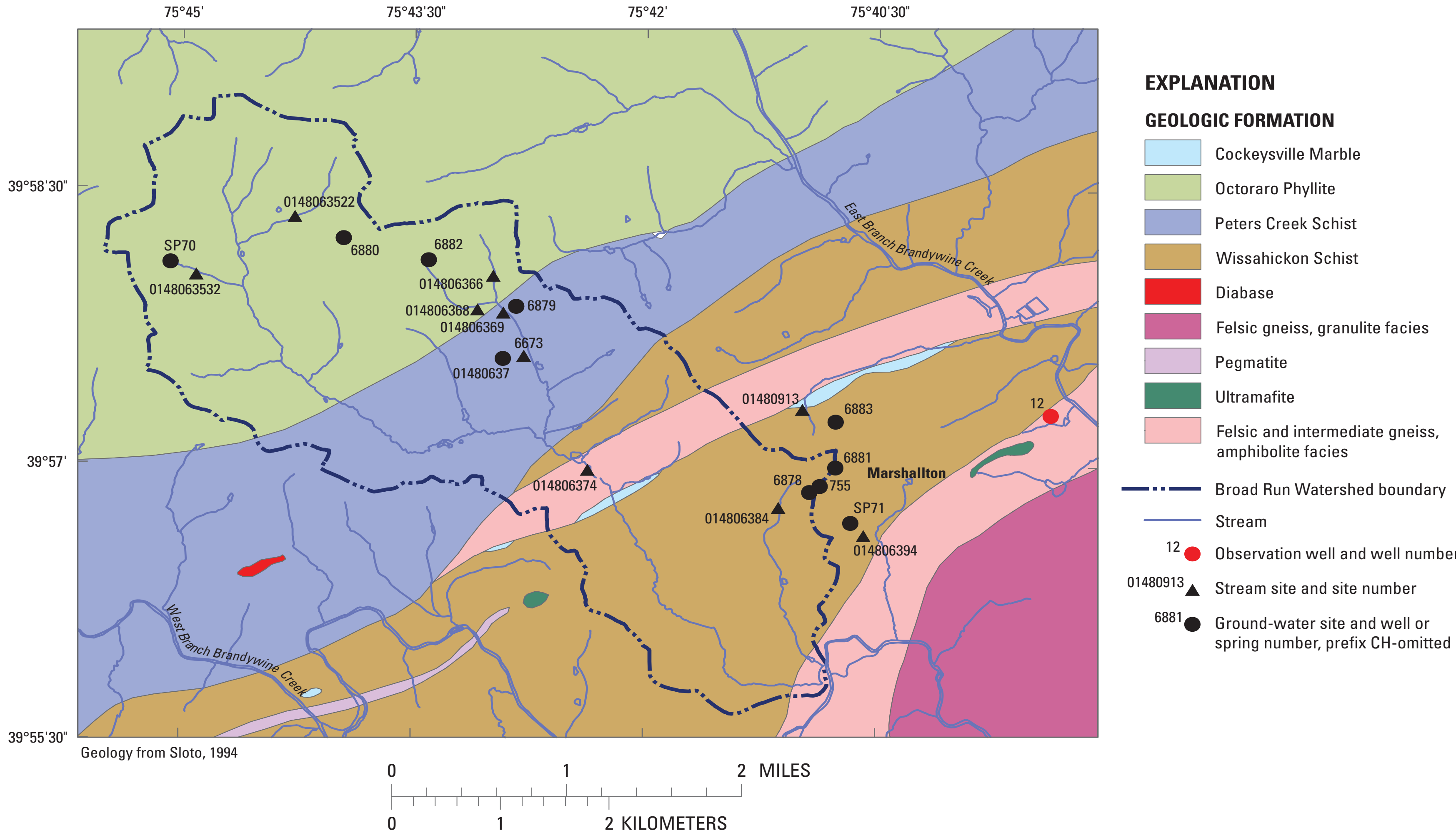


Figure 2. Bedrock geology in and near the Broad Run watershed, Chester County, Pennsylvania. Location of wells and stream sites sampled in 2005 and long-term observation well CH-12 also are shown.

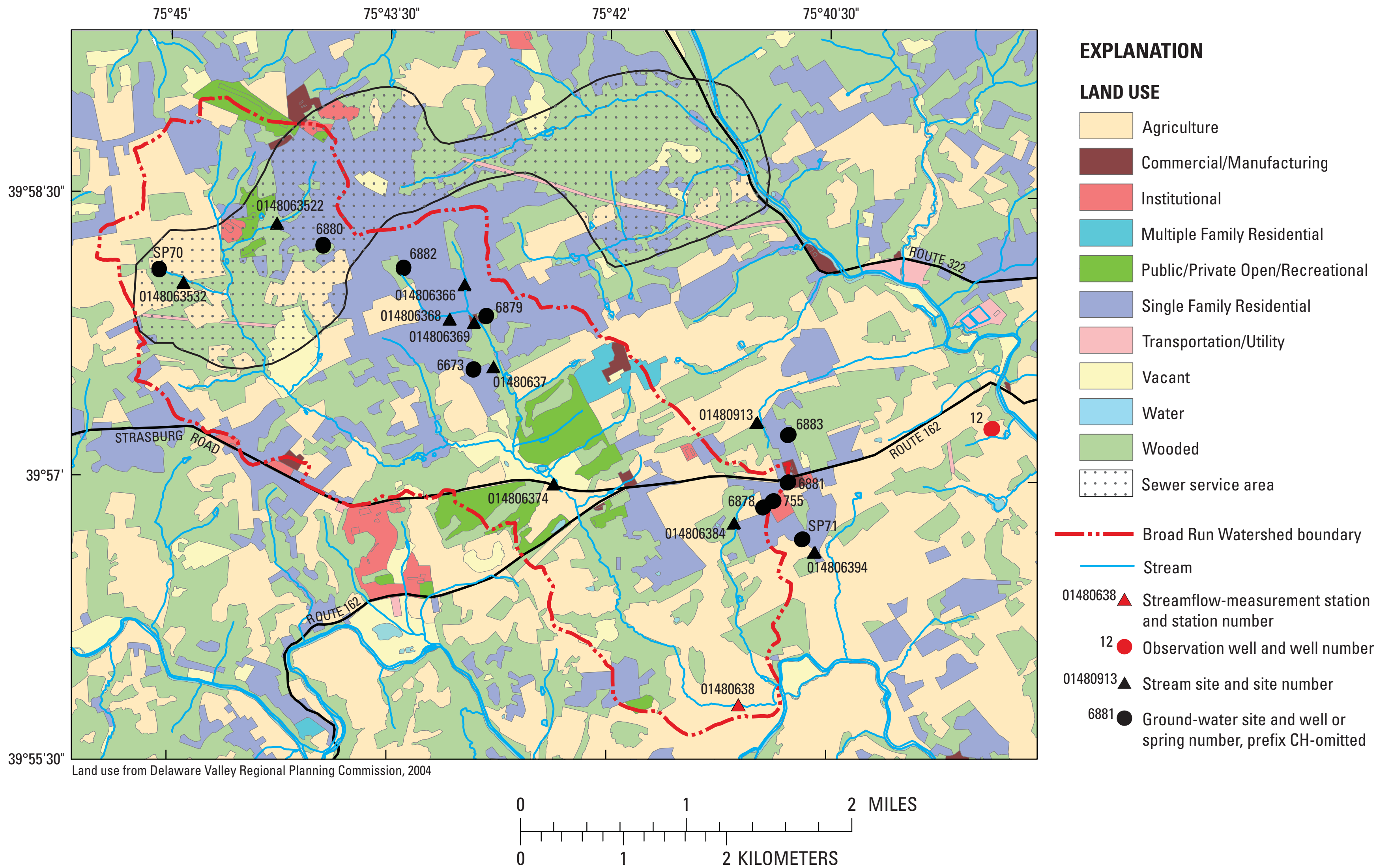


Figure 3. Land use in 2000 and location of streamflow-measurement station 01480638, observation well CH-12, and 2005 ground-water and base-flow sampling sites in and near the Broad Run watershed, Chester County, Pennsylvania.

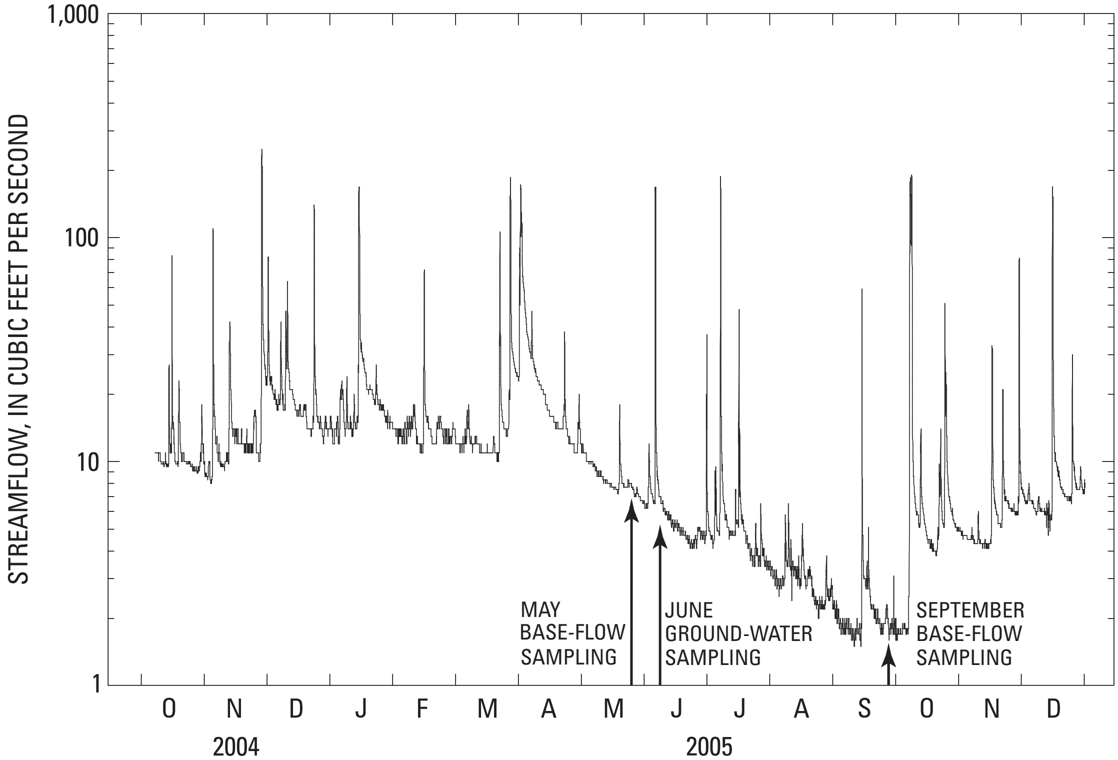


Figure 4. Streamflow at streamflow-measurement station 01480638, Broad Run at Northbrook, Pa., in 2005 and periods of base-flow and ground-water sample collection

The sampling times were selected to collect stream samples under high base-flow (May-June 2005) and low base-flow (September 2005) conditions to determine if water quality was affected by hydrologic conditions. The ground-water samples were collected in mid-June 2005 to approximately represent ground-water quality at the time of the late May base-flow sampling. Streamflow in May and September 2005 in the study area was probably below average for those months. Long-term averages are not available for Broad Run because the streamflow record only began in 2003, but estimates can be made using streamflow data for nearby unregulated streams. Using long-term (1960-2005) data at streamflow-measurement station 01480300, West Branch Brandywine Creek near Honeybrook, Pa., a site with a relatively small drainage area (18.7 mi^2), May 2005 streamflow was about 27 percent below average and September 2005 streamflow was about 66 percent below average (Durlin and others, 2006). Ground-water levels in a nearby observation well CH-12 (Durlin and others, 2006) were slightly higher in June 2005 than the long-term median for that month and slightly lower in September 2005 than the long-term median for that month. Descriptions of the sampling locations and procedures for collecting and analyzing samples follow.

Selection of Sampling Locations

Land use in headwater areas of some tributaries to Broad Run is relatively homogenous (fig. 3). Because recharge and discharge are local in the headwater areas, ground water and base flow in tributary subbasins might be expected to show the effects of those specific land uses. Sampling locations were selected to characterize ground-water and base-flow water quality in drainage areas of each land use. A conceptual schematic of land use in areas drained by tributaries selected for sampling is shown in fig. 5. Sites were selected for the following land-use areas: agricultural (minimal human on-site wastewater disposal), residential area with sewers, residential area with moderate density on-site wastewater disposal (septic systems), and residential area with high-density on-site wastewater disposal (cesspools and septic systems). Locations of the 10 stream sites and 10 ground-water sites sampled are shown in figs. 2 and 3.

Prior to finalizing the location of stream-sampling sites, a field survey of stream temperature and specific conductance was completed in mid-May 2005 in tributaries within the Broad Run watershed to locate areas of ground-water discharge (on the basis of temperature) and to identify areas of different water quality (on the basis of specific conductance) (fig. 6). Stream temperatures ranged from 11.5 to 15.9 degrees Celsius, up to 10 degrees Celsius cooler than the average air temperature (23 degrees Celsius) in the week prior to the survey, as reported at the meteorological station in West Chester (West Chester 2 NW) by the National Oceanic and Atmospheric Administration (2005b); stream temperatures similar to ground-water temperature (about 12 degrees Celsius) indicate nearby ground-water discharge to the streams. In these small streams, water temperatures can be raised rapidly by exposure to sun and warm air. The specific conductance, a measure of dissolved constituents, ranged from 114 to 368 µS/cm. One of the stream sites (014806374, fig. 3) selected during the survey for sampling was a seep from a hillside in an agricultural area undergoing new land development, was near a suspected leaking sewer, and had the highest specific conductance of 368 µS/cm. This site is not discussed at length later in the report because it is unlike the other headwater stream sites selected for sampling, and sampling results indicate little or no water-quality problems there.

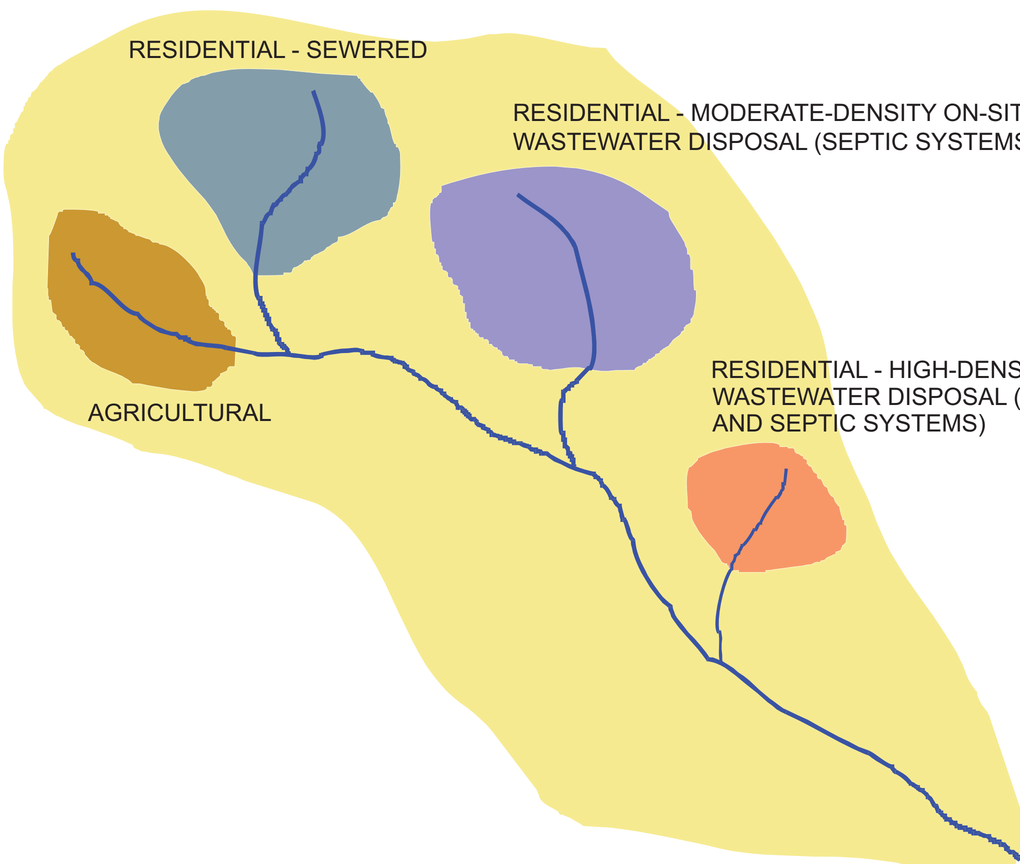


Figure 5. Conceptual schematic showing predominant land use in tributaries selected for sampling in the Broad Run watershed, Chester County, Pennsylvania.

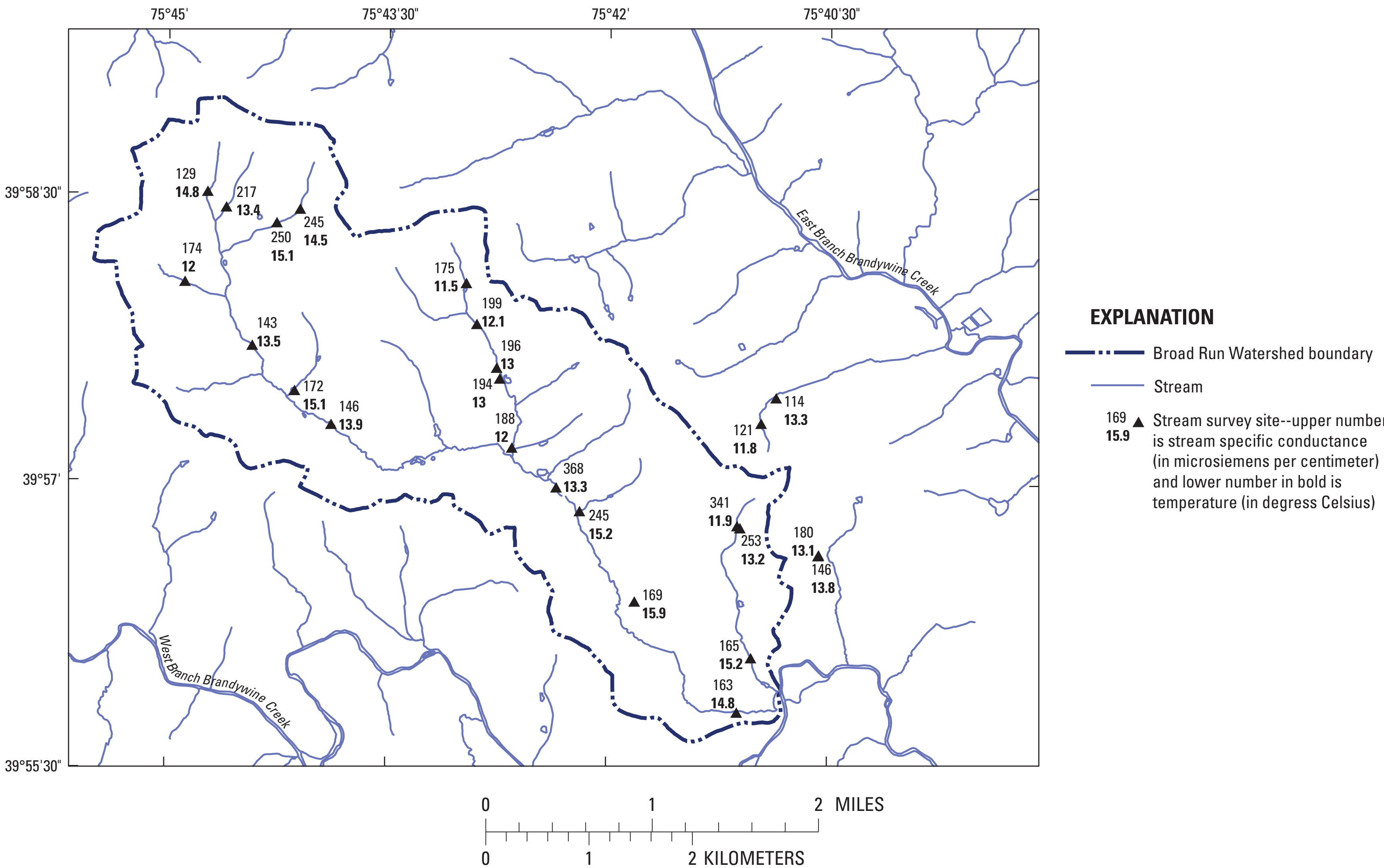


Figure 6. Location of stream sites and specific conductance and stream temperature measured during field survey in and near Broad Run watershed, Chester County, Pa., May 2005.

Base-flow samples were collected at 10 stream sites in May-June 2005 and at 8 of the 10 sites in September 2005. Originally, all 10 stream sites were sampled in May but 3 had to be resampled for wastewater compound analysis in June 2005 because of laboratory problems with the original samples. Two of the 10 stream sites could not be re-sampled in September 2005 because there was no flow (site 0148063522 and 014806374, fig. 3); 1 (site 014806374) of the 2 stream sites that went dry was from a hillside seep discussed above. Ground-water samples were collected from eight wells and two springs (fig. 3) in June 2005. Depths to water ranged from about 18 to 64 ft bls in six wells in which water levels were measured. The depth to water measured in well CH-6673 in June 2005 was 30 to 40 ft greater than had previously been measured in the well, suggesting that the well may have been pumped recently prior to the time of water-level measurement. Well depths ranged from 92 to 430 ft in four wells with construction information. Some differences in ground-water quality may be related to different depths and flow paths of ground water supplying wells and springs, which are unknown or little known in the study area. Descriptions of the stream sites and well characteristics are given in tables 1 and 2.

Table 1. Description of stream sites where base-flow samples were collected in and near the Broad Run watershed, Chester County, Pa., May-June and September 2005.

[mi^2, square miles; NAD 27, North American Datum of 1927; DDMMSS, degrees, minutes, seconds; --, no data]

U.S. Geological Survey site identification number	Site name	Drainage area (mi^2)	Location (NAD 27)		Predominant land use in drainage area (type of wastewater disposal)
			Latitude (DDMMSS)	Longitude (DDMMSS)	
0148063522	Unnamed tributary to Broad Run above school near Thorndale, Pa.	0.24	39°58’21”	75°44’15”	Residential (sewer)
0148063532	Unnamed tributary to Broad Run at Chestnut Lane near Thorndale, Pa.	.27	39°58’02”	75°44’53”	Agricultural (on-site wastewater disposal)[1]
014806366	Little Broad Run above Shadyside Road near Romansville, Pa.	.11	39°58’02”	75°42’58”	Residential (on-site wastewater disposal)
014806368	Unnamed tributary to Little Broad Run near Romansville, Pa.	.21	39°57’51”	75°43’04”	Residential (on-site wastewater disposal) and some agricultural
014806369	Little Broad Run below Shadyside Road near Romansville, Pa.	.49	39°57’50”	75°42’54”	Residential (on-site wastewater disposal)
01480637	Little Broad Run near Marshallton, Pa.	.60	39°57’38”	75°42’44”	Residential (on-site wastewater disposal)
014806374	Outfall tributary to Broad Run above Rt. 162 near Marshallton, Pa.	--	39°56’59”	75°42’21”	Agricultural (possible leaking sewer?)
014806384	Unnamed tributary to Broad Run at Marshallton, Pa.	.05	39°56’47”	75°41’07”	Residential (high density on-site wastewater disposal-septic systems and cesspools)
014806394	Unnamed tributary to West Br. Brandywine Cr. at Marshallton, Pa.	.16	39°56’38”	75°40’30”	Residential (high density on-site wastewater disposal-septic systems and cesspools)
01480913	Unnamed tributary to East Br. Brandywine Cr. at Marshallton, Pa.	.06	39°57’19”	75°40’58”	Residential (high density on-site wastewater disposal-septic systems and cesspools) and wooded

[1]In sewer-service area.

Table 2. Description of ground-water sites where samples were collected in and near the Broad Run watershed, Chester County, Pa., June 2005.

[NAD 27, North American Datum of 1927; DDMMSS, degrees, minutes, seconds; ft, feet; NGVD, National Geodetic Vertical Datum of 1929; ft bls, feet below land surface; --, no data; na, not applicable]

U.S. Geological Survey local well or spring number	U.S. Geological Survey site identification number	Location (NAD 27)		Land-surface elevation (ft above NGVD 1929)	Well depth (ft)	Date well drilled (year)	Depth to water (ft bls)	Most recent date of water-level measurement	Predominant land use in drainage area (type of wastewater disposal)
		Latitude (DDMMSS)	Longitude (DDMMSS)						
CH-755	395651075405601	39°56'52"	75°40'55"	390	92	1940	57.3	10/25/1963	Residential (high-density on-site wastewater disposal-septic systems and cesspools)
CH-6673	395735075425301	39°57'35"	75°42'54"	369	430	1990	[1]62.95	6/1/2005	Residential (on-site wastewater disposal)
CH-6878	395654075405001	39°56'54"	75°40'51"	395	--	--	--	--	Residential (high density on-site wastewater disposal-septic systems and cesspools)
CH-6879	395752075424801	39°57'52"	75°42'49"	398	128	1958	41.34	6/2/2005	Residential (on-site wastewater disposal)
CH-6880	395815075435501	39°58'14"	75°43'56"	557	--	--	38.25	6/2/2005	Residential (sewer)
CH-6881	395701075404401	39°57'00"	75°40'45"	405	150	--	24.03	6/6/2005	Residential (high density on-site wastewater disposal-septic systems and cesspools)
CH-6882	395807075432201	39°58'07"	75°43'23"	535	--	--	64.03	6/7/2005	Residential (on-site wastewater disposal)
CH-6883	395715075404401	39°57'15"	75°40'45"	354	--	--	17.89	6/8/2005	Residential (high density on-site wastewater disposal-septic systems and cesspools) and wooded
CH-SP-70	395807075450201	39°58'06"	75°45'03"	425	na	--	0	--	Agricultural (on-site wastewater disposal)[2]
CH-SP-71	395642075403801	39°56'42"	75°40'39"	290	na	--	0	--	Residential (high density on-site wastewater disposal-septic systems and cesspools)

[1]Previously, the depth to water measured monthly in well CH-6673 during the period from December 2002 to January 2004 ranged from a maximum of 34.70 ft bls on July 14, 2003, to a minimum of 18.70 ft bls on June 10, 2003, suggesting that the value of 62.95 ft bls may be related to recent pumping of the well.

[2]In sewer-service area.

Collection of Samples

Samples were collected and processed using standard methods (U.S. Geological Survey, variously dated). Samples of base flow were collected as grab samples because the streams were small (less than 5 ft in width) and shallow (less than 0.6 ft in depth) with low flows (less than 1 ft^3/s). These small streams were assumed to be well mixed. Streamflow at the time of base-flow sample collection was measured using a current meter or a flume if flow was too small to be measured with a current meter. Ground-water samples were collected from wells using existing pumps and plumbing but bypassing any treatment systems. Water levels in the wells were measured prior to pumping, and wells were pumped until field constituents (pH, temperature, specific conductance, and concentration of dissolved oxygen) stabilized before sample collection. For the two springs, samples were collected using a peristaltic pump immersed in the spring pool.

Samples for dissolved-constituent analysis were filtered in the field using a 0.45 micron capsule filter. Samples for dissolved major ions and trace elements were preserved using nitric acid. Samples for analysis of organic wastewater compounds were unfiltered and collected directly in baked glass bottles from the stream or well head; these samples were subsequently filtered through a baked glass fiber filter at the laboratory before analysis. Whole-water samples for bacteriological analysis were collected in plastic bottles provided by the Chester County Health Department. As necessary, samples were chilled after collection and during shipment to the laboratory.

Three of the 10 base-flow sites sampled in May 2005 were re-sampled in June 2005 for organic wastewater compounds because the May 2005 samples from these sites were adversely impacted at the laboratory and could not be analyzed. The three affected samples were from sites 014806368, 014806369, and 01480637 (fig. 3; table 7 at the back of the report).

Analysis of Samples

Analyses of samples were selected to characterize general water quality and to screen for wastewater indicators. Wastewater indicators included chloride, nutrients (nitrogen and phosphorus compounds), boron (a laundry additive), selected organic compounds, and bacteria.

The pH, water temperature, alkalinity (acid neutralizing capacity), specific conductance, and concentration of dissolved oxygen were measured in the field for ground-water and base-flow samples using standard methods (U.S. Geological Survey, variously dated). Water samples were sent to the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., to be analyzed for selected dissolved inorganic constituents and organic compounds. Analyses for inorganic constituents included major ions (calcium, magnesium, sodium, potassium, silica, sulfate, chloride, and fluoride), nutrients (nitrate, nitrite, ammonia, and orthophosphate), and selected trace elements (boron, iron, and manganese). Analyses for organic compounds included a suite of about 65 compounds commonly present in domestic or industrial wastewater (such as detergent metabolites, food additives, fragrances, antioxidants, flame retardants, plasticizers, industrial solvents, disinfectants, fecal sterols, polycyclic aromatic hydrocarbons, and high-use domestic pesticides) (Zaugg and others, 2002; Zaugg and Leiker, 2006). Many of these wastewater compounds are potential endocrine-disrupters or are toxic (Zaugg and others, 2002). Complete listings of constituents and compounds analyzed and associated parameter codes are given with analyzed data in tables 7 and 8 at the back of the report.

Fecal coliform and enterococci bacteria were analyzed by the Chester County Health Department Laboratory in West Chester, Pa., using standard membrane filtration methods (such as described by Myers and Wilde, 1997). Membrane filtration and plating of samples were done within 6 hours of sample collection. The minimum detection level for fecal coliform and enterococci bacteria was 0.4 col/100 mL.

For quality assurance, a replicate base-flow sample was collected from site 01480637 in September 2005 for analysis of inorganic constituents, organic wastewater compounds, and bacteria (table 7 at the back the report). No field or equipment blanks were collected because, in other studies done recently by USGS using the same or similar equipment and procedures, organic and inorganic analytes were not or were rarely detected in field and equipment blanks (Loper and others, 2007; Senior and Sloto, 2006; Reif, 2002) and funds for this study were limited. Also, samples for organic and bacteria analyses were collected directly from the stream or well head in bottles and had little to no contact with field equipment. In addition, laboratory blanks routinely are run during these analyses. Results of replicate inorganic analyses were within 2 percent of each other except for dissolved iron, which differed by 30 percent (but iron concentrations were low and differed by only 3 µg/L). Results of replicate analyses for bacteria differed by about 22 percent for enterococci and 13 percent for fecal coliform. Results of replicate analyses for organic wastewater compounds showed that five wastewater compounds were detected in at least one of the replicate samples. Of those five wastewater compounds, phenol concentrations were identical and two compounds (4-nonylphenol and p-cresol) were detected in both replicates, and two compounds (camphor and methyl salicylate) were detected in only one of the replicates in September but had been detected previously in the May 2005 sample from this site. Phenol and acetophenone results should be used with caution because in some studies these compounds were detected in both field and laboratory blanks (Zaugg and Leiker, 2006). Recovery rates of surrogate compounds (caffeine-$^{13}C_3$, fluoranthene-d_{10}, decafluorobiphenyl, and bisphenol-d_3) added at the NWQL to the wastewater sample and used by the laboratory to measure gross sample-processing problems and matrix effects were generally within the range commonly reported by the NWQL (Zaugg and Leiker, 2006). These surrogate recovery rates indicate acceptable analytical results but are of limited use for assessing method compound recoveries (Zaugg and others, 2002). However, the generally poor recovery rate of bisphenol A-d_3 (tables 7 and 8) indicates results for analyte bisphonol A are not reliable. Overall, the replicate analyses indicate no major quality-assurance problems, given the limited quality control, low concentrations, and possible false detections of organic wastewater compounds, and natural variability of bacteria.

Ground-Water and Base-Flow Water Quality

Potential sources of constituents in ground water and base flow include precipitation, weathering of minerals in soils and rocks, and human activities on the land surface and subsurface. Biochemical and geochemical processes may alter the concentrations of many constituents, including trace metals (iron, manganese, and others), major cations (calcium, magnesium, sodium, and potassium), nutrients (nitrogen and phosphorus compounds), and organic compounds (natural and introduced). Processes that can increase or decrease the concentrations of constituents include sorption/desorption, ion exchange, oxidation/reduction, and biologically mediated reactions. Constituents that can be altered by such processes are considered to be non-conservative or semi-conservative tracers in the environment. Some inorganic constituents, such as chloride and boron, generally are not very reactive and commonly are considered conservative tracers in the environment.

Ground-water quality may vary locally because of local differences in soil types, aquifer lithology, and land use or other factors. The base-flow component of streamflow is ground-water discharge from the drainage area, and therefore, base-flow quality integrates (is a volume-weighted mixture of) the locally variable ground-water quality in a drainage area. Additional chemical and physical processes can change the composition of ground-water discharge (base flow) while and after it enters and is transported within the stream channel.

For the purposes of discussion of results of this pilot study in and near the Broad Run watershed, ground-water and base-flow sites sampled in 2005 were assigned to land-use categories listed in table 3.

Inorganic Constituents

Water samples were analyzed for inorganic constituents to provide data about general water quality in each of the areas potentially affected by human activities. Inorganic analyses included major ions, nutrients, and the trace elements iron, manganese, and boron (tables 7and 8 at the back of the report). Nutrients, chloride, and boron are potential wastewater indicators, because they all typically are present in domestic sewage. Concentrations of chloride, boron, and nitrate are listed by sample type and land-use category in table 3. The range and average concentrations of selected inorganic constituents reported in septic-tank effluent are listed in table 4.

Table 3. Concentrations of chloride, boron, and nitrate in ground-water and base-flow samples collected May-June 2005 in and near the Broad Run watershed, Chester County, Pa., listed by land use for each tributary drainage area. Location of samples shown in fig. 3

[mg/L, milligrams per liter; µg/L, micrograms per liter; E, estimated value; <, less than]

U.S. Geological Survey local number or station number	Site type	Predominant land use - type of wastewater disposal	Concentrations in water samples				
			Chloride (mg/L)	Boron (µg/L)	Nitrate (mg/L as N)	Dissolved oxygen (mg/L)	Manganese (µg/L)
Ground-water sites[1]							
CH-6880	well	residential - sewered	63.6	12	2.46	10.1	20.5
CH-SP-70	spring	agricultural - on-site system[2]	26.1	8.3	9.18	8.3	.5E
CH-6882	well	residential - moderate-density on-site system[2]	32.3	23	5.69	9.0	5.1
CH-6879	well	residential - moderate-density on-site system[2]	242	4.9E	.97	8.5	8.4
CH-6673	well	residential - moderate-density on-site system[2]	4.91	7.7	.40	2.7	25.0
CH-6878	well	residential - high-density on-site system[3]	27.4	3.9E	6.26	5.8	2.9
CH-755	well	residential - high-density on-site system[3]	66.5	27	10.7	9.1	39.2
CH-SP-71	spring	residential - high-density on-site system[3]	30.4	11	2.68	8.9	<.6
CH-6881	well	residential - high-density on-site system[3]	373	26	3.11	5.3	279
CH-6883	well	residential - high-density on-site system[3] wooded	5.37	8.2	7.32	9.7	.3E
Base-flow sites[4]							
0148063522	stream	residential - sewered	50.5	6.4E	3.23	11.0	4.8
0148063532	stream	agricultural - on-site system[2]	21.4	8.5	6.37	10.0	16
014806368	stream	residential - moderate-density on-site system[2]	29.1	33	6.29	10.5	3.7
014806366	stream	residential - moderate-density on-site system[2]	39.3	28	4.45	11.0	5.4
014806369	stream	residential - moderate-density on-site system[2]	37.1	29	4.14	10.3	51.9
01480637	stream	residential - moderate-density on-site system[2]	34.6	29	4.01	10.6	19
014806374	seep	undefined	20.0	7.5	3.33	5.8	17.5
014806384	stream	residential - high-density on-site system[3]	65.0	44	6.61	10.5	2.1
014806394	stream	residential - high-density on-site system[3]	30.6	14	2.82	10.7	4.6
01480913	stream	wooded and residential - high-density on-site system[3]	11.7	11	1.94	10.4	37.1

[1]Local number used for ground-water sites, where CH is the county code, SP denotes spring, and up to a 4-digit number is sequentially assigned for well or spring in the county.

[2]Typically septic system.

[3]Septic system or cesspool.

[4]Station number used for surface-water sites is assigned in downstream order.

Table 4. Reported minimum, maximum, and average concentrations of selected constituents in septic-tank effluent. Modified from Senior, 1993.

[Sources: 1 = Canter and Knox (1985); 2 = Walker and others (1973); 3 = Andreoli and others (1979); 4 = Robertson and others (1991); 5 = Roberston and Blowes (1995); 6 = Minnesota Pollution Control Agency (1999); 7 = Schreffler and others (2005); 8 = Vengosh and others (1994); mg/L milligrams per liter; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; --, not reported]

Constituent or property	Minimum	Maximum	Average	Sources
Nitrate (mg/L as N)	0.1	1	0.1	3,4
Ammonia (mg/L as N)	40	100	70	2
Organic N (mg/L as N)	5	25	15	2
Phosphate (mg/L as P)	--	--	15	1
Chloride (mg/L)	37	200	53	1,2,4
Iron (mg/L)	0	20	2.6	1
pH (pH units)	6.5	7.5	6.9	1,3
Alkalinity	--	--	186	3
Calcium (mg/L)[1]	2	8	5	5
Magnesium (mg/L)[1]	0	2	1.5	5
Sodium (mg/L)[1]	25	50	38	4, 5
Potassium (mg/L)[1]	12	40	26	4, 5
Sulfate (mg/L)[1]	0	36	--	4
Boron (µg/L)	55	13,248	[2]400	6, 7, 8

[1]Constituent concentration adjusted for background concentrations in source water (upgradient ground water).

[2]Median of three studies (for 8 septic systems in Minnesota, median was 616 µg/L; for spray effluent in Chester County site, median was less than 200 µg/L; for raw sewage, adjusted for background, in Israel, median was about 400 µg/L).

Chloride and boron are relatively stable (conservative indicators), but the nutrients may not be conservative. Denitrification and oxidation/reduction reactions can affect nitrogen compounds (nitrate, nitrite, and ammonia), and sorption can affect phosphorus compounds and ammonia. Most nitrogen enters the septic tanks as organic nitrogen and ammonia, but after the effluent leaves the tanks, it is oxidized in the soil zone to nitrate if sufficient oxygen is available. The oxidation of these nitrogen compounds and organic carbon produces acid and may lower pH in the vicinity of the plume from the tank (Robertson and Blowes, 1995). Wastewater disposal may change the geochemical environment through oxidation of organic compounds in wastewater that enter the ground-water system, resulting in depletion of oxygen in ground water. Nitrate is not stable in reducing environments, and subsequently, nitrate reduction decreases concentrations of nitrate. Concentrations of dissolved iron and manganese can be elevated in oxygen-depleted or reducing environments.

General Water Quality

In samples collected in the study area in 2005, ground water generally was acidic (pH ranged from 5.2 to 6.8), with low alkalinity [ranged from 9 to 47 mg/L as calcium carbonate ($CaCO_3$)] and moderate hardness (based on calcium and magnesium concentrations, hardness ranged from 48 to 100 mg/L as $CaCO_3$). The composition of ground water in the study area generally was within the range reported for water in schist aquifers in Chester County (Sloto, 1994), although the study-area ground water is slightly more acidic. Water samples from two wells (CH-6879 and CH-6881) had higher concentrations of calcium and magnesium than the other samples and, consequently, could be categorized as very hard (hardness of 286 and 418 mg/L, respectively); these samples also had the highest concentrations of sodium and chloride and were in residential areas with on-site wastewater disposal. Ground water in all but three samples was well oxygenated (dissolved-oxygen saturation greater than 80 percent); concentrations of dissolved oxygen and percent saturation were lowest (ranging from 2.7 to 5.8 mg/L and 26 to 55 percent, respectively) in samples from wells CH-6673, CH-6879, and CH-6881 (table 3 and table 8 at the back of the report), indicating oxygen depletion resulting from chemical or biochemical reactions. These three wells were in residential areas with on-site wastewater disposal.

In comparison to the ground-water samples, base-flow samples collected in May-June 2005 had a more neutral to slightly alkaline pH (pH ranged from 7.0 to 8.0), with similarly low alkalinity (range for nine sites was 17 to 56 mg/L as $CaCO_3$) and moderate hardness (range for eight sites was 53 to 101 mg/L as $CaCO_3$). Base flow from the seep site 014806374 (fig. 5) had relatively high alkalinity (154 mg/L as $CaCO_3$) and calcium and magnesium hardness (212 mg/L as $CaCO_3$), suggesting that the water may be derived in part from the thin occurrence of carbonate bedrock in the study area (fig. 2).

Concentrations of dissolved iron and manganese in ground water generally were low. In ground-water samples collected in June 2005, concentrations of dissolved iron were near or below the reporting level of 6 µg/L in water from all but one well. The concentration of dissolved iron was 619 µg/L in water from well CH-6881, exceeding the U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level (SMCL) of 300 µg/L for iron in drinking water. Similarly, concentrations of dissolved manganese were less than 40 µg/L in water from all but the same well (CH-6881), which had a concentration of dissolved manganese of 279 µg/L, exceeding the USEPA SMCL of 50 µg/L for manganese. Water from this well had oxygen concentrations below saturation (table 8 at the back of the report).

Concentrations of dissolved iron and manganese in base-flow samples collected May-June 2005 also were relatively low, ranging from less than 6 to 43 µg/L for dissolved iron and 2.1 to 51.9 µg/L for dissolved manganese. The highest base-flow concentrations of dissolved iron and manganese were in samples from stream site 014806369 that drains a residential area with septic systems (fig. 3).

Nitrate and Other Nutrients

Natural background concentrations of nitrate in ground water and base flow are about 1 mg/L as nitrogen (N) or less in the study area, as estimated from precipitation chemistry (Senior and others, 1997). Nitrate concentrations were greater than background concentrations of 1 mg/L as N in most ground-water samples and all base-flow samples collected in the study area (table 3; fig. 7), indicating probable addition of nitrate from human activities, such as application of fertilizers and use of septic systems. Nitrate was elevated above natural background in samples from all land-use areas—agricultural, residential with sewers, and residential with on-site wastewater disposal.

Nitrate concentrations were more variable in ground-water samples than in base-flow samples and ranged from 0.4 mg/L up to 10.7 mg/L as N. Nitrate concentrations were highest (greater than 6 mg/L as N) in ground-water samples from the agricultural area (spring CH-SP-70) and the residential area with high-density on-site wastewater disposal systems (wells CH-755, CH-6883, and CH-6878) (fig. 7). The highest nitrate concentration (10.7 mg/L as N) was in water from residential well CH-755, which exceeded the drinking-water maximum contaminant level (MCL) of 10 mg/L as N for nitrate established by the USEPA to protect human health. The low concentrations of nitrate in some ground-water samples in areas with septic systems may be partly attributable to loss through oxidation-reduction reactions. Some of the lower concentrations of nitrate observed are associated with lower concentrations of dissolved oxygen (table 3).

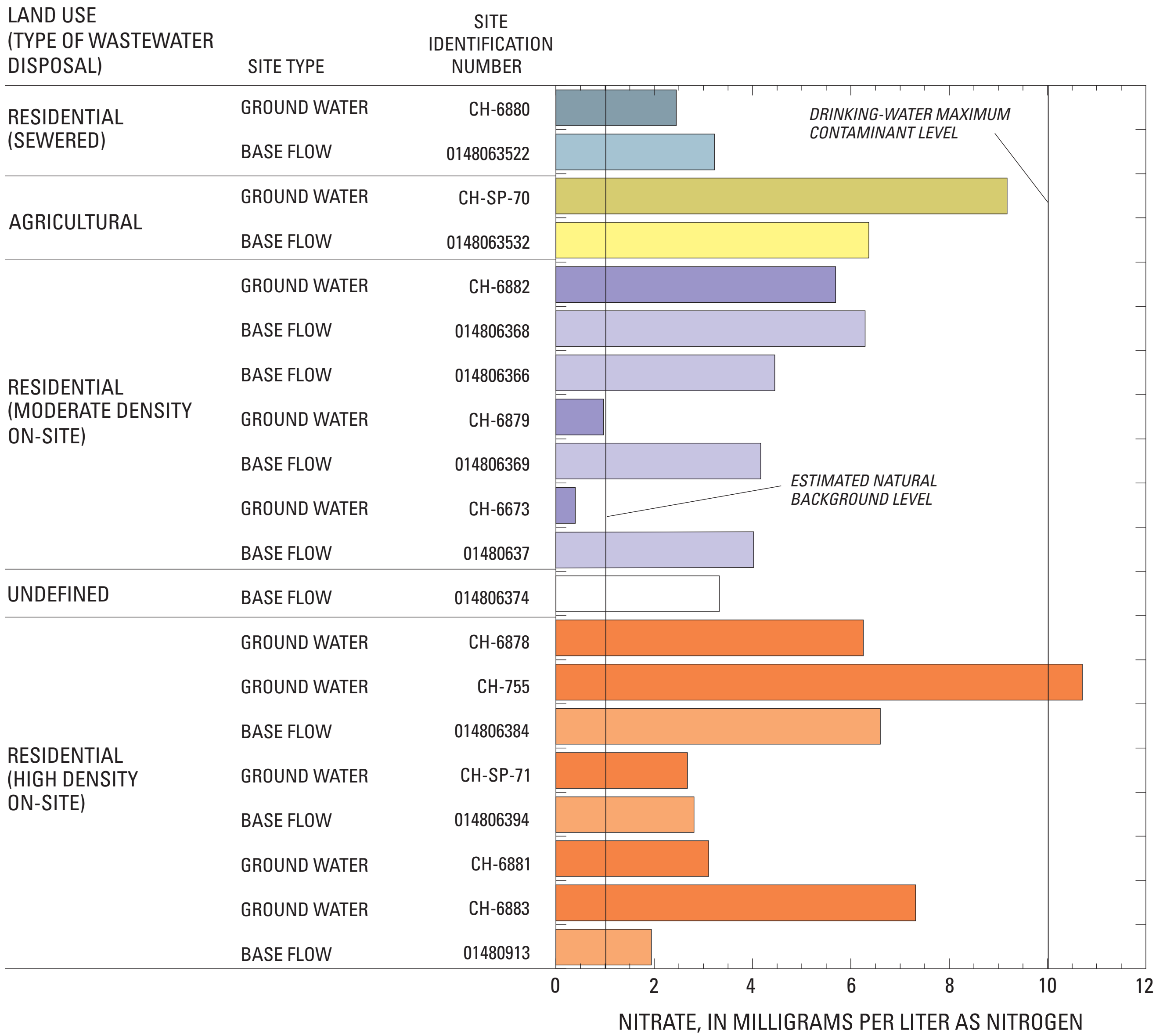
The highest concentrations of nitrate in the May 2005 base-flow samples (about 6 mg/L as N) also were in streams draining the agricultural area (site 0148063522) and the residential area with high-density on-site wastewater disposal (site 014806384), in addition to a stream draining a residential area with septic systems (site 014806368) (fig. 7). The lowest concentrations of nitrate in the May 2005 base-flow samples (about 2 to 3 mg/L as N) were in streams draining the residential area with sewers (site 0148063522), one of the residential areas with high-density on-site wastewater disposal (site 014806394), and a mixed forested/residential area (site 01480913) (fig. 7). About half the drainage area above stream site 01480913 that had the lowest nitrate concentration in base flow apparently is forested (fig. 3). Base-flow concentrations of nitrate in the residential area with moderate-density on-site wastewater disposal generally were about 4 mg/L as N in May 2005.

Concentrations of nitrite and ammonia, nitrogen compounds that are stable under reducing conditions, were low in ground-water and base-flow samples collected May-June 2005 (table 8 at the back of the report). Nitrite and ammonia commonly are present in septic-system effluent and fertilizers. Nitrite concentrations were below the reporting level of 0.008 mg/L as N in all but the base-flow samples from site 014806369 and nearby downstream site 01480637, which drain a residential area with moderate-density on-site wastewater disposal (fig. 3), in which nitrite concentrations were 0.027 and 0.019 mg/L as N, respectively. Ammonia concentrations were below the reporting level of 0.04 mg/L as N in base-flow samples from all but site 014806389, which had 0.06 mg/L as N of ammonia and also had the highest detected nitrite concentration.

Concentrations of dissolved orthophosphate, a soluble form of phosphorus, in ground-water and base-flow samples collected in May-June 2005 were low (tables 7 and 8 at the back of the report). Orthophosphate concentrations were less than the reporting level of 0.02 mg/L as P in all spring 2005 base-flow samples. Orthophosphate concentrations in ground-water samples were slightly higher than in base-flow samples and ranged from 0.01 to 0.04 mg/L as P. The highest orthophosphate concentrations in ground water (0.3 to 0.4 mg/L as P) were in the four wells CH-755, CH-6878, CH-6883, and CH-6882 in residential areas; three of these four wells were in the residential areas with high-density on-site wastewater disposal, and the remaining well was in the residential area with moderate-density on-site wastewater disposal (table 8 at the back of the report; fig. 3).

Chloride

Natural background concentrations of chloride in ground water and base flow are about 10 mg/L or less, as estimated from precipitation chemistry (Senior and others, 1997). Chloride concentrations were greater than 10 mg/L in most ground-water samples and all base-flow samples collected in the study area (table 3; fig. 8), indicating probable additions of chloride from human activities, such as road salting and septic systems. Chloride was elevated above natural background levels in sam-



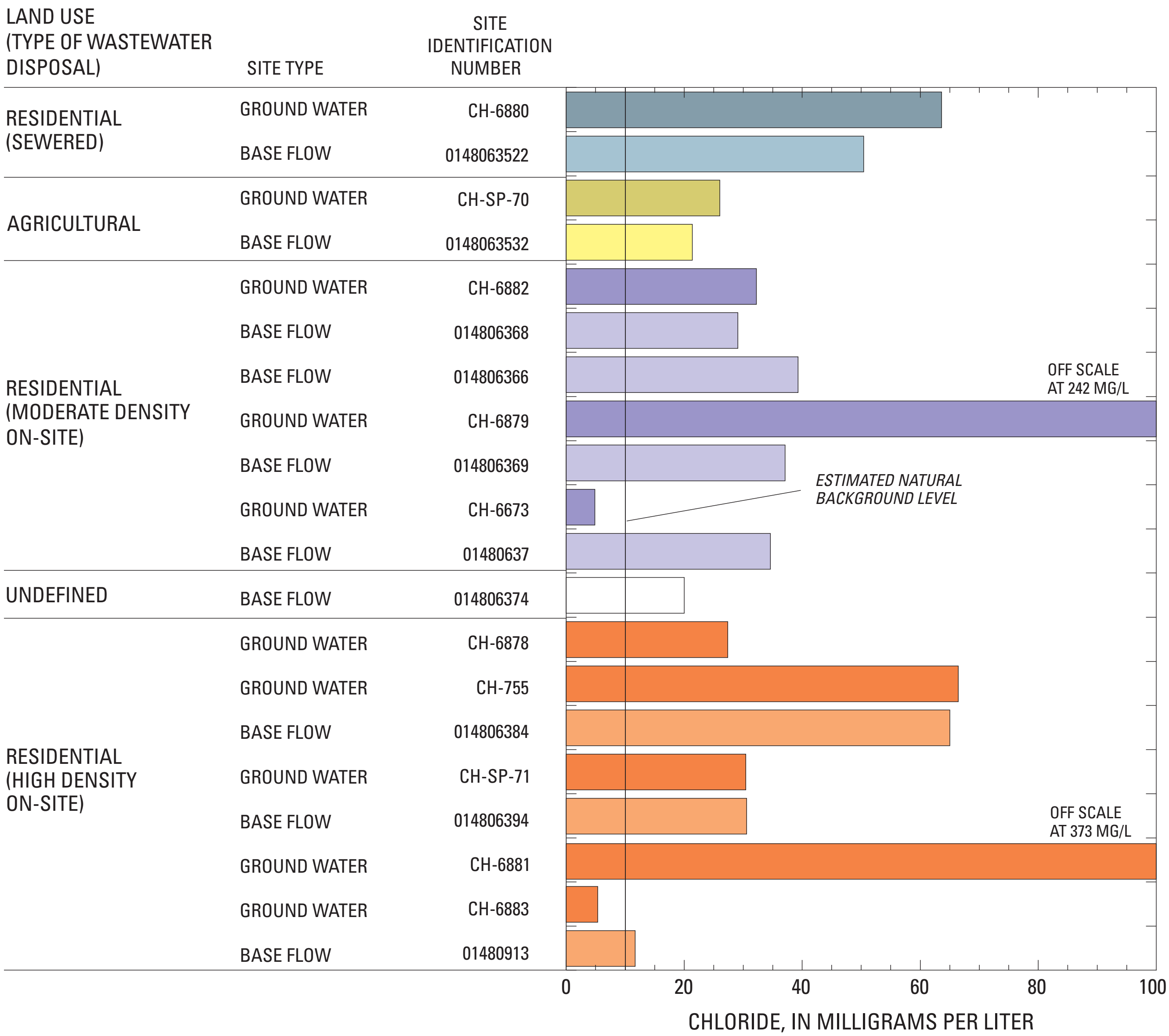
EXPLANATION - Concentrations shown by land use and site type, in approximate downgradient order from ground-water site to base-flow site in each land-use category.

Figure 7. Nitrate concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005. See figure 3 for location of sites.

ples from all land-use areas—agricultural, residential with sewers, and residential with on-site wastewater disposal.

Chloride concentrations were more variable in ground-water samples than in base-flow samples and were highest in ground-water samples from residential areas (table 3). The highest measured chloride concentrations of 373 and 242 mg/L in samples from wells CH-6881 and CH-6879, respectively, both in areas with on-site wastewater disposal (septic or septic and cesspool), were near or greater than the USEPA SMCL for chloride of 250 mg/L in drinking water. The highest concentrations of chloride in base-flow samples (50 to 65 mg/L) were in streams draining the residential area with sewers (site 0148063522) and a residential area with high-density on-site wastewater disposal (site 014806384); the lowest chloride concentrations (11.7 to 21.4 mg/L) were in streams draining agricultural (site 0148063532) or mixed forested/residential areas (site 01480913) (table 3, fig. 8). Base-flow concentrations of chloride in the residential area with moderate-density on-site wastewater disposal ranged from 29 to 39 mg/L.

The predominant source of chloride is salt, either as sodium or calcium chloride in road salt or in septic effluent. Chloride concentrations are correlated most strongly with sodium concentrations in samples collected in May-June 2005 and to a lesser extent with magnesium, calcium, and potassium



EXPLANATION - Concentrations shown by land use and site type, in approximate downgradient order from ground-water site to base-flow site in each land-use category.

Figure 8. Chloride concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005. See figure 3 for location of sites.

concentrations. Sodium enrichment is likely to occur with chloride enrichment in ground water and base flow, regardless of the source of chloride. Sodium concentrations above 20 mg/L may pose a health concern and above 60 mg/L may pose a taste problem (U.S. Environmental Protection Agency, 2006). The relation between sodium and chloride concentrations for the May-June 2005 base-flow and ground-water samples (fig. 9) shows that base-flow and ground-water concentrations of sodium and chloride are similar for each of the land uses. Points plotting near the line showing the 1:1 molar ratio of sodium to chloride indicate that most of the chloride is associated with sodium; points plotting above the line indicate excess sodium relative to chloride, and points plotting below the line indicate excess chloride relative to sodium.

Boron

Natural background concentrations of boron in ground water and base flow will vary by lithology and probably are about 20 µg/L or less in the study area based on previous investigations (Sloto, 1994; Senior and others, 1997). Boron concentrations were greater than 20 µg/L in 3 of 10 ground-water samples and in 5 of 10 base-flow samples collected May-June 2005

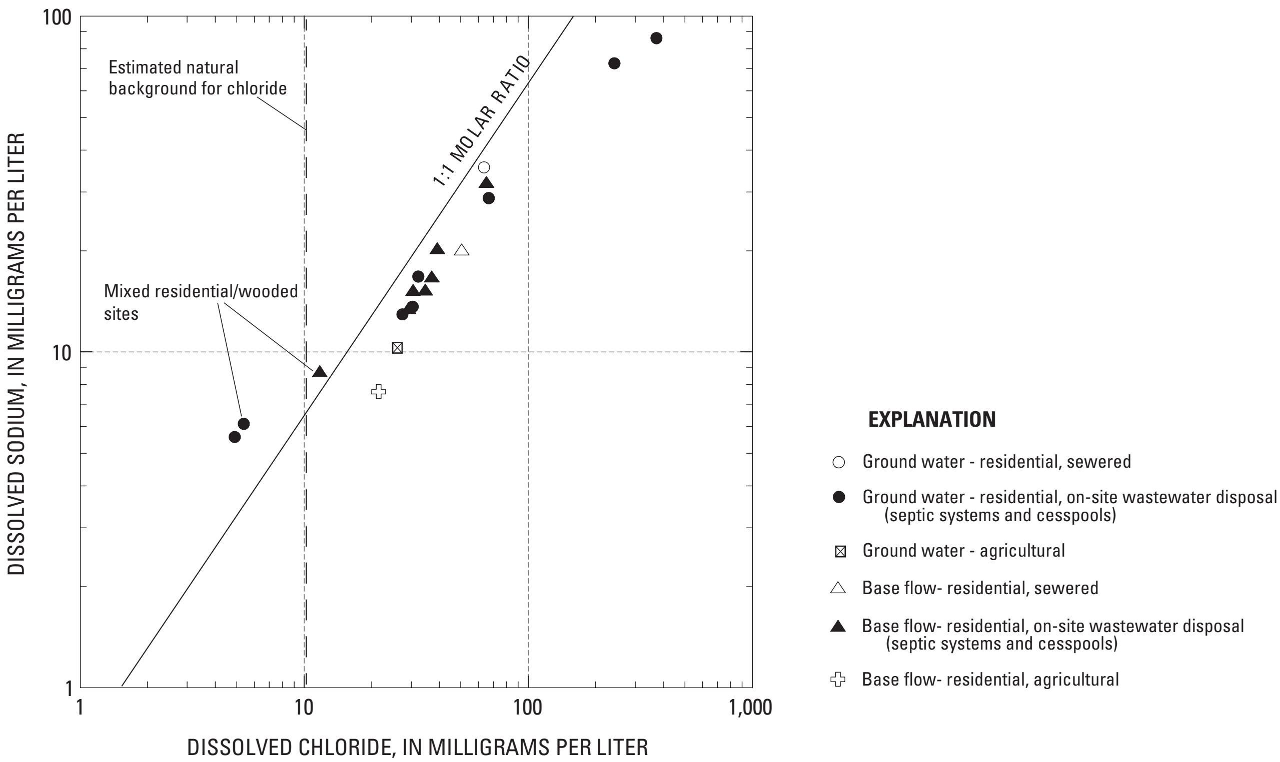


Figure 9. Sodium and chloride concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005.

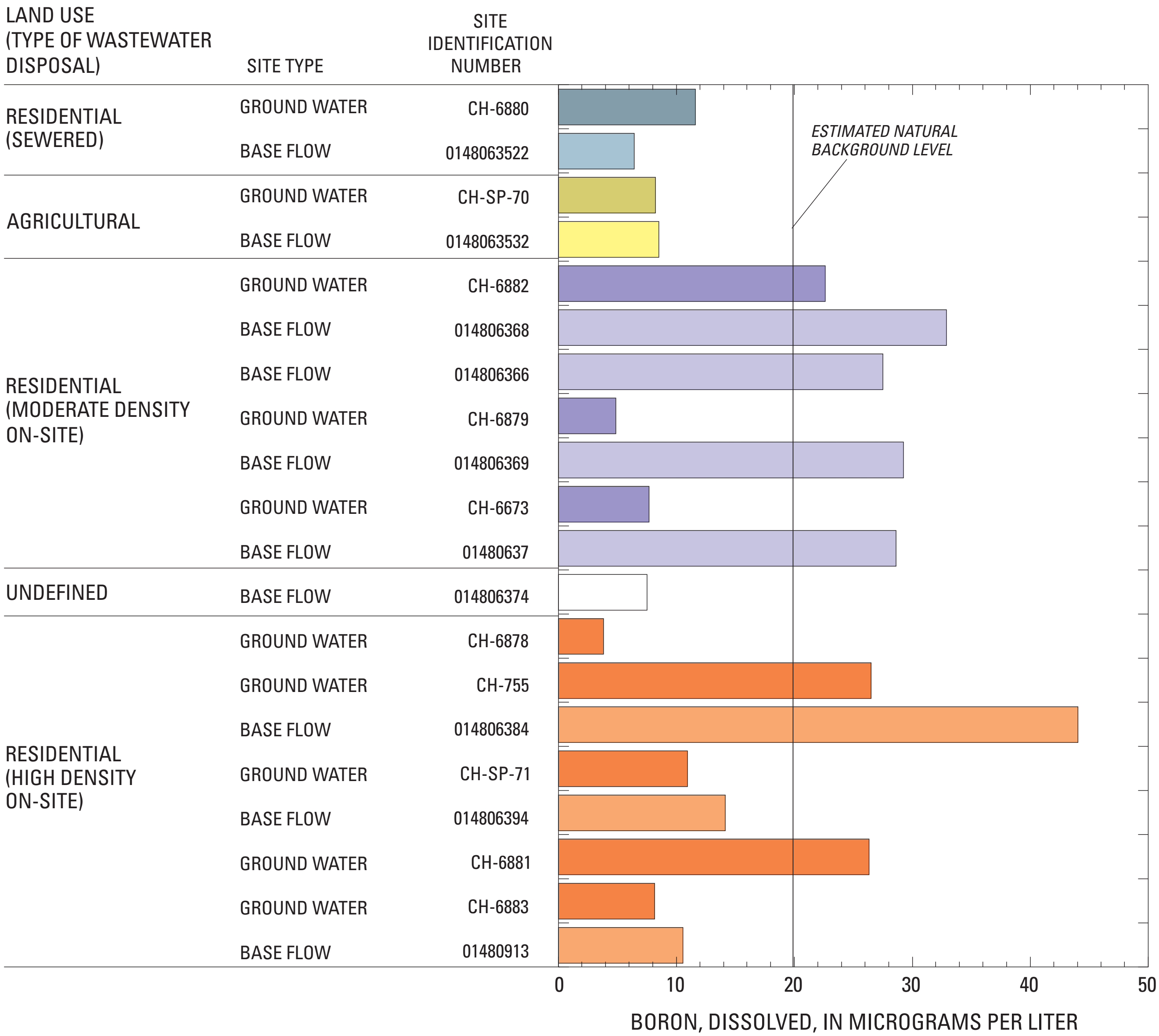
(table 3), suggesting some possible addition of boron from human activities, such as laundry discharge into septic systems. Boron was elevated above 20 µg/L (estimated maximum natural background concentration in study area) only in samples from the residential areas with on-site wastewater disposal (fig. 10).

Boron concentrations ranged up to 27 µg/L in the June 2005 ground-water samples and up to 44 µg/L in the May 2005 base-flow samples. No sample contained boron in concentrations above the current USEPA life-time health advisory of 1 mg/L (1,000 µg/L) for drinking water (U.S. Environmental Protection Agency, 2006). The highest concentrations of boron in ground water (26 to 27 µg/L) were in samples from wells in the residential area with high-density on-site wastewater disposal (CH-6881 and CH-755) (table 3, fig. 10). The highest concentrations of boron in base flow (28 to 44 µg/L) were in streams draining the residential areas with moderate-density and high-density on-site wastewater disposal (sites 014806366, 014806369, 01480637, 014806368, and 014806384), and the lowest concentrations (6 to 11 µg/L) were in streams draining the agricultural area (site 0148063532), the residential area with sewers (site 0148063522), and the mixed forested/residential area (site 01480913) (table 3, fig. 10).

Organic Compounds

Of the 62 compounds in the emerging contaminant analysis, 30 different organic wastewater compounds were detected (table 5). The types of compounds detected included disinfectants, flavors, fragrances, detergent metabolites, flame retardants, fumigants, components of coal tar and feces, pesticides, solvents, and wood preservatives. Generally low levels of the wastewater compounds were measured. The concentrations of most compounds were at or below reporting levels (tables 7 and 8 at the back of the report) that ranged from less than 0.5 µg/L to less than 5 µg/L. The reporting levels were less than 0.5 µg/L for 42 compounds, less than 1 µg/L for 11 compounds, less than 2 µg/L for 6 compounds, and less than 5 µg/L for 3 compounds. Most compounds detected in samples are reported as "measured" concentrations (listed as "M" in tables 7 and 8), which means the compound was detected below the laboratory method reporting level (MRL) but the concentration could not be quantified precisely. Some compounds are reported as "estimated" concentrations (listed as "E" in tables 7 and 8), which means the laboratory was relatively confident in quantifying a concentration that was less than the MRL for that analyte. Phenol was the only compound for which concentrations consistently were reported in quantity above the MRL.

More compounds were detected in base-flow samples (25 compounds) collected May-June and September 2005 than in ground-water samples (17 compounds) collected June 2005,



EXPLANATION - Concentrations shown by land use and site type, in approximate downgradient order from ground-water site to base-flow site in each land-use category.

Figure 10. Boron concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005. See figure 3 for location of sites.

Table 5. Organic wastewater compounds detected in samples from 10 surface-water and 10 ground-water sites, May-June and September 2005, Broad Run watershed and vicinity, Chester County, Pa., listed in order of the number of surface-water sites with detections.

[µg/L, micrograms per liter; sp, spring; Other studies: H = Hinkle and others (2005); K = noted by Hinkle and others (2005) to be also frequently detected in wastewater-affected surface water by Kolpin and others (2002); C = detected in ground water in Chester County (see table 6)]

Organic wastewater compound (use or origin)	Parameter code	Method reporting level (µg/L)	Number of surface-water sites with detections[1]		Number of ground-water sites with detections[2]	Compound frequently detected in other studies of on-site wastewater
			May-June 2005 10 sites sampled	September 2005[3] 8 sites sampled	June 2005 10 sites sampled	
Phenol (disinfectant, leachate)	34466	0.5	9	7 (6)	9 (2 sp)	C
Methyl salicylate (food, liniment)	62081	.5	2	8 (2)	2 (2 sp)	
Camphor (flavor, ointments)	62070	.5	3	6 (2)	1 (1 sp)	
para-Nonylphenol (detergent metabolite)	62085	5	0	5 (0)	0	
Isophorone (solvent)	34409	.5	5	0	2 (2 sp)	
para-Cresol (wood preservative)	62084	1	3	3 (2)	2 (2 sp)	H, K
Tri(dichloroisopropyl)phosphate (flame retardant)	62088	.5	4	0	1	C
Skatol[4] (constituent in feces, coal tar)	62058	1	3	1 (0)	0	H
DEET[5] (insect repellent)	62082	.5	2	2 (1)	3 (2 sp)	H, K, C
Metolachlor (agricultural pesticide)	39415	.5	3	1 (1)	1 (1sp)	C
4-n-Octylphenol (detergent metabolite)	62061	1	3	0	0	H
AHTN[6] (musk fragrance)	62065	.5	3	0	0	C
Fluoranthene (coal tar, asphalt)	34377	.5	0	3 (0)	0	
Indole (fragrance in coffee)	62706	.5	2	1(0)	0	H
Octylphenol,monoethoxy- (detergent metabolite)	61706	1	2	0	0	C
Phenanthrene	34462	.5	2	2(1)	0	
Pyrene (coal tar, asphalt)	34470	.5	0	3(0)	0	
Anthracene (wood preservative)	34221	.5	2	0	2	
Menthol (flavor, fragrance)	62080	.5	2	0	2 (2 sp)	H
1,4-dichlorobenzene (fumigant)	34572	.5	2	0	1	
Caffeine (beverages)	50305	.5	2	1(1)	0	H, K, C
Napthalene (fumigant)	34443	.5	0	2 (0)	0	
Tri (2-chloroethyl)phosphate[7] (flame retardant)	62087	.5	1	0	1	H, K, C
Chlorpyrifos (pesticide - termites)	38933	.5	1	0	0	
Octylphenol, diethoxy (detergent metabolite)	61705	1	1	0	0	
Tetrachloroethylene (solvent)	34476	.5	0	0	2 (1 sp)	
Tri(2-butoxyethyl)phosphate (flame retardant)	62093	.5	0	0	2 (1 sp)	C
Acetophenone (fragrance in detergent, tobacco.)	62064	.5	0	0	2 (1 sp)	C
Benzophenone (perfumes, soaps)	62067	.5	0	0	2 (2 sp)	C
4-*tert*-Octylphenol (detergent metabolite)	62062	1	0	0	1	

[1]All compounds except phenol were detected at concentrations below the method reporting level.

[2]Total number of ground-water sites with detections (with number of springs shown in parentheses).

[3]Number of surface-water sites that had detections in both fall and spring shown in parentheses.

[4]3-methyl-1H-indole.

[5]N,N-diethyl-*meta*-toluamide.

[6]acetyl-hexamethyl-tetrahydro-napthalene.

[7]FYROL CEF.

suggesting potential preferential pathways for on-site wastewater disposal to streams through shallow ground-water flow. Comparing results of base-flow and ground-water sampling during the spring period only (May-June 2005), 12 of the 21 compounds detected at base-flow sites also were detected in 1 or more ground-water sites. For ground water, more compounds were detected in samples from the 2 springs (12 compounds) than in samples from the 8 wells (9 compounds) (table 5, table 8 at the back of the report).

In samples from springs, a larger number of organic wastewater compounds were detected in the sample collected in the agricultural area (12 compounds, spring CH-SP-70) than in the sample collected in the residential area with high-density on-site wastewater disposal (8 compounds, spring CH-SP-71) (fig. 11). Many of the specific compounds detected in the ground-water samples from the two springs were the same and included phenol, methyl salicylate, isophorone, para-Cresol, DEET, menthol, and benzophenone (table 5 and table 8 at the back of the report). Of the well-water samples, more compounds generally were detected in samples from wells in the residential areas with high-density on-site wastewater disposal (up to three compounds in samples from wells CH-755 and CH-6878) than elsewhere, although the largest number of wastewater compounds detected in a well-water sample (four compounds) was from well CH-6879 in the residential area with moderate-density on-site wastewater disposal (fig. 11). Compounds detected in well-water samples included phenol, DEET, a few flame retardants, a solvent, a fragrance, a detergent metabolite, and a fumigant (table 5 and table 8 at the back of the report).

Of the base-flow samples collected in May-June 2005, the largest number of organic wastewater compounds (10 to 14 compounds) were detected in samples from sites in the residential area with moderate-density on-site wastewater disposal (sites 014806369, 01480637, 014806368) and the fewest (1 compound) was in a sample from the sewered residential area (site 0148063522) (fig. 11). The base-flow sample from the site in the agricultural area (0148063532) had more compounds (7 compounds) than base-flow samples from the residential area with high-density on-site wastewater disposal (2 to 4 compounds) (fig. 11).

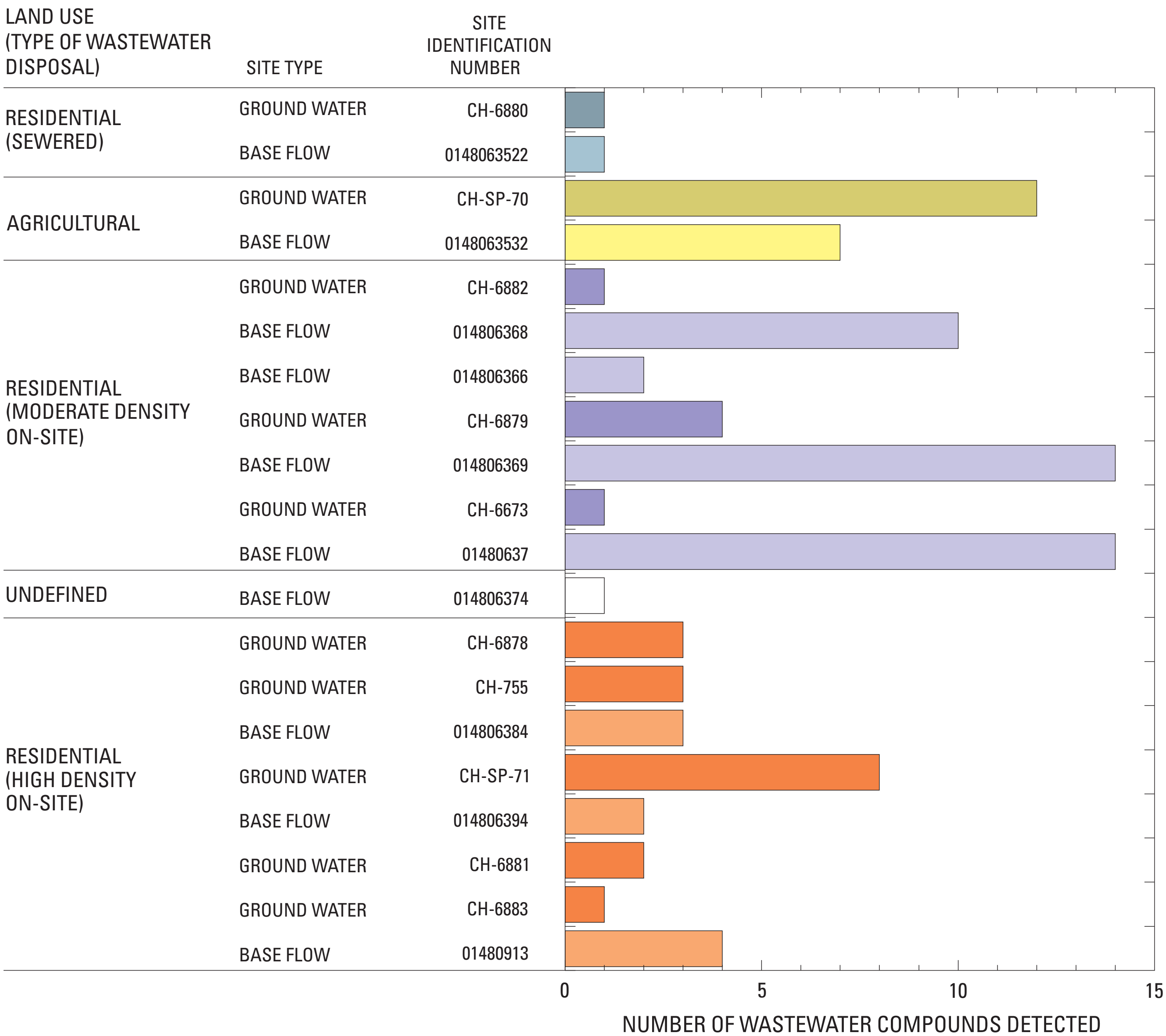
Bacteria

Bacteria were detected in all base-flow samples but in only 3 of the 10 ground-water samples, 2 of which were springs, in the June 2005 sampling period. Bacteria concentrations could not be determined in one ground-water sample from well CH-6881 because suspended sediment impaired bacteria growth on the plate. Bacteria concentrations in the ground-water samples from springs ranged from 2 to 18 col/100 mL for enterococci and 0.8 to 6 col/100 mL for fecal coliform. Enterococci bacteria were detected in only one well-water sample at a concentration of 0.4 col/100 mL (just at the detection level); this well (CH-6673) is in a residential area with septic systems (fig. 3). The highest concentration of bacteria in ground-water samples was from spring CH-SP-70 in the agricultural area. To protect human health in drinking water, the USEPA recommends a MCL goal (MCLG) of zero total coliforms [including fecal coliforms and *Escherichia coli* (*E. coli*)] (U.S. Environmental Protection Agency, 2006). The sample from spring CH-SP-70 (fig. 12) had 6 col/100 mL of fecal coliform bacteria, exceeding the MCLG for drinking water.

Enterococci bacteria were detected in base-flow samples from all 10 sites and fecal coliform were detected in base-flow samples from all but 1 of the 10 stream sites in May 2005. Enterococci ranged in concentration from 20 to 960 col/100 mL and fecal coliform concentrations ranged from less than 1 to 310 col/100 mL in base-flow samples. Enterococci concentrations were greater than fecal coliform concentrations in 9 of the 10 base-flow samples (table 7). The highest concentrations of bacteria in May 2005 base-flow samples (greater than 100 col/100 mL for both enterococci and fecal coliform) were from the residential area with sewers (site 0148063522), the agricultural area (site 0148063532), the residential area with moderate-density on-site wastewater disposal (site 014806369), and the residential area with high-density on-site wastewater disposal (site 014806384) (fig. 12).

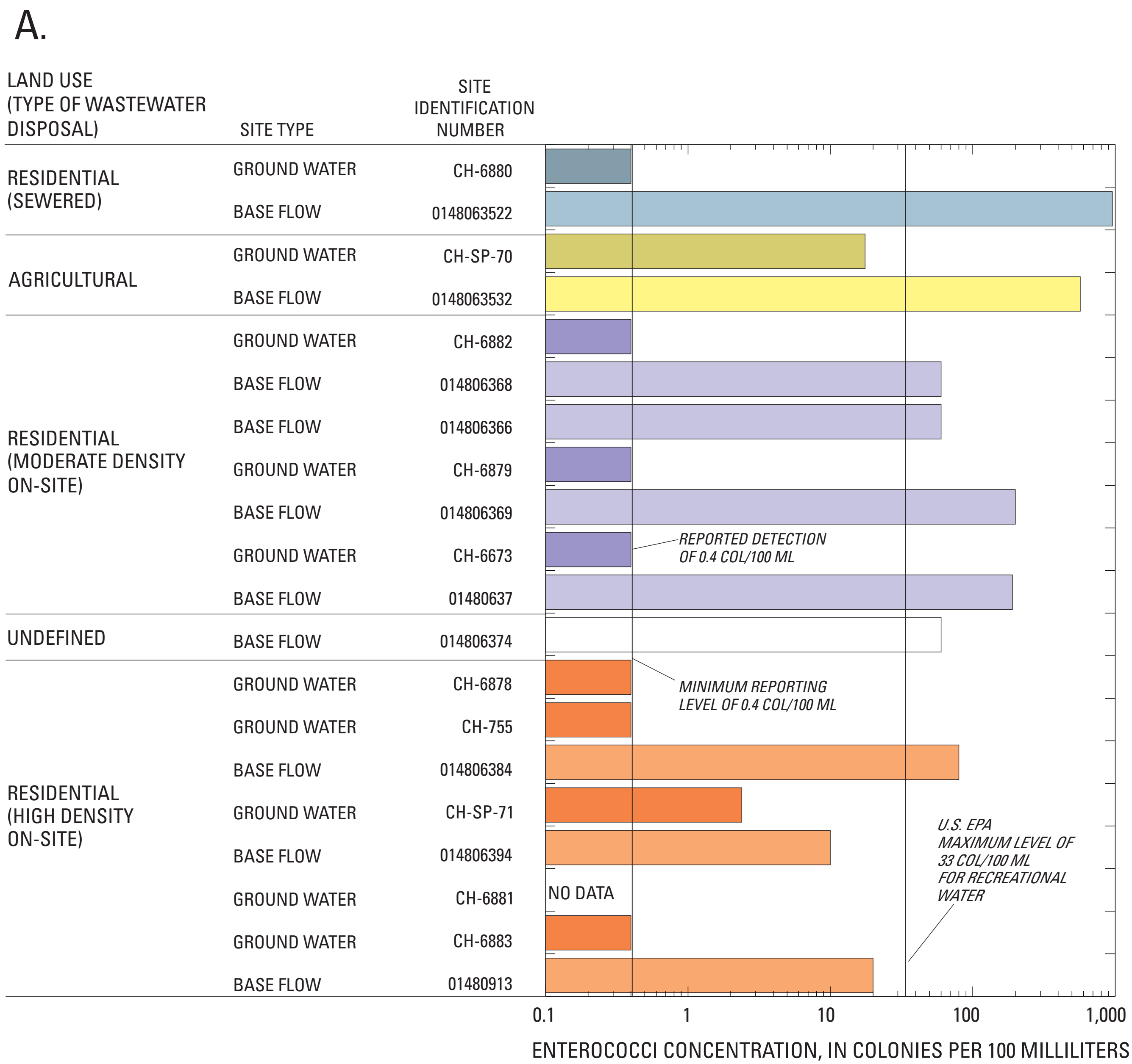
Bacteria were present in relatively elevated concentrations in base flow from all land-use areas. Sources of the bacteria are unknown but could include wildlife or domesticated animals. In an evaluation of bacteria in Chester County, Pa., in 1998-99, the median concentration of fecal coliform in base flow did not appear to differ by land use and were about 250 col/100 mL for areas draining agricultural, forested, residential, and mixed land uses (Town, 2001, p. 12).

To protect human health in recreational waters, the USEPA recommends using *E. coli* bacteria in fresh waters and enterococci bacteria in fresh or marine waters and suggests the standards of 126 col/100 mL for *E. coli* and 33 col/100 mL for enterococci bacteria in fresh waters (U.S. Environmental Protection Agency, 1986). The Commonwealth of Pennsylvania uses a standard of 200 col/100 mL for fecal coliform bacteria in recreational waters during the swimming season, May 1 through September 30 (Pennsylvania Department of Environmental Protection, 1996). On the basis of the one-time sampling (rather than the 5-day geometric mean specified in the standards), bacteria in samples from eight stream sites exceeded the USEPA standard of 33 col/100 mL for enterococci and from one of the eight stream sites exceeded the state standard of 200 col/100 mL for fecal coliform (fig. 12, table 7 at the back of the report).



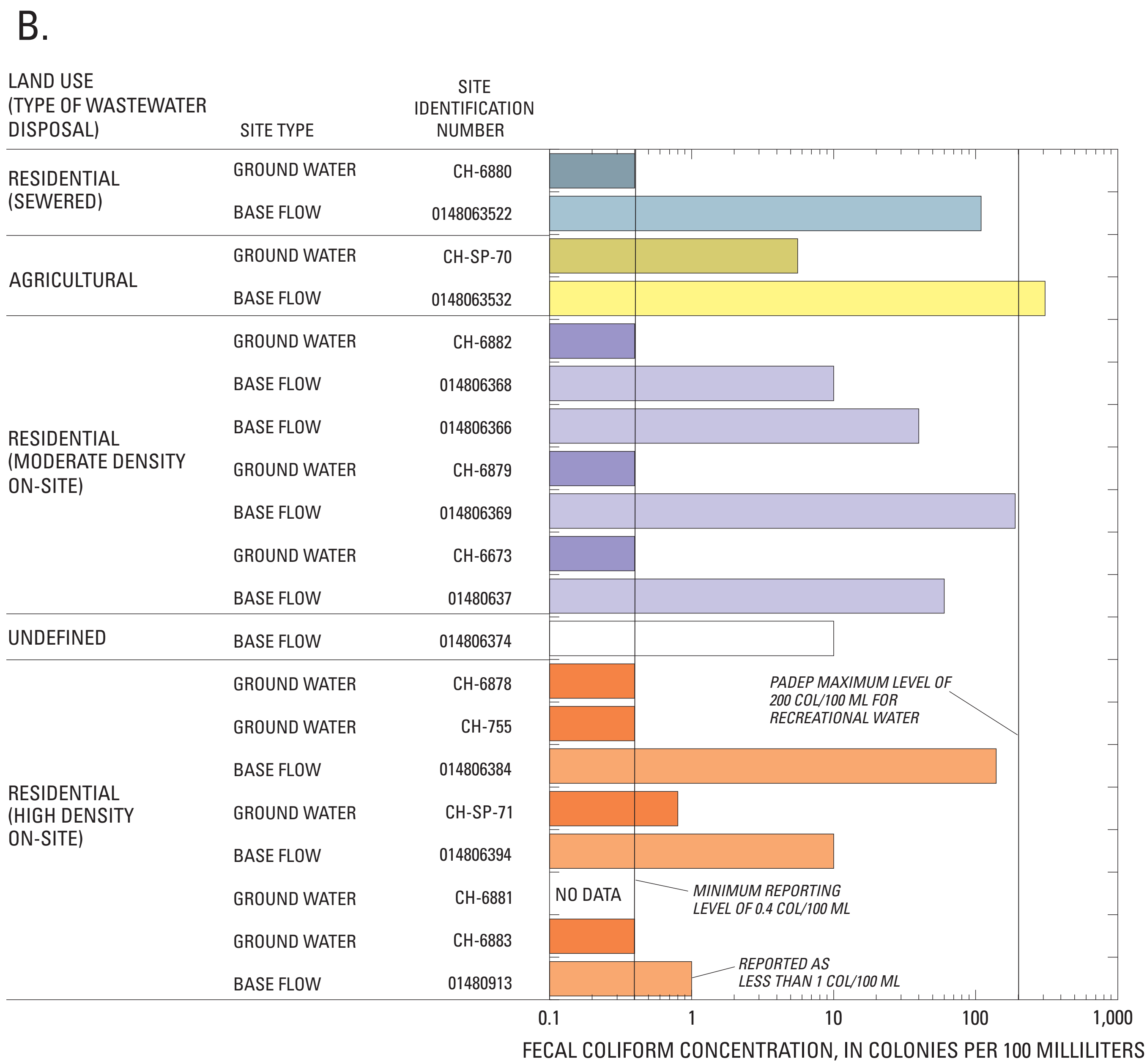
EXPLANATION - Concentrations shown by land use and site type, in approximate downgradient order from ground-water site to base-flow site in each land-use category.

Figure 11. Number of wastewater compounds detected in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005. See figure 3 for location of sites.



EXPLANATION - Concentrations shown by land use and site type, in approximate downgradient order from ground-water site to base-flow site in each land-use category. [Abbreviation: U.S. EPA, U.S. Environmental Protection Agency]

Figure 12. Bacteria concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005.
See fig. 3 for location of sites.



EXPLANATION - Concentrations shown by land use and site type, in approximate downgradient order from ground-water site to base-flow site in each land-use category. [Abbreviation: PADEP, Pennsylvania Department of Environmental Protection]

Figure 12. Bacteria concentrations in ground-water and base-flow samples in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., May-June 2005.—Continued
See figure 3 for location of sites.

Seasonal Base-Flow Quality

Of the 10 stream sites sampled in May-June 2005, only 8 were re-sampled in September 2005 because 2 sites (0148063522 and 014806374) were dry in September. Base flow at the eight sites with flow in September 2005 was about 25 percent of the flow (range 7 to 34 percent) in May 2005 (fig. 13). The hydrograph for streamflow-measurement station 014806368 Broad Run at Northbrook, Pa., near the bottom of the watershed (fig. 3), shows the decline in streamflow (fig. 4). Ground-water levels also declined from May to September 2005 as measured in a nearby long-term observation well, CH-12 (fig. 3), in which the water level declined about 5 ft (4.86 ft) from 32.40 to 37.26 ft bls during that period (Durlin and others, 2006, p. 493).

Despite the decrease in streamflow, concentrations of most major ions in base flow remained relatively constant from May to September 2005 (table 7 at the back of the report). Generally, the concentrations of most major ions in September base-flow samples were similar or slightly (commonly about 5 to 20 percent) higher than concentrations in the May base-flow samples. Nitrate concentrations in base-flow samples were about 10 percent lower in September than in May 2005. The lower nitrate concentrations in September may be related to nutrient uptake by algae in the stream. The relatively constant composition of

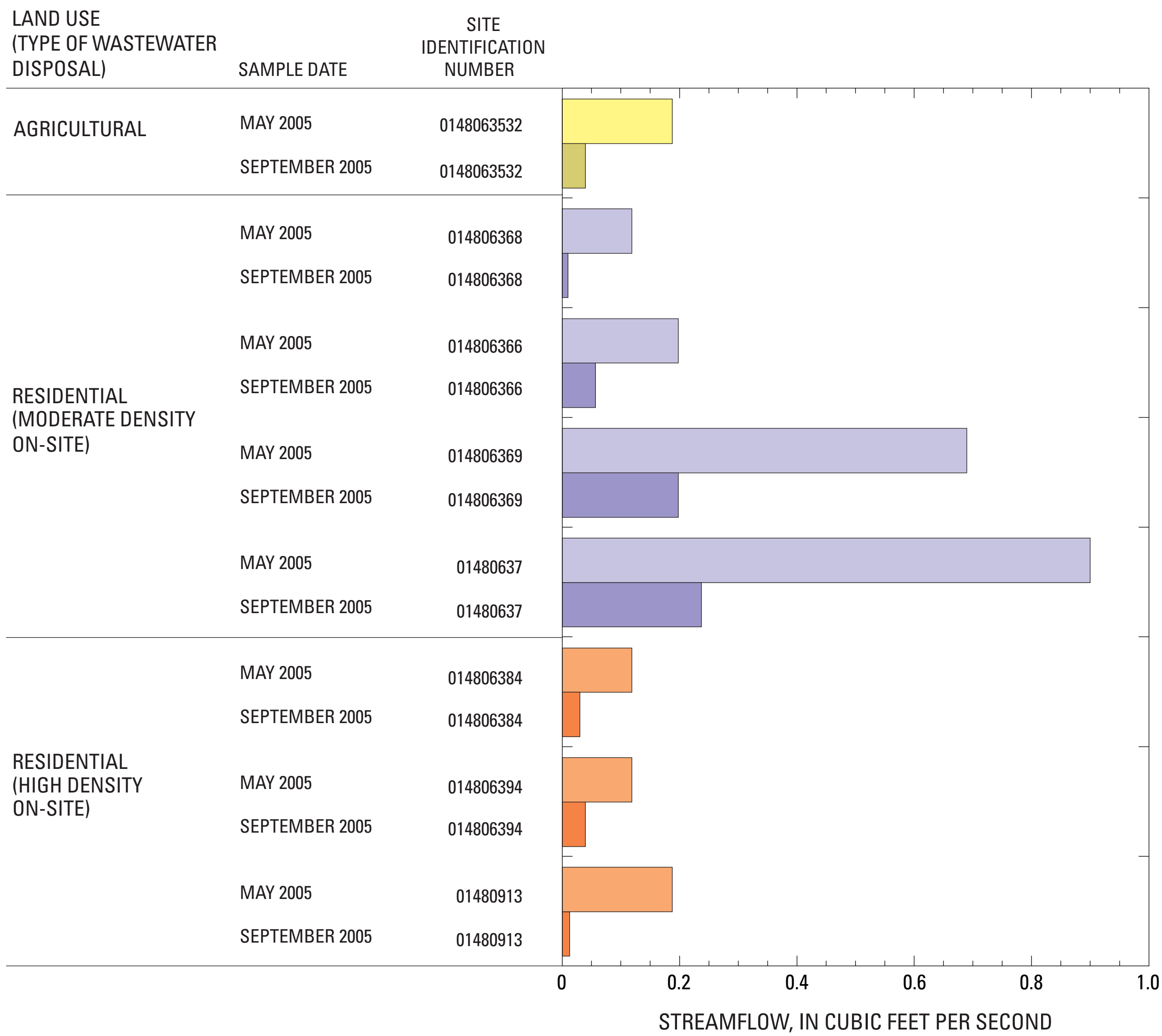


Figure 13. Base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005.
See figure 3 for location of sites.

base flow during this period indicates that the overall composition of ground water discharging to the stream also did not vary much.

The concentrations of boron and bacteria, however, did change generally by more than 20 percent in base-flow samples from May to September 2005. The concentrations of boron in base-flow samples were two to three times higher in September than in May 2005. The reason for the apparent increase in boron concentrations from May to September and the lack of comparable increases of other constituents of probable anthropogenic origin, such as chloride, is unknown. Concentrations of boron in September 2005 base-flow samples ranged from 26 to 90 µg/L; the highest concentrations (greater than 45 µg/L) were in base flow draining the residential area with moderate-density on-site wastewater disposal (sites 01480368, 014806366, 014806369, and 01480637) and a residential area with high-density on-site wastewater disposal (site 014806384) (fig. 14). The sites with the highest concentrations of boron in base flow in September 2005 also had the highest concentrations of boron in base flow in May 2005.

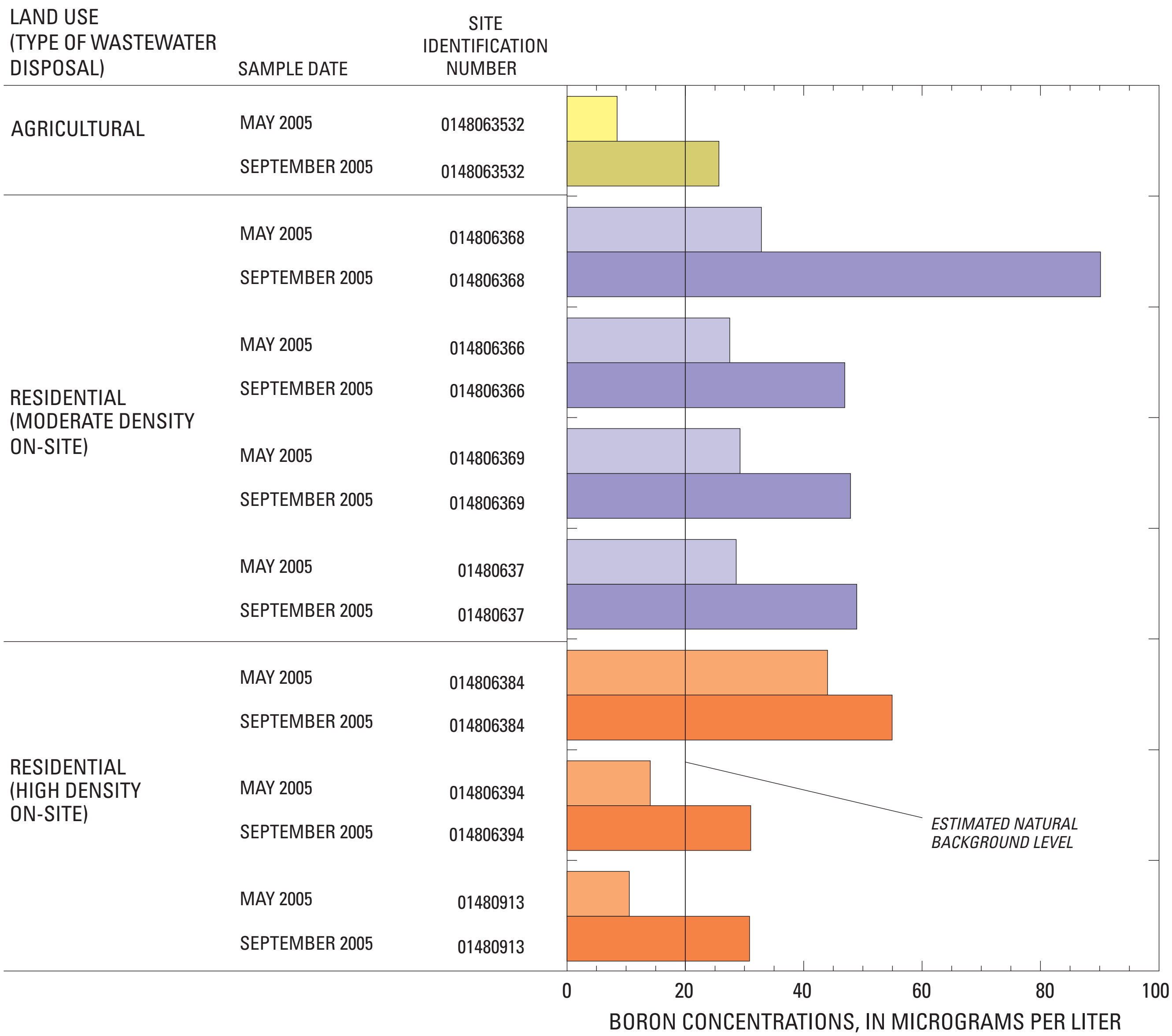
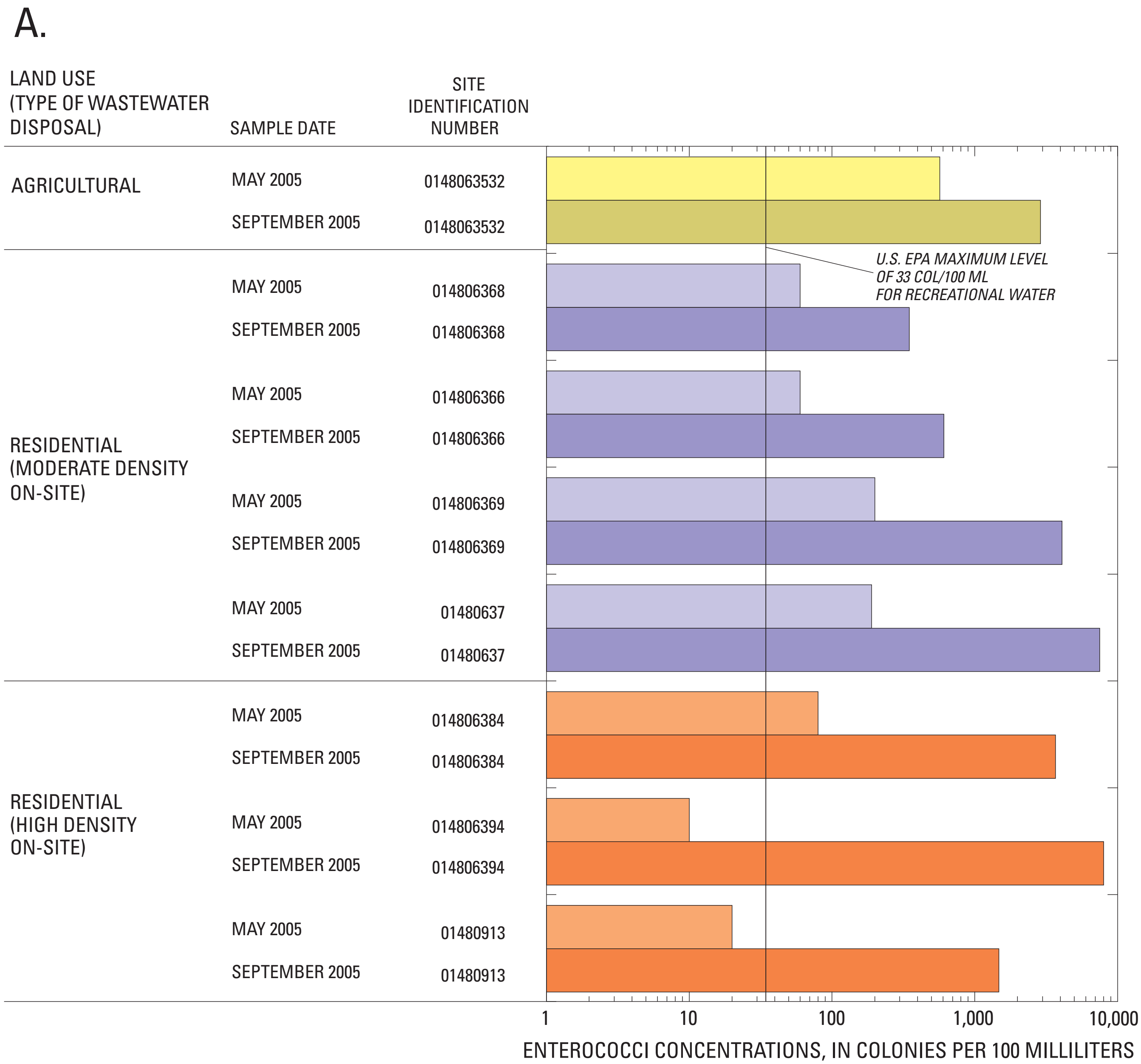


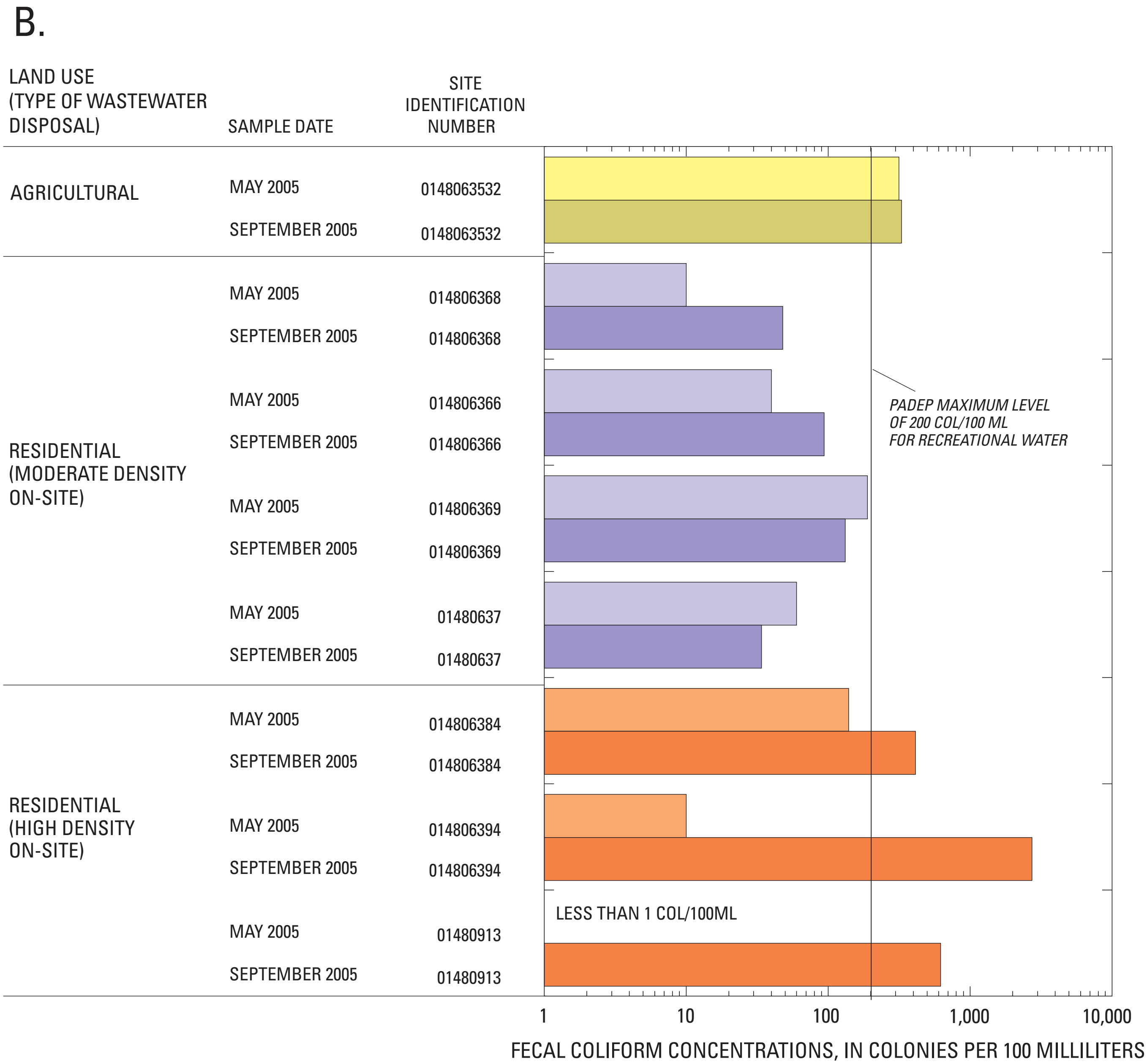
Figure 14. Boron concentrations in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005.
See figure 3 for location of sites.



EXPLANATION - [Abbreviations: U.S. EPA, U.S. Environmental Protection Agency]

Figure 15. Concentrations of (A) enterococci and (B) fecal coliform bacteria in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005.
See figure 3 for location of sites.

Enterococci concentrations in base-flow samples were greater by one to two orders of magnitude (factors of 10 to 100) in September 2005 compared to May 2005 (fig. 15a). In contrast to enterococci, concentrations of fecal coliform in base-flow samples were about the same order of magnitude in September and May 2005 except at two sites (01480913 and 014806394) where the September concentrations were two orders of magnitude greater than the May concentrations (fig. 15b). Bacteria concentrations in streams commonly are greatest during the warmest months of the year, from June to September in Chester County, Pa. (Town, 2001, p. 14-15). In the study area, base-flow temperatures were 2 to 5 degrees Celsius higher in September than in May 2005 (table 7 at the back of the report).



EXPLANATION - [Abbreviation: PADEP, Pennsylvania Department of Environmental Protection]

Figure 15. Concentrations of (A) enterococci and (B) fecal coliform bacteria in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005.—Continued
See figure 3 for location of sites.

The number and concentrations of the analyzed emerging contaminant organic wastewater compounds differed in May-June and September 2005 samples. More compounds were detected in May-June 2005 base flow than in September 2005 base flow (fig. 16). Twenty-one organic wastewater compounds were detected in May-June 2005 base-flow samples and 14 compounds were detected in September 2005 base-flow samples (table 5). Eight compounds, including phenol, methyl salicylate, camphor, *para*-Cresol, DEET, metolachlor, phenanthrene, and caffeine, were detected in both the May-June and the September 2005 base-flow samples (table 5). Given the low reported concentrations of most of the organic wastewater compounds, some of the differences between the May-June and September detections could be caused by variations in recovery and analysis at the laboratory. Phenol is the only compound with sufficient quantified concentrations to compare May-June and September 2005 results. Phenol concentrations in base-flow samples were greater in September 2005 than in May-June 2005 at six of the eight sites sampled in both periods (table 7 at the back of report).

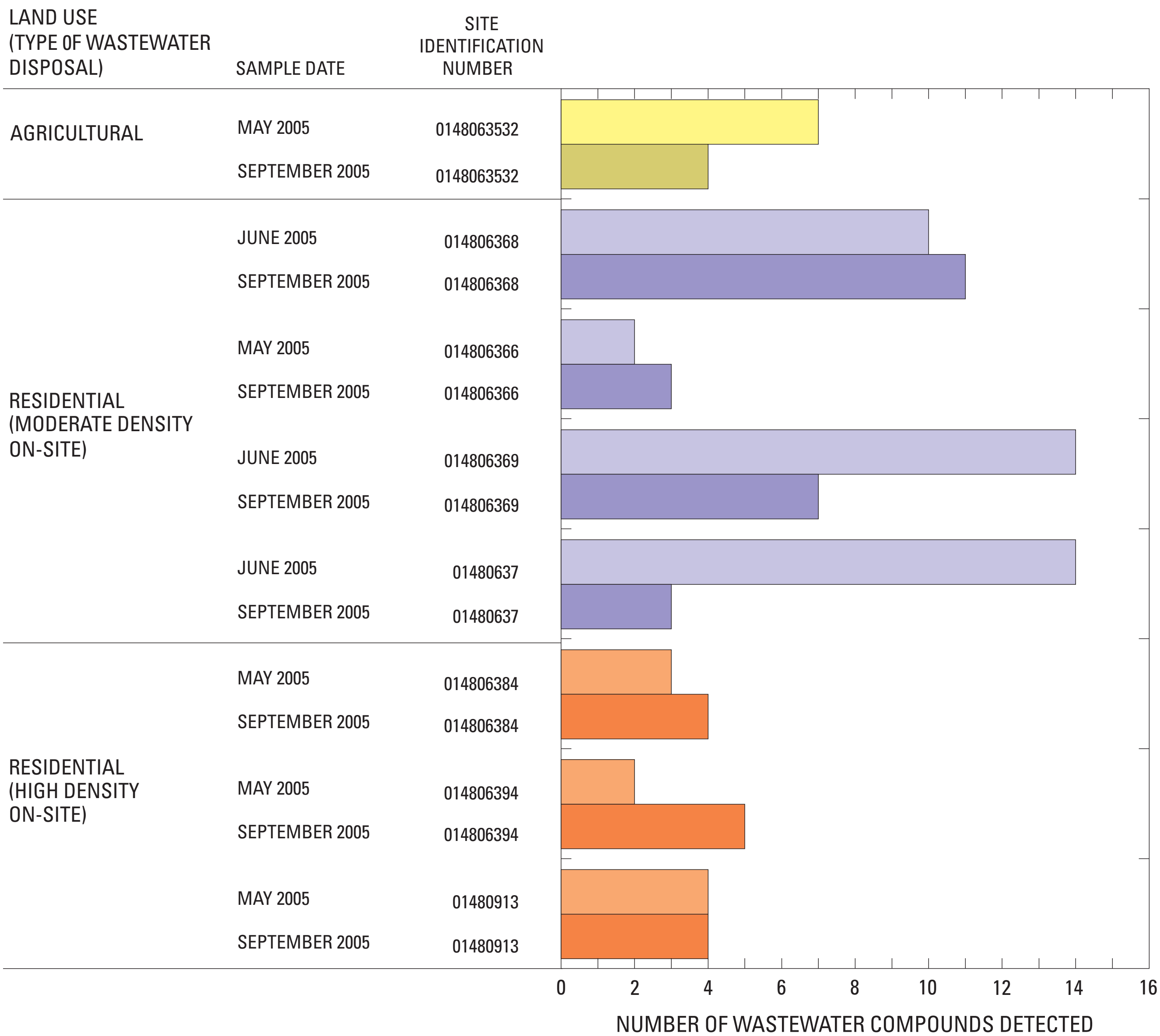


Figure 16. Number of organic wastewater compounds detected in base flow in areas of different land uses in and near the Broad Run watershed, Chester County, Pa., in May and September 2005.
See figure 3 for location of sites.

Effects of On-Site Wastewater Disposal

On the basis of the limited data, results of the pilot study in the Broad Run watershed indicate that the combination of nitrate, chloride, and boron were inorganic indicators of effects of on-site wastewater disposal on ground-water and associated base-flow water quality. Nitrate concentrations were higher in residential areas with on-site disposal than in residential areas with sewers. Nitrate concentrations were as high as 10.7 mg/L as N in ground water and 6.6 mg/L as N in base flow from the residential areas with on-site disposal. Chloride concentrations in ground-water and base-flow samples generally were higher in residential areas (with sewers and on-site wastewater disposal) than in the agricultural areas. Boron concentrations in most base-flow samples and in some ground-water samples were higher in residential areas with on-site disposal than in residential areas with sewers or in agricultural areas.

The presence of some organic wastewater compounds in both ground water and base flow in the study area indicates that the effects of on-site wastewater disposal are not limited to an increase in concentrations of nitrate, boron, and chloride. Apparently, some of the organic wastewater compounds can enter the ground-water system and later be discharged to streams. The results showing that the largest number of organic wastewater compounds were detected in streams and that the springs had the larger number of wastewater compounds detected compared to the well-water samples suggest transport of these compounds along shallow flow paths. More organic wastewater compounds were detected in ground-water samples from the residential area with high-density on-site wastewater disposal (septic systems and cesspools) than from the residential area with moderate-density on-site wastewater disposal (septic systems only), although the converse is apparent for base flow in those two areas, which possibly could be related to differences in soil properties or other physical properties in the two areas or in differences in retention/degradation rates or in maintenance and age of the cesspools relative to the septic systems or be an artifact of variable recovery and detection rates in laboratory analyses. Depth to water in the residential area with high-density on-site wastewater disposal (about 18 and 24 ft in two wells with water-level data) tended to be less than in the residential area with moderate-density on-site wastewater disposal (about 41 to 64 ft in three wells) (table 8 at the back of the report). Additional studies would be needed to determine the role of soil properties, depth to water, and type of on-site disposal system on the transport of organic wastewater compounds to ground water.

Enterococci and fecal coliform bacteria do not appear to be independent indicators of the effects of on-site wastewater disposal on ground-water and base-flow water quality, because elevated concentrations of bacteria were measured in samples from all land uses in the pilot study.

Comparison to Results from Previous Studies

As part of a previous stream assessment for Broad Run, base-flow and biological samples were collected at three sites along the main stem of Broad Run in the period 1999 to 2002 (Cinotto and others, 2005). The data from these three sites on the upper, middle, and lower reaches of the Broad Run, which integrate the effects of all land uses in the drainage area, showed that base-flow concentrations of nitrate ranged from about 2.1 to 2.8 mg/L as N and generally were slightly higher in the upper reach than in the middle or lower reaches. The main-stem concentrations of nitrate, chloride (19.2 to 22.6 mg/L), and boron (16 to 38 mg/L) were higher or slightly higher than concentrations of those constituents at a background reference site in Chester County (Cinotto and others, 2005, p. 40). The biological (benthic macroinvertebrates) data indicate that water quality in the main stem of Broad Run was good but slightly affected, because organisms intermediate in pollution tolerance were present (Cinotto and others, 2005, p. 40). Compared to the main-stem concentrations of nitrate, chloride, and boron measured in 1999-2002, concentrations of those constituents in base flow in most tributaries of the current study in 2005 were similar or higher. Nitrate concentrations were highest in tributaries draining an agricultural area (5.7 to 6.4 mg/L as N) and residential areas with on-site wastewater disposal (septic systems and (or) cesspools) (3.8 to 6.6 mg/L as N) in base flow in 2005. Chloride concentrations were highest in tributaries draining predominantly residential areas and ranged from 21 to 65 mg/L for base flow in 2005. Boron concentrations were highest in tributaries draining residential areas with on-site wastewater disposal and ranged from 14 to 90 µg/L for base flow in 2005.

As part of an assessment of the role of nonpoint sources on water quality in the Christina River Basin, base-flow and stormflow samples were collected in 1998 from site 01480637 (fig. 3) on a tributary to Broad Run that drains an area of predominantly residential land with septic systems (Senior and Koerkle, 2003a; Senior and Koerkle, 2003b). Selected sub-basins with a predominant land use were instrumented for flow monitoring and water-quality sample collection. These data showed that nitrate concentrations in base flow from the residential area with septic systems (3 to 5 mg/L as N) were higher than in base flow from sewered residential, forested, and urban areas (0.5 to 2 mg/L as N) but somewhat lower than from agricultural areas (3.5 to 6 mg/L) of the Christina River Basin.

In an evaluation of water quality of West Valley Creek Basin, which is about 2 mi east of the Broad Run watershed of this study, base-flow concentrations of nitrate were about 3 mg/L as N in tributaries draining residential areas with septic systems (Senior and others, 1997, p. 81-83). These residential areas are underlain by the same or similar rocks as those that underlie the Broad Run watershed, and the associated nitrate concentrations in base flow are similar but slightly lower than those measured in base flow in 2005 from the residential areas with septic systems (3.8 to 6.3 mg/L as N) in the current study.

Wells in other areas possibly affected by on-site wastewater disposal were sampled in 2000 and 2002 as part of an ongoing ground-water-quality monitoring program in Chester County, Pa., conducted by USGS in cooperation with the Chester County Health Department and Chester County Water Resources Authority. In 2000, samples from 6 wells in areas with different types of on-site wastewater disposal (table 6) were analyzed for major ions, nutrients, boron, selected antibiotics, human drugs, hormones, and wastewater compounds as part of a national reconnaissance for which 47 ground-water samples were collected by USGS nationwide (Barnes and others, 2005). In 2002, samples from six wells in areas with either drip or spray-irrigation on-site wastewater disposal (table 6) were analyzed for major ions, nutrients, boron, selected antibiotics, and wastewater compounds. Results of the 2000 and 2002 sampling of 12 wells indicate ground-water quality was affected by anthropogenic constituents: nitrate concentrations generally were above the natural background of about 1 mg/L and ranged up to 12 mg/L as N; boron concentrations above natural background (greater than about 20 to 30 µg/L) and as high as 250 µg/L were measured in samples from 3 wells; chloride concentrations above natural background (greater than 10 to 20 mg/L) were measured in samples from 10 wells; 18 wastewater compounds, 4 pesticides or pesticide degradates, and 1 antibiotic (sulfamethoxole) were detected at low concentrations, with at least of 1 of these compounds detected in samples from 11 wells. The highest measured concentrations of boron (250 µg/L) and the antibiotic sulfamethoxole (0.37 µg/L) were in a sample from a monitor well at a drip-irrigation site. Several of the wastewater compounds detected in the 2000 and 2002 ground-water samples, including phenol and DEET, also were detected in base flow and ground water in the Broad Run watershed in 2005 (tables 5 and 6).

Summary and Conclusions

On-site wastewater disposal has the potential to introduce contaminants into ground water and subsequently, by ground-water discharge, to streams. In Chester County, Pa., and other rural areas undergoing development, the change in land use consists of residential and commercial uses replacing forested and agricultural uses. In many of the areas being developed, residential wastewater is disposed of on-site. In 2005, the U.S. Geological Survey, in cooperation with the Chester County Water Resources Authority and the Chester County Health Department, conducted a pilot study of the effect of residential on-site wastewater disposal on stream base-flow and ground-water quality based on reconnaissance-level data.

The Broad Run watershed drains about 7.1 mi^2 in central Chester County. The area is underlain by Paleozoic and older metamorphic rocks (primarily schist and gneiss), which form fractured-rock aquifers. Soils are generally permeable. Depth to water typically varies by topography; depths to water are greater under hilltops than on slopes or in valleys and can range from 1 to 86 ft below land surface. Ground-water levels and base flow fluctuate seasonally because of changes in net recharge rates; depth to water is greatest in the fall and least in the spring. Ground-water discharge to streams (base flow) comprises about 80 percent of streamflow in Broad Run.

Sites selected for base-flow and ground-water sampling were in tributary areas predominantly covered by one land use. Land uses in tributary areas included row-crop agriculture, residential with sewers, moderate-density residential (lot sizes 1 to 2 acres or greater) with on-site wastewater disposal (septic systems), and high-density residential (village) with on-site wastewater disposal (cesspools and septic systems). Data were collected for a preliminary assessment of potential effects of on-site wastewater disposal on ground-water and base-flow water quality and were not intended to support statistical analyses. Because of limited data and lack of statistical analysis, conclusions should be considered preliminary and results interpreted with caution.

Stream samples under base-flow conditions were collected twice at 8 sites and once at 2 other sites, and ground-water samples were collected once at 10 sites (8 wells and 2 springs) in the period from May to September 2005 (fig. 4). The sampling times were selected to collect stream samples under high base-flow (May-June 2005) and low base-flow (September 2005) conditions to determine if water quality was affected by hydrologic conditions. The ground-water samples were collected in mid-June 2005 to approximately represent ground-water quality at the time of the late May base-flow sampling. Streamflow in May and September 2005 in the study area was probably below average for those months. Samples were analyzed for dissolved major ions, nutrients, boron, manganese, iron, selected organic wastewater compounds, and bacteria.

Nitrate, chloride, and boron were considered possible indicators of wastewater on ground-water and base-flow quality, and concentrations of all three constituents were relatively elevated in the residential areas with on-site wastewater disposal. Concentrations of these constituents were more variable in ground-water samples than in base-flow samples. Concentrations of nitrate generally were higher in ground-water and base-flow samples from the agricultural and residential areas with on-site wastewater disposal than in the residential area with sewers. Nitrate concentrations of 10 mg/L as N, exceeding the USEPA MCL of 10 mg/L as N in drinking water, were measured in a ground-water sample from a well in the residential area with high-density on-site wastewater disposal. Base-flow concentrations of nitrate in the residential areas with on-site wastewater disposal ranged from 2 to 6.6 mg/L as N. Concentrations of chloride were higher in ground-water and base-flow samples from the residential areas (with on-site wastewater disposal and with sewers) than in the agricultural area. Chloride concentrations up to 373 mg/L, exceeding the USEPA SMCL of 250 mg/L in drinking water, were measured in a ground-water sample from a well in the residential area with septic systems. Concentrations of boron were higher in ground-water and base-flow samples from the residential areas with on-site wastewater disposal than in the residential area with sewers and the agricultural area.

Table 6. Results of laboratory analysis for nitrate, chloride, boron, and selected wastewater compounds in samples collected from 12 wells in summer 2000 or summer 2002 in areas possibly affected by on-site wastewater disposal, Chester County, Pennsylvania

[mg/L as N; milligrams per liter as nitrogen; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; E, estimated value less than method reporting level; M, measured value for compound detected but not quantifiable below method reporting level]

U.S. Geological Survey local well number	Date of sample	Possible waste source	Ground-water sample concentrations				
			Nitrate (mg/L as N)	Chloride (mg/L)	Boron (µg/L)	Wastewater compounds[1] (µg/L)	Parameter code
Summer 2000							
CH-75	8/8/2000	Treated sewage effluent applied by spray irrigation to land	4.75	33	<16	E0.086 Octylphenol, monoethoxy	61706
CH-1281	8/7/2000	Cow manure -pasture, crop land and human septic system	9.93	18	<16	E0.083 Octylphenol, monoethoxy	61706
CH-3331	8/9/2000	Human septic system	5.98	34	67	0.563 bisphenol A[2]	62069
CH-3516	8/24/2000	Large-animal veterinary center and human septic system	11.1	34	17	E0.348 phenol 0.099 bisphenol A[2] 0.04 sulfamethoxole[3]	34466 62069
CH-4413	8/24/2000	Large-animal veterinary center and human septic system	5.01	59	<16	2.21 bisphenol A[2] 0.01 sulfamethoxole[3]	62069
CH-4730	8/3/2000	Spent compost from mushroom operations and human septic systems	11.8	52	<16	E0.031 tri(2-chloroethyl) phosphate E0.047 caffeine	62087 50305
Summer 2002							
CH-410	7/29/2002	Treated sewage effluent applied by spray irrigation to land and human septic effluent	<.05	47	30	E.1 acetophenone M benzophenone E0.1 DEET 0.6 phenol E0.1 triphenylphosphate[4] E0.1 tri (2-butoxy)phosphate	62064 62067 62082 34466 62092 62093
CH-5178	7/31/2002	Treated sewage effluent applied by spray irrigation to land	1.61	66	20	0.05 sulfamethoxole[3]	
CH-6653	8/1/2002	Treated sewage effluent applied by spray irrigation to land	3.46	6	20		
CH-6654	8/5/2002	Treated sewage effluent applied by drip irrigation to land	7.79	91	250	E0.1 AHTN M metolachlor M DEET E0.1 tri (2-chloroethyl) phosphate E0.2 Tri(dichloroisopropyl)phosphate 0.37 sulfamethoxole[3]	62065 39415 62082 62087 62088
CH-6655	8/6/2002	Treated sewage effluent applied by spray irrigation to land	3.80	62	90	M DEET M tri (2-chloroethyl) phosphate M Tri(dichloroisopropyl)phosphate 0.06 sulfamethoxole[3]	62082 62087 62088
CH-6656	8/7/2002	Treated sewage effluent applied by spray irrigation to land	5.35	88	20	E0.1 bromoform[5] M metalaxyl[6] M triclosan[7]	34288 50359 62090

[1]Includes selected pharmaceuticals; if compound not listed in table 5, use listed in footnote of this table.

[2]Polycarbonate resins manufacture, antioxidant, flame retardant, plasticizer.

[3]Antibiotic.

[4]Plasticizer, flame retardant.

[5]Wastewater ozonation product.

[6]Pesticide.

[7]Disinfectant.

Organic wastewater compounds were detected at low concentrations in ground-water and base-flow samples from the study area, indicating that the effects of on-site wastewater disposal is not limited to an increase in concentrations of nitrate, boron, and chloride. Of the 62 compounds in the emerging contaminant organic wastewater analysis, 30 different organic wastewater compounds were detected at low levels. More compounds were detected in base-flow samples than in ground-water samples. Of the ground-water samples, more compounds were detected in samples from springs than from wells. The difference in number of detections among base flow, springs, and well samples suggests the presence of shallow ground-water flowpaths. Of the well-water samples, more compounds generally were detected in samples from wells in the residential areas with high-density on-site wastewater disposal than elsewhere. Of the base-flow samples collected in May-June 2005, the largest number of organic wastewater compounds (10 to 14 compounds) were detected in samples from sites in the residential area with moderate density on-site wastewater disposal (septic systems), and the fewest were in samples from the sewered residential area. Base-flow samples from the site in the agricultural area had more compounds than base-flow samples from the residential area with high-density on-site wastewater disposal.

Bacteria were detected in samples from one well and two springs and in all base-flow samples. Enterococci and fecal coliform bacteria do not appear to be independent indicators of on-site wastewater disposal on ground-water and base-flow water quality, because elevated concentrations of bacteria were measured in samples from all land uses in the pilot study.

Seasonal base-flow samples showed some differences. Base flow in September 2005 was about 25 percent of base flow in May 2005, and in September, two of the 10 stream sites were dry. Despite the decrease in streamflow, concentrations of most major ions in base flow remained relatively constant from May to September 2005. Generally, the concentrations of most major ions in September base-flow samples were similar or slightly (commonly about 5 to 20 percent) higher than concentrations in May base-flow samples. Nitrate concentrations in base-flow samples were about 10 percent lower in September than in May 2005, which may be related to seasonal differences in nutrient uptake by algae in the stream. The concentrations of boron and of bacteria, however, did change generally by more than 20 percent in base-flow samples from May to September 2005. The concentrations of boron in base-flow samples were two to three times higher in September than in May 2005 and were not accompanied by comparable increases of other constituents of probable anthropogenic origin, such as chloride. The sites with the highest concentrations of boron in base flow in September 2005 also had the highest concentrations of boron in base flow in May 2005. The number and concentrations of the analyzed emerging contaminant organic wastewater compounds differed in the May-June and the September 2005 samples. More compounds were detected in base-flow samples collected in May-June 2005 than in base-flow samples collected in September 2005, suggesting seasonal factors such as higher springtime ground-water levels may affect base-flow quality. Twenty-one organic wastewater compounds were detected in base-flow samples collected in May-June 2005 and 14 compounds were detected in base-flow samples collected in September 2005. Eight compounds were detected in both May-June and September 2005 base-flow samples, including phenol, methyl salicylate, camphor, *para*-Cresol, DEET, metolachlor, phenanthrene, and caffeine. Bacteria concentrations in base-flow samples were greater in September 2005 compared to May 2005. Enterococci concentrations were greater by one to two orders of magnitude, and fecal coliform concentrations were similar (except at two sites where the September concentrations were two orders of magnitude greater than the May concentrations). Bacteria concentrations in streams commonly are greatest during the warmest months of the year, from June to September in Chester County, Pa.

Comparison of results of the pilot study in and near Broad Run watershed to other studies in Chester County, Pa., and elsewhere indicates that some of the same wastewater compounds were detected and elevated concentrations of nitrate, boron, and chloride were measured in ground water in areas of on-site wastewater disposal. The combination of relatively elevate nitrate, boron, and chloride concentrations appear to be an indicator of the presence of wastewater in ground water and associated base flow. Concentrations of nitrate in base flow in drainage areas of residential land uses with on-site wastewater disposal in these studies ranged from to 3 to more than 6 mg/L as N and were higher than in forested areas or in residential areas with sewers.

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Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005. (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

U.S. Geological Survey station identification number	Station name	Date	Time	Agency analyzing sample, code (00028)	Altitude of land surface feet (72000)	Instantaneous discharge, ft^3/s (00061)	Drainage area, mi^2 (81024)
0148063532	Unn Trib to Broad Run at Chestnut Ln nr Thorndale, Pa.	5/26/2005	1130	80020	411.8	0.19	0.27
0148063532	Unn Trib to Broad Run at Chestnut Ln nr Thorndale, Pa.	9/27/2005	1130	80020	411.8	.04	.27
0148063522	Unn Trib to Broad Run ab school nr Thorndale, Pa.	5/26/2005	1230	80020	436.7	.10	.24
014806368	Unn Trib to Little Broad Run nr Romansville, Pa.	5/25/2005	1100	80020	365	.12	.21
014806368	Unn Trib to Little Broad Run nr Romansville, Pa.	6/10/2005	1010	80020	365	.12	.21
014806368	Unn Trib to Little Broad Run nr Romansville, Pa.	9/28/2005	1000	80020	365	.01	.21
014806366	L Broad Run ab Shadyside Rd nr Romansville, Pa.	5/25/2005	0830	80020	386.4	.20	.11
014806366	L Broad Run ab Shadyside Rd nr Romansville, Pa.	9/28/2005	0900	80020	386.4	.06	.11
014806369	L Broad Run bl Shadyside Road near Romansville, Pa.	5/25/2005	1210	80020	340.7	.69	.49
014806369	L Broad Run bl Shadyside Road near Romansville, Pa.	6/10/2005	0800	80020	340.7	.52	.49
014806369	L Broad Run bl Shadyside Road near Romansville, Pa.	9/28/2005	1100	80020	340.7	.20	.49
01480637	Little Broad Run near Marshallton, Pa.	5/25/2005	1310	80020	307.6	.90	.6
01480637	Little Broad Run near Marshallton, Pa.	6/10/2005	1120	80020	307.6	.82	.6
01480637	Little Broad Run near Marshallton, Pa.	9/28/2005	1200	80020	307.6	.24	.6
01480637	Little Broad Run near Marshallton, Pa.	9/28/2005	1201	80020	307.6	.24	.6
014806374	Outfall Trib to Broad Run ab Rt 162 nr Marshallton, Pa.	5/26/2005	1315	80020	273.4	.02	--
014806384	Unnamed Tributary to Broad Run at Marshallton, Pa.	5/26/2005	1010	80020	308.9	.12	.05
014806384	Unnamed Tributary to Broad Run at Marshallton, Pa.	9/27/2005	0900	80020	308.9	.03	.05
014806394	Un Tr to Un Tr to WB Brandywine Cr at Marshallton, Pa.	5/26/2005	0900	80020	257.8	.12	.16
014806394	Un Tr to Un Tr to WB Brandywine Cr at Marshallton, Pa.	9/27/2005	1030	80020	257.8	.04	.16
01480913	Unn Trib to EB Brandywine Creek at Marshallton, Pa.	5/26/2005	0730	80020	295	.19	.06
01480913	Unn Trib to EB Brandywine Creek at Marshallton, Pa.	9/27/2005	0800	80020	295	.01	.06

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

U.S. Geological Survey station identification number	Date	Barometric pressure, mm Hg (00025)	Dissolved oxygen, mg/L (00300)	Dissolved oxygen, percent of saturation (00301)	pH, water, unfltrd field, std units (00400)	pH, water, unfltrd lab, std units (00403)	Specific conductance, wat unf lab, µS/cm 25 °C (90095)	Specific conductance, water, unf, µS/cm 25 °C (00095)	Temperature, air, °C (00020)	Temperature, water, °C (00010)	Calcium water, fltrd, mg/L (00915)	Magnesium, water, fltrd, mg/L (00925)
0148063532	5/26/2005	741	10.0	93	7.2	7.5	217	221	15.0	12.3	19.1	10.6
0148063532	9/27/2005	748	8.7	88	7.4	6.6	272	271	--	16.2	26.3	12.3
0148063522	5/26/2005	741	11.0	104	8.0	7.8	292	295	17.5	12.8	17.9	12.9
014806368	5/25/2005	749	10.5	98	7.5	7.4	261	262	11.0	11.4	19.5	12.7
014806368	6/10/2005	754	9.7	97	7.3	--	--	281	27.5	15.5	--	--
014806368	9/28/2005	753	9.6	92	7.8	5.9	385	386	14.0	13.7	32.9	14.1
014806366	5/25/2005	749	11.0	100	7.1	7.3	215	216	11.0	11.3	9.57	7.82
014806366	9/28/2005	753	10.0	96	7.3	6.4	250	253	14.0	13.4	11.2	8.13
014806369	5/25/2005	749	10.3	95	7.0	7.5	239	245	11.5	11.8	16.7	10.3
014806369	6/10/2005	755	9.0	94	6.8	--	--	270	25.5	17.6	--	--
014806369	9/28/2005	753	9.0	89	7.2	6.2	271	276	17.5	15.2	18.4	10.2
01480637	5/25/2005	749	10.6	100	7.2	7.2	231	232	--	11.7	16.4	8.63
01480637	6/10/2005	755	9.0	96	7.2	--	--	255	25.0	18.4	--	--
01480637	9/28/2005	753	10.0	103	7.5	6.2	265	269	22.0	16.6	19.0	8.62
01480637	9/28/2005	753	10.0	103	7.5	6.3	266	269	22.0	16.6	19.0	8.83
014806374	5/26/2005	741	5.8	57	7.3	7.7	437	444	20.5	13.8	61.6	14.2
014806384	5/26/2005	741	10.5	98	7.1	7.5	427	408	14.5	12.2	24.0	19.1
014806384	9/27/2005	748	8.5	86	7.2	6.6	375	368	--	15.5	23.4	15.4
014806394	5/26/2005	741	10.7	99	7.5	7.5	220	225	13.5	11.7	14.9	8.20
014806394	9/27/2005	748	8.6	89	7.5	6.7	264	264	--	16.8	18.4	10.0
01480913	5/26/2005	741	10.4	94	7.0	7.3	155	155	13.5	11.2	12.2	5.49
01480913	9/27/2005	748	8.3	83	7.2	6.8	144	144	--	15.3	12.2	4.31

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

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U.S. Geological Survey station identification number	Date	Potassium, water, fltrd, mg/L (00935)	Sodium, water, fltrd, mg/L (00930)	Alkalinity, water, flt inc tit field, mg/L as $CaCO_3$ (39086)	Chloride, water, fltrd, mg/L (00940)	Fluoride, water, fltrd, mg/L (00950)	Silica, water, fltrd, mg/L (00955)	Sulfate, water, fltrd, mg/L (00945)	Ammonia water, fltrd, mg/L as N (00608)	Nitrite + nitrate water, fltrd, mg/L as N (00631)	Nitrite water, fltrd, mg/L as N (00613)	Orthophosphate, water, fltrd, mg/L as P (00671)
0148063532	5/26/2005	1.07	7.61	41	21.4	<0.10	11.3	11.1	E0.03	6.37	E0.006	<0.02
0148063532	9/27/2005	1.74	7.08	48	21.5	<.10	14.7	9.54	<.04	5.69	<.008	E.01
0148063522	5/26/2005	1.05	20.2	46	50.5	<.10	7.2	14.8	<.04	3.23	E.005	<.02
014806368	5/25/2005	2.60	13.5	36	29.1	<.10	8.7	24.4	<.04	6.30	.008	E.01
014806368	6/10/2005	--	--	--	--	--	--	--	--	--	--	--
014806368	9/28/2005	2.19	19.3	58	44.1	E.07	12.3	29.6	<.04	5.52	<.008	.02
014806366	5/25/2005	1.31	20.4	17	39.3	<.10	5.6	13.0	<.04	4.45	<.008	E.01
014806366	9/28/2005	1.25	20.0	10	43.6	<.10	5.9	12.4	<.04	5.17	<.008	<.02
014806369	5/25/2005	1.39	16.8	30	37.1	<.10	8.7	16.4	.06	4.17	.027	<.02
014806369	6/10/2005	--	--	--	--	--	--	--	--	--	--	--
014806369	9/28/2005	1.44	16.4	32	40.3	<.10	9.3	16.0	.05	3.93	.033	<.02
01480637	5/25/2005	1.37	15.3	31	34.6	<.10	9.1	15.0	E.03	4.03	.019	<.02
01480637	6/10/2005	--	--	--	--	--	--	--	--	--	--	--
01480637	9/28/2005	1.46	15.6	36	39.8	<.10	9.6	14.7	<.04	3.83	E.005	E.01
01480637	9/28/2005	1.48	15.5	36	39.6	<.10	9.6	14.5	<.04	3.82	E.004	E.01
014806374	5/26/2005	2.00	14.3	154	20.0	E.08	16.4	30.7	<.04	3.33	<.008	<.02
014806384	5/26/2005	3.29	32.2	56	65.0	<.10	11.8	27.4	<.04	6.61	<.008	E.02
014806384	9/27/2005	2.74	23.2	42	51.8	<.10	12.8	22.5	<.04	5.32	<.008	.02
014806394	5/26/2005	2.23	15.3	34	30.6	<.10	14.8	16.8	<.04	2.82	<.008	<.02
014806394	9/27/2005	2.52	14.6	27	34.7	<.10	17.2	18.3	<.04	2.71	<.008	.03
01480913	5/26/2005	1.76	8.78	30	11.7	<.10	14.7	17.4	<.04	1.94	<.008	<.02
01480913	9/27/2005	2.12	7.56	24	9.61	<.10	16.5	14.7	<.04	1.17	<.008	<.02

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

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U.S. Geological Survey station identification number	Date	Enterococi, m-E MF, water, col/100 mL (31649)	Fecal coliform, M-FC 0.7µ MF col/100 mL (31625)	Boron, water, fltrd, µg/L (01046)	Iron, water, fltrd, µg/L (01046)	Mangan-ese, water, fltrd, µg/L (01056)	1,4-Di-chloro-benzene water, fltrd, µg/L (34572)	1-Methyl-naphth-alene, water, fltrd, µg/L (62054)	2,6-Di-methyl-naphth-alene, water, fltrd, µg/L (62055)	2-Methyl-naphth-alene, water, fltrd, µg/L (62056)	3-beta-Copros-tanol, water, fltrd, µg/L (62057)	3-Methyl-1H-indole, water, fltrd, µg/L (62058)
0148063532	5/26/2005	570	310	8.5	16	39.1	<0.5	<0.5	<0.5	<0.5	<2	M
0148063532	9/27/2005	2,900	330	26	17	12.2	<.5	<.5	<.5	<.5	<2	<1
0148063522	5/26/2005	960	110	E6.4	E4	4.8	<.5	<.5	<.5	<.5	<2	<1
014806368	5/25/2005	60	10	33	<6	3.7	--	--	--	--	--	--
014806368	6/10/2005	--	--	--	--	--	<.5	<.5	<.5	<.5	<2	<1
014806368	9/28/2005	350	48	90	6	4.5	<.5	<.5	<.5	<.5	<2	M
014806366	5/25/2005	60	40	28	7	5.4	<.5	<.5	<.5	<.5	<2	<1
014806366	9/28/2005	610	94	47	E3	.8	<.5	<.5	<.5	<.5	<2	<1
014806369	5/25/2005	200	190	29	43	51.9	--	--	--	--	--	--
014806369	6/10/2005	--	--	--	--	--	M	<.5	<.5	<.5	<2	M
014806369	9/28/2005	4,100	130	48	74	24.9	<.5	<.5	<.5	<.5	<2	<1
01480637	5/25/2005	190	60	29	19	8.7	--	--	--	--	--	--
01480637	6/10/2005	--	--	--	--	--	M	<.5	<.5	<.5	<2	M
01480637	9/28/2005	7,500	34	49	13	7.6	<.5	<.5	<.5	<.5	<2	<1
01480637	9/28/2005	9,200	30	49	10	7.5	<.5	<.5	<.5	<.5	<2	<1
014806374	5/26/2005	60	10	7.5	12	17.5	<.5	<.5	<.5	<.5	<2	<1
014806384	5/26/2005	80	140	44	<6	2.1	<.5	<.5	<.5	<.5	<2	<1
014806384	9/27/2005	3,700	410	55	E5	1.2	<.5	<.5	<.5	<.5	<2	<1
014806394	5/26/2005	10	10	14	7	4.6	<.5	<.5	<.5	<.5	<2	<1
014806394	9/27/2005	8,000	2700	31	E6	3.1	<.5	<.5	<.5	<.5	<2	<1
01480913	5/26/2005	20	<1	11	28	37.1	<.5	<.5	<.5	<.5	<2	<1
01480913	9/27/2005	1,480	620	31	106	55.1	<.5	<.5	<.5	<.5	<2	<1

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

U.S. Geological Survey station identification number	Date	3-tert-Butyl-4-hydroxy-anisole water, fltrd, µg/L (62059)	4-Cumyl-phenol, water, fltrd, µg/L (62060)	4-Octyl-phenol, water, fltrd, µg/L (62061)	4-Nonyl-phenol, water, fltrd, µg/L (62085)	4-tert-Octyl-phenol, water, fltrd, µg/L (62062)	5-Methyl-1H-benzo-triazole, water, fltrd, µg/L (62063)	9,10-Anthra-quinone water, fltrd, µg/L (62066)	Aceto-phenone water, fltrd, µg/L (62064)	AHTN, water, fltrd, µg/L (62065)	Anthra-cene, water, fltrd, µg/L (34221)	Benzo-[a]-pyrene, water, fltrd, µg/L (34248)
0148063532	5/26/2005	<5	<1	M	<5	<1	<2	<0.5	<0.5	<0.5	<0.5	<0.5
0148063532	9/27/2005	<5	<1	<1	E1	<1	<2	<.5	<.5	<.5	<.5	<.5
0148063522	5/26/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
014806368	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806368	6/10/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	M	<.5	<.5
014806368	9/28/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
014806366	5/25/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
014806366	9/28/2005	<5	<1	<1	M	<1	<2	<.5	<.5	<.5	<.5	<.5
014806369	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806369	6/10/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	M	M	<.5
014806369	9/28/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
01480637	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
01480637	6/10/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	M	M	<.5
01480637	9/28/2005	<5	<1	<1	M	<1	<2	<.5	<.5	<.5	<.5	<.5
01480637	9/28/2005	<5	<1	<1	M	<1	<2	<.5	<.5	<.5	<.5	<.5
014806374	5/26/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
014806384	5/26/2005	<5	<1	M	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
014806384	9/27/2005	<5	<1	<1	M	<1	<2	<.5	<.5	<.5	<.5	<.5
014806394	5/26/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
014806394	9/27/2005	<5	<1	<1	E1	<1	<2	<.5	<.5	<.5	<.5	<.5
01480913	5/26/2005	<5	<1	M	<5	<1	<2	<.5	<.5	<.5	<.5	<.5
01480913	9/27/2005	<5	<1	<1	<5	<1	<2	<.5	<.5	<.5	<.5	<.5

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

U.S. Geological Survey station identification number	Date	Benzophenone water, fltrd, µg/L (62067)	beta-Sitosterol, water, fltrd, µg/L (62068)	beta-Stigmastanol, water, fltrd, µg/L (62086)	Bisphenol A, water, fltrd, µg/L (62069)	Bisphenol A-d3 sur Sch 2033 & 8033, water, fltrd, pct rcv (99583)	Bromacil, water, fltrd, µg/L (04029)	Caffeine, water, fltrd, µg/L (50305)	Caffeine-13C sur Sch 2033 & 8033, water, fltrd, pct rcv (99584)	Camphor water, fltrd, µg/L (62070)	Carbaryl, water, fltrd 0.7u GF µg/L (82680)	Carbazole, water, fltrd, µg/L (62071)
0148063532	5/26/2005	<0.5	<2	<2	--	13.6	<0.5	<0.5	81.0	<0.5	<1	<0.5
0148063532	9/27/2005	<.5	<2	<2	--	.0	<.5	<.5	85.7	M	<1	<.5
0148063522	5/26/2005	<.5	<2	<2	--	27.6	<.5	<.5	83.6	<.5	<1	<.5
014806368	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806368	6/10/2005	<.5	<2	<2	<1	.0	<.5	M	77.8	M	<1	<.5
014806368	9/28/2005	<.5	<2	<2	--	.0	<.5	M	110	<.5	<1	<.5
014806366	5/25/2005	<.5	<2	<2	--	72.4	<.5	<.5	86.1	<.5	<1	<.5
014806366	9/28/2005	<.5	<2	<2	--	.0	<.5	<.5	100	<.5	<1	<.5
014806369	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806369	6/10/2005	<.5	<2	<2	<1	.0	<.5	<.5	76.2	M	<1	<.5
014806369	9/28/2005	<.5	<2	<2	--	.0	<.5	<.5	94.5	M	<1	<.5
01480637	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
01480637	6/10/2005	<.5	<2	<2	<1	.0	<.5	M	84.3	M	<1	<.5
01480637	9/28/2005	<.5	<2	<2	--	16.3	<.5	<.5	91.6	<.5	<1	<.5
01480637	9/28/2005	<.5	<2	<2	--	.0	<.5	<.5	96.0	M	<1	<.5
014806374	5/26/2005	<.5	<2	<2	--	22.1	<.5	<.5	81.9	<.5	<1	<.5
014806384	5/26/2005	<.5	<2	<2	--	24.9	<.5	<.5	80.9	<.5	<1	<.5
014806384	9/27/2005	<.5	<2	<2	--	.0	<.5	<.5	90.0	M	<1	<.5
014806394	5/26/2005	<.5	<2	<2	--	25.0	<.5	<.5	80.0	<.5	<1	<.5
014806394	9/27/2005	<.5	<2	<2	--	.0	<.5	<.5	87.0	M	<1	<.5
01480913	5/26/2005	<.5	<2	<2	M	25.4	<.5	<.5	81.3	<.5	<1	<.5
01480913	9/27/2005	<.5	<2	<2	--	.0	<.5	<.5	86.7	M	<1	<.5

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

U.S. Geological Survey station identification number	Date	Chlor-pyrifos water, fltrd, µg/L (38933)	Choles-terol, water, fltrd, µg/L (62072)	Cotinine, water, fltrd, µg/L (62005)	DecaF-biphenl sur Sch 2033 & 8033, water, fltrd, pct rcv (99585)	DEET, water, fltrd, µg/L (62082)	Diazinon, water, fltrd, µg/L (39572)	Di-ethoxy-nonyl-phenol, water, fltrd, µg/L (62083)	Di-ethoxy-octyl-phenol, water, fltrd, µg/L (61705)	D-Limo-nene, water, fltrd, µg/L (62073)	Ethoxy-octyl-phenol, water, fltrd µg/L (61706)	Fluor-anthene water, fltrd, µg/L (34377)
0148063532	5/26/2005	<0.5	<2	<1.00	78.7	<0.5	<0.5	<5	<1	<0.5	<1	<0.5
0148063532	9/27/2005	<.5	<2	<1.00	56.3	<.5	<.5	<5	<1	<.5	<1	<.5
0148063522	5/26/2005	<.5	<2	<1.00	75.7	<.5	<.5	<5	<1	<.5	<1	<.5
014806368	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806368	6/10/2005	<.5	<2	<1.00	61.2	M	<.5	<5	<1	<.5	<1	<.5
014806368	9/28/2005	<.5	<2	<1.00	86.2	M	<.5	<5	<1	<.5	<1	M
014806366	5/25/2005	<.5	<2	<1.00	76.8	M	<.5	<5	<1	<.5	<1	<.5
014806366	9/28/2005	<.5	<2	<1.00	69.3	<.5	<.5	<5	<1	<.5	<1	<.5
014806369	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806369	6/10/2005	M	<2	<1.00	48.7	<.5	<.5	<5	M	<.5	M	<.5
014806369	9/28/2005	<.5	<2	<1.00	74.7	<.5	<.5	<5	<1	<.5	<1	M
01480637	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
01480637	6/10/2005	<.5	<2	<1.00	62.1	<.5	<.5	<5	<1	<.5	M	<.5
01480637	9/28/2005	<.5	<2	<1.00	88.5	<.5	<.5	<5	<1	<.5	<1	<.5
01480637	9/28/2005	<.5	<2	<1.00	67.4	<.5	<.5	<5	<1	<.5	<1	<.5
014806374	5/26/2005	<.5	<2	<1.00	74.1	<.5	<.5	<5	<1	<.5	<1	<.5
014806384	5/26/2005	<.5	<2	<1.00	73.4	<.5	<.5	<5	<1	<.5	<1	<.5
014806384	9/27/2005	<.5	<2	<1.00	48.8	M	<.5	<5	<1	<.5	<1	<.5
014806394	5/26/2005	<.5	<2	<1.00	61.5	<.5	<.5	<5	<1	<.5	<1	<.5
014806394	9/27/2005	<.5	<2	<1.00	68.1	<.5	<.5	<5	<1	<.5	<1	<.5
01480913	5/26/2005	<.5	<2	<1.00	64.3	<.5	<.5	<5	<1	<.5	<1	<.5
01480913	9/27/2005	<.5	<2	<1.00	51.7	<.5	<.5	<5	<1	<.5	<1	M

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

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U.S. Geological Survey station identification number	Date	Fluoranthene - d10, sur Sch 20/8033 water, fltrd, pct rcv (99586)	HHCB, water, fltrd, µg/L (62075)	Indole, water, fltrd, µg/L (62076)	Isoborneol, water, fltrd, µg/L (62077)	Isophorone water, fltrd, µg/L (34409)	Isopropylbenzene water, fltrd, µg/L (62078)	Isoquinoline, water, fltrd, µg/L (62079)	Menthol water, fltrd, µg/L (62080)	Metalaxyl, water, fltrd, µg/L (50359)	Methyl salicylate, water, fltrd, µg/L (62081)	Metolachlor, water, fltrd, µg/L (39415)
0148063532	5/26/2005	72.7	<0.5	<0.5	<0.5	M	<0.5	<0.5	M	<0.5	<0.5	<0.5
0148063532	9/27/2005	85.7	<.5	<.5	<.5	<0.5	<.5	<.5	<0.5	<.5	E.1	<.5
0148063522	5/26/2005	74.7	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
014806368	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806368	6/10/2005	72.1	<.5	<.5	<.5	M	<.5	<.5	M	<.5	M	M
014806368	9/28/2005	95.1	<.5	M	<.5	<.5	<.5	<.5	<.5	<.5	M	E.1
014806366	5/25/2005	78.9	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
014806366	9/28/2005	97.6	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	M	<.5
014806369	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
014806369	6/10/2005	70.7	<.5	M	<.5	M	<.5	<.5	<.5	<.5	<.5	M
014806369	9/28/2005	95.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	M	<.5
01480637	5/25/2005	--	--	--	--	--	--	--	--	--	--	--
01480637	6/10/2005	75.9	<.5	M	<.5	M	<.5	<.5	<.5	<.5	M	M
01480637	9/28/2005	94.0	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
01480637	9/28/2005	97.0	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	M	<.5
014806374	5/26/2005	73.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
014806384	5/26/2005	76.1	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
014806384	9/27/2005	84.1	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	M	<.5
014806394	5/26/2005	73.8	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
014806394	9/27/2005	87.9	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	M	<.5
01480913	5/26/2005	72.6	<.5	<.5	<.5	M	<.5	<.5	<.5	<.5	<.5	<.5
01480913	9/27/2005	85.7	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	E.1	<.5

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

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U.S. Geological Survey station identification number	Date	Naphthalene, water, fltrd, µg/L (34443)	p-Cresol, water, fltrd, µg/L (62084)	Pentachlorophenol, water, fltrd, µg/L (34459)	Phenanthrene, water, fltrd, µg/L (34462)	Phenol, water, fltrd, µg/L (34466)	Prometon, water, fltrd, µg/L (04037)	Pyrene, water, fltrd, µg/L (34470)	Tetrachloroethene, water, fltrd, µg/L (34476)	Tribromomethane water, fltrd, µg/L (34288)	Tributyl phosphate, water, fltrd, µg/L (62089)
0148063532	5/26/2005	<0.5	<1	--	<0.5	E0.3	<0.5	<0.5	<0.5	<0.5	<0.5
0148063532	9/27/2005	<.5	M	--	<.5	<.5	<.5	<.5	<.5	<.5	<.5
0148063522	5/26/2005	<.5	<1	--	<.5	E.2	<.5	<.5	<.5	<.5	<.5
014806368	5/25/2005	--	--	--	--	--	--	--	--	--	--
014806368	6/10/2005	<.5	M	<2	<.5	E.2	<.5	<.5	<.5	<.5	<.5
014806368	9/28/2005	M	M	--	M	1.4	<.5	M	<.5	<.5	<.5
014806366	5/25/2005	<.5	<1	--	<.5	E.2	<.5	<.5	<.5	<.5	<.5
014806366	9/28/2005	<.5	<1	--	<.5	1.0	<.5	<.5	<.5	<.5	<.5
014806369	5/25/2005	--	--	--	--	--	--	--	--	--	--
014806369	6/10/2005	<.5	M	<2	M	E.1	<.5	<.5	<.5	<.5	<.5
014806369	9/28/2005	M	<1	--	M	1.1	<.5	M	<.5	<.5	<.5
01480637	5/25/2005	--	--	--	--	--	--	--	--	--	--
01480637	6/10/2005	<.5	M	<2	M	E.5	<.5	<.5	<.5	<.5	<.5
01480637	9/28/2005	<.5	M	--	<.5	.6	<.5	<.5	<.5	<.5	<.5
01480637	9/28/2005	<.5	M	--	<.5	.6	<.5	<.5	<.5	<.5	<.5
014806374	5/26/2005	<.5	<1	--	<.5	E.1	<.5	<.5	<.5	<.5	<.5
014806384	5/26/2005	<.5	<1	--	<.5	E.3	<.5	<.5	<.5	<.5	<.5
014806384	9/27/2005	<.5	<1	--	<.5	E.1	<.5	<.5	<.5	<.5	<.5
014806394	5/26/2005	<.5	<1	--	<.5	E.1	<.5	<.5	<.5	<.5	<.5
014806394	9/27/2005	<.5	<1	--	<.5	E.2	<.5	<.5	<.5	<.5	<.5
01480913	5/26/2005	<.5	<1	--	<.5	<.5	<.5	<.5	<.5	<.5	<.5
01480913	9/27/2005	<.5	<1	--	<.5	E.1	<.5	M	<.5	<.5	<.5

Table 7. Results of laboratory analysis of base-flow samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, May-June and September 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

U.S. Geological Survey station identification number	Date	Triclosan, water, fltrd, µg/L (62090)	Triethyl citrate water, fltrd, µg/L (62091)	Triphenyl phosphate, water, fltrd, µg/L (62092)	Tris (2-butoxyethyl) phosphate, water, fltrd, µg/L (62093)	Tris (2-chloroethyl) phosphate, water, fltrd, µg/L (62087)	Tris (dichloro-i-Pr) phosphate, water, fltrd, µg/L (62088)	Sample volume, wastewater method water, fltrd, mL (99587)
0148063532	5/26/2005	<1	<0.5	<0.5	<0.5	E0.1	M	798
0148063532	9/27/2005	<1	<.5	<.5	<.5	<.5	<0.5	868
0148063522	5/26/2005	<1	<.5	<.5	<.5	<.5	<.5	826
014806368	5/25/2005	--	--	--	--	--	--	--
014806368	6/10/2005	<1	<.5	<.5	<.5	<.5	<.5	786
014806368	9/28/2005	<1	<.5	<.5	<.5	<.5	<.5	838
014806366	5/25/2005	<1	<.5	<.5	<.5	<.5	<.5	866
014806366	9/28/2005	<1	<.5	<.5	<.5	<.5	<.5	797
014806369	5/25/2005	--	--	--	--	--	--	--
014806369	6/10/2005	<1	<.5	<.5	<.5	<.5	<.5	870
014806369	9/28/2005	<1	<.5	<.5	<.5	<.5	<.5	846
01480637	5/25/2005	--	--	--	--	--	--	--
01480637	6/10/2005	<1	<.5	<.5	<.5	<.5	<.5	821
01480637	9/28/2005	<1	<.5	<.5	<.5	<.5	<.5	525
01480637	9/28/2005	<1	<.5	<.5	<.5	<.5	<.5	887
014806374	5/26/2005	<1	<.5	<.5	<.5	<.5	<.5	--
014806384	5/26/2005	<1	<.5	<.5	<.5	<.5	M	845
014806384	9/27/2005	<1	<.5	<.5	<.5	<.5	<.5	798
014806394	5/26/2005	<1	<.5	<.5	<.5	<.5	M	811
014806394	9/27/2005	<1	<.5	<.5	<.5	<.5	<.5	874
01480913	5/26/2005	<1	<.5	<.5	<.5	<.5	M	785
01480913	9/27/2005	<1	<.5	<.5	<.5	<.5	<.5	891

Table 8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005. (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

Local identifier	U.S. Geological Survey station identification number	Date	Time	Agency analyzing sample, code (00028)	Depth of well, feet below LSD (72008)	Depth to water level, feet below LSD (72019)	Altitide of land surface feet (72000)	Flow rate, instan-taneous gal/min (00059)	Pump or flow period prior to sampling, minutes (72004)	Barometric pressure, mm Hg (00025)
CH-SP-70	395807075450201	6/7/2005	0830	80020	--	--	425	0.25	27	748
CH-6880	395815075435501	6/2/2005	1210	80020	--	38.25	557	1.5	32	752
CH-6882	395807075432201	6/7/2005	1020	80020	--	64.03	535	1.5	58	745
CH-6879	395752075424801	6/2/2005	1050	80020	128	41.34	398	1.5	66	751
CH-6673	395735075425301	6/1/2005	1130	80020	430	62.95	369	1.5	51	757
CH-6878	395654075405001	6/2/2005	0850	80020	--	--	395	1.2	52	756
CH-755	395651075405601	6/7/2005	1120	80020	92	--	390	1.5	35	746
CH-SP-71	395642075403801	6/8/2005	1000	80020	--	--	290	.2	21	753
CH-6881	395701075404401	6/6/2005	1130	80020	150	24.03	405	1.5	61	750
CH-6883	395715075404401	6/8/2005	1140	80020	--	17.89	354	1.5	53	750

Local identifier	Date	Dissolved oxygen, mg/L (00300)	Dissolved oxygen, percent of saturation (00301)	pH, water, unfltrd field, std units (00400)	pH, water, unfltrd lab, std units (00403)	Specific conductance, wat unf lab, µS/cm 25 degC (90095)	Specific conductance, wat unf, µS/cm 25 degC (90095)	Temperature, air, deg C (00020)	Temperature, water, deg C (00010)	Calcium, water, fltrd, mg/L (00915)
CH-SP-70	6/7/2005	8.3	78	5.7	5.9	230	244	23.5	12.4	18.3
CH-6880	6/2/2005	10.1	94	5.6	5.8	295	312	18.5	11.9	8.69
CH-6882	6/7/2005	9	87	5.2	5.6	192	207	23.5	13.8	8.82
CH-6879	6/2/2005	8.5	81	5.8	6.1	831	871	17	13.3	59.9
CH-6673	6/1/2005	2.7	26	6.8	7.2	148	152	22.5	14	17.6
CH-6878	6/2/2005	5.8	55	5.9	6.3	248	264	10	12.7	17.3
CH-755	6/7/2005	9.1	87	5.3	5.6	340	371	27.5	13.3	21
CH-SP-71	6/8/2005	8.9	83	5.9	6.2	223	239	28.5	12.1	15.6
CH-6881	6/6/2005	5.3	52	5.3	5.8	1350	1340	28	14.2	80.5
CH-6883	6/8/2005	9.7	93	5.5	6	181	189	29.5	13.7	15.1

Table 8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

Local identifier	Date	Magnesium, water, mg/L (00925)	Potassium, water, fltrd, mg/L (00935)	Sodium, water, fltrd, mg/L (00930)	Alkalinity, water, fltrd, inc tit field, mg/L as $CaCO_3$ (39086)	Chloride, water, fltrd, mg/L (00940)	Fluoride, water, fltrd, mg/L (00950)	Silica, water, fltrd, mg/L (00955)	Sulfate, water, fltrd, mg/L (00945)
CH-SP-70	6/7/2005	8.39	2.16	10.3	18	26.1	<0.10	11.7	17.9
CH-6880	6/2/2005	10.6	1.11	35.5	19	63.6	<.10	5.1	19.2
CH-6882	6/7/2005	6.33	1.45	16.8	9	32.3	<.10	5.5	12.9
CH-6879	6/2/2005	21.1	2.4	72.4	29	242	<.10	14.8	6.45
CH-6673	6/1/2005	3.94	1.34	5.59	43	4.91	E.08	17	17.8
CH-6878	6/2/2005	13.5	1.61	12.9	47	27.4	E.06	27.3	13.6
CH-755	6/7/2005	8.47	2.42	28.8	13	66.5	<.10	15.8	12.8
CH-SP-71	6/8/2005	8.93	2.32	13.6	35	30.4	<.10	17.3	19
CH-6881	6/6/2005	52.7	4.8	86.1	26	373	E.06	17.6	36.1
CH-6883	6/8/2005	7.6	3.56	6.11	27	5.37	<.10	13	22.4

Local identifier	Date	Ammonia water, fltrd, mg/L as N (00608)	Nitrite + nitrate water fltrd, mg/L as N (00631)	Nitrite water, fltrd, mg/L as N (00613)	Ortho-phosphate, water, fltrd, mg/L as P (00671)	Enterococi, m-E mf, water, col/100 mL (31649)	Fecal coliform, M-FC 0.7µ MF col/100 mL (31625)	Boron, water, fltrd, µg/L (01046)	Iron, water, fltrd, µg/L (01046)	Manganese, water, fltrd, µg/L (01056)
CH-SP-70	6/7/2005	<0.04	9.18	<0.008	0.02	18	6	8.3	<6	E0.5
CH-6880	6/2/2005	<.04	2.46	<.008	E.01	<.4	<.4	12	9	20.5
CH-6882	6/7/2005	<.04	5.69	<.008	.03	<.4	<.4	23	<6	5.1
CH-6879	6/2/2005	<.04	.97	<.008	<.02	<.4	<.4	E4.9	<6	8.4
CH-6673	6/1/2005	<.04	.4	<.008	<.02	0	<.4	7.7	<6	25
CH-6878	6/2/2005	<.04	6.26	<.008	.04	<.4	<.4	E3.9	E4	2.9
CH-755	6/7/2005	<.04	10.7	<.008	.03	<.4	<.4	27	<6	39.2
CH-SP-71	6/8/2005	<.04	2.68	<.008	E.01	2	0	11	<6	<.6
CH-6881	6/6/2005	<.04	3.11	E.006	<.02	--	<.4	26	619	279
CH-6883	6/8/2005	<.04	7.32	<.008	.03	<.4	<.4	8.2	<6	E.3

Table 8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

Local identifier	Date	1,4-Di-chloro-benzene water, fltrd, µg/L (34572)	1-Methyl-naphthalene, water, fltrd, µg/L (62054)	2,6-Di-methyl-naphthalene, water, fltrd, µg/L (62055)	2-Methyl-naphthalene, water, fltrd, µg/L (62056)	3-beta-Copros-tanol, water, fltrd, µg/L (62057)	3-Methyl-1H-indole, water, fltrd, µg/L (62058)	3-tert-Butyl-4-hydrozy-anisole water, fltrd, µg/L (62059)	4-Cumyl-phenol, water, fltrd, µg/L (62060)	4-Octyl-phenol, water, fltrd, µg/L (62061)
CH-SP-70	6/7/2005	<0.5	<0.5	<0.5	<0.5	<2	<1	<5	<1	<1
CH-6880	6/2/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-6882	6/7/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-6879	6/2/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-6673	6/1/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-6878	6/2/2005	M	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-755	6/7/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-SP-71	6/8/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-6881	6/6/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1
CH-6883	6/8/2005	<.5	<.5	<.5	<.5	<2	<1	<5	<1	<1

Local identifier	Date	4-Nonyl-phenol, water, fltrd, µg/L (62085)	4-tert-Octyl-phenol, water, fltrd, µg/L (62062)	5-Methyl-1H-benzo-triazole, water, fltrd, µg/L (62063)	9,10-Anthra-quinone water, fltrd, µg/L (62066)	Aceto-phenone water, fltrd, µg/L (62064)	AHTN, water, fltrd, µg/L (62065)	Anthracene, water, fltrd, µg/L (34221)	Benzo-[a]-pyrene, water, fltrd, µg/L (34248)	Benzo-phenone water, fltrd, µg/L (62067)
CH-SP-70	6/7/2005	<5	<1	<2	<0.5	E0.2	<0.5	<0.5	<0.5	M
CH-6880	6/2/2005	<5	<1	<2	<.5	<.5	<.5	<.5	<.5	<.5
CH-6882	6/7/2005	<5	<1	<2	<.5	<.5	<.5	<.5	<.5	<.5
CH-6879	6/2/2005	<5	M	<2	<.5	<.5	<.5	M	<.5	<.5
CH-6673	6/1/2005	<5	<1	<2	<.5	<.5	<.5	<.5	<.5	<.5
CH-6878	6/2/2005	<5	<1	<2	<.5	<.5	<.5	<.5	<.5	<.5
CH-755	6/7/2005	<5	<1	<2	<.5	<.5	<.5	<.5	<.5	<.5
CH-SP-71	6/8/2005	<5	<1	<2	<.5	E.1	<.5	<.5	<.5	M
CH-6881	6/6/2005	<5	<1	<2	<.5	<.5	<.5	M	<.5	<.5
CH-6883	6/8/2005	<5	<1	<2	<.5	<.5	<.5	<.5	<.5	<.5

Table 8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

Local identifier	Date	beta-Sitos-terol, water, fltrd, µg/L (62068)	beta-Stigmastanol, water, fltrd, µg/L (62086)	Bisphenol A, water, fltrd, µg/L (62069)	Bisphenol A-d3 sur Sch 2033 & 8033, water, fltrd, pct rcv (99583)	Bromacil, water, fltrd, µg/L (04029)	Caffeine, water, fltrd, µg/L (50305)	Caffeine-13C sur Sch 2033 & 8033, water, fltrd, pct rcv (99584)	Camphor water, fltrd, µg/L (62070)	Carbaryl, water, fltrd 0.7u GF µg/L (82680)
CH-SP-70	6/7/2005	<2	<2	<1	59.4	<0.5	<0.5	75.5	M	<1
CH-6880	6/2/2005	<2	<2	<1	80.6	<.5	<.5	78.6	<.5	<1
CH-6882	6/7/2005	<2	<2	<1	25.1	<.5	<.5	77.2	<.5	<1
CH-6879	6/2/2005	<2	<2	<1	78.2	<.5	<.5	78.6	<.5	<1
CH-6673	6/1/2005	<2	<2	--	24.4	<.5	<.5	86.3	<.5	<1
CH-6878	6/2/2005	<2	<2	<1	67.1	<.5	<.5	76.5	<.5	<1
CH-755	6/7/2005	<2	<2	<1	28.3	<.5	<.5	79.3	<.5	<1
CH-SP-71	6/8/2005	<2	<2	<1	30.3	<.5	<.5	80.7	<.5	<1
CH-6881	6/6/2005	<2	<2	<1	32.7	<.5	<.5	73.3	<.5	<1
CH-6883	6/8/2005	<2	<2	<1	74.3	<.5	<.5	71.9	<.5	<1

Local identifier	Date	Carbazole, water, fltrd, µg/L (62071)	Chlorpyrifos water, fltrd, µg/L (38933)	Cholesterol, water, fltrd, µg/L (62072)	Cotinine, water, fltrd, µg/L (62005)	DecaF-biphenl sur Sch 2033 & 8033, water, fltrd, pct rcv (99585)	DEET, water, fltrd, µg/L (62082)	Diazinon, water, fltrd, µg/L (39572)	Di-ethoxy-nonyl-phenol, water, fltrd, µg/L (62083)	Di-ethoxy-octyl-phenol, water, fltrd, µg/L (61705)
CH-SP-70	6/7/2005	<0.5	<0.5	<2	<1.00	96.3	M	<0.5	<5	<1
CH-6880	6/2/2005	<.5	<.5	<2	<1.00	78.6	<.5	<.5	<5	<1
CH-6882	6/7/2005	<.5	<.5	<2	<1.00	74.5	<.5	<.5	<5	<1
CH-6879	6/2/2005	<.5	<.5	<2	<1.00	83.9	<.5	<.5	<5	<1
CH-6673	6/1/2005	<.5	<.5	<2	<1.00	101	<.5	<.5	<5	<1
CH-6878	6/2/2005	<.5	<.5	<2	<1.00	88.9	<.5	<.5	<5	<1
CH-755	6/7/2005	<.5	<.5	<2	<1.00	78	M	<.5	<5	<1
CH-SP-71	6/8/2005	<.5	<.5	<2	<1.00	65.4	M	<.5	<5	<1
CH-6881	6/6/2005	<.5	<.5	<2	<1.00	84.3	<.5	<.5	<5	<1
CH-6883	6/8/2005	<.5	<.5	<2	<1.00	89	<.5	<.5	<5	<1

Table 8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005.—Continued (Results listed by land-use category as shown in table 3.)

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Local identifier	Date	D-Limonene, water, fltrd, µg/L (62073)	Ethoxyoctylphenol, water, fltrd µg/L (61706)	Fluoranthene water, fltrd, µg/L (34377)	Fluoranthene -d10, sur Sch 20/8033 water, fltrd, pct rcv (99586)	HHCB, water, fltrd, µg/L (62075)	Indole, water, fltrd, µg/L (62076)	Isoborneol, water, fltrd, µg/L (62077)	Isophorone water, fltrd, µg/L (34409)	Isopropylbenzene water, fltrd, µg/L (62078)
CH-SP-70	6/7/2005	<0.5	<1	<0.5	70.9	<0.5	<0.5	<0.5	M	<0.5
CH-6880	6/2/2005	<.5	<1	<.5	75	<.5	<.5	<.5	<.5	<.5
CH-6882	6/7/2005	<.5	<1	<.5	75.6	<.5	<.5	<.5	<.5	<.5
CH-6879	6/2/2005	<.5	<1	<.5	73.8	<.5	<.5	<.5	<.5	<.5
CH-6673	6/1/2005	<.5	<1	<.5	83.6	<.5	<.5	<.5	<.5	<.5
CH-6878	6/2/2005	<.5	<1	<.5	73.7	<.5	<.5	<.5	<.5	<.5
CH-755	6/7/2005	<.5	<1	<.5	76.5	<.5	<.5	<.5	<.5	<.5
CH-SP-71	6/8/2005	<.5	<1	<.5	76.7	<.5	<.5	<.5	M	<.5
CH-6881	6/6/2005	<.5	<1	<.5	72.6	<.5	<.5	<.5	<.5	<.5
CH-6883	6/8/2005	<.5	<1	<.5	68.9	<.5	<.5	<.5	<.5	<.5

Local identifier	Date	Isoquinoline, water, fltrd, µg/L (62079)	Menthol water, fltrd, µg/L (62080)	Metalaxyl, water, fltrd, µg/L (50359)	Methyl salicylate, water, fltrd, µg/L (62081)	Metolachlor, water, fltrd, µg/L (39415)	Naphthalene, water, fltrd, µg/L (34443)	p-Cresol, water, fltrd, µg/L (62084)	Pentachlorophenol, water, fltrd, µg/L (34459)	Phenanthrene, water, fltrd, µg/L (34462)
CH-SP-70	6/7/2005	<0.5	M	<0.5	M	M	<0.5	M	<2	<0.5
CH-6880	6/2/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5
CH-6882	6/7/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5
CH-6879	6/2/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5
CH-6673	6/1/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	-	<.5
CH-6878	6/2/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5
CH-755	6/7/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5
CH-SP-71	6/8/2005	<.5	M	<.5	M	<.5	<.5	M	<2	<.5
CH-6881	6/6/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5
CH-6883	6/8/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5

Table 8. Results of laboratory analysis of ground-water samples collected in and near the Broad Run watershed, Chester County, Pennsylvania, June 2005.—Continued (Results listed by land-use category as shown in table 3.)

[ft^3/s, cubic feet per second; mi^2, square miles; mm Hg, millimeters of mercury; °C, degrees Celsius; µS/cm, microsiemens per centimeter; fltrd, filtered; mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; <, less than; E, estimated value; M, measured where presence verified but not quantified; mL, milliliters; --, no data]

Local identifier	Date	Phenol, water, fltrd, µg/L (34466)	Prometon, water, fltrd, µg/L (04037)	Pyrene, water, fltrd, µg/L (34470)	Tetrachloroethene, water, fltrd, µg/L (34476)	Tribromomethane water, fltrd, µg/L (34288)	Tributyl phosphate, water, fltrd, µg/L (62089)	Triclosan, water, fltrd, µg/L (62090)	Triethyl citrate water, fltrd, µg/L (62091)	Triphenyl phosphate, water, fltrd, µg/L (62092)
CH-SP-70	6/7/2005	E0.2	<0.5	<0.5	M	<0.5	<0.5	<1	<0.5	<0.5
CH-6880	6/2/2005	E.2	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-6882	6/7/2005	E.3	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-6879	6/2/2005	E.2	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-6673	6/1/2005	.6	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-6878	6/2/2005	E.4	<.5	<.5	M	<.5	<.5	<1	<.5	<.5
CH-755	6/7/2005	E.3	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-SP-71	6/8/2005	E.4	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-6881	6/6/2005	<.5	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5
CH-6883	6/8/2005	E.1	<.5	<.5	<.5	<.5	<.5	<1	<.5	<.5

Local identifier	Date	Tris (2-butoxyethyl) phosphate, water, fltrd, µg/L (62093)	Tris (2-chloroethyl) phosphate, fltrd, µg/L (62087)	Tris (di chloro-i-Pr) phosphate, water, fltrd, µg/L (62088)	Sample volume, wastewater method water, fltrd mL (99587)	Sampler type, code (84164)	Sampling condition, code (72006)
CH-SP-70	6/7/2005	E0.2	<0.5	<0.5	832	4080	.10
CH-6880	6/2/2005	<.5	<.5	<.5	897	4040	.10
CH-6882	6/7/2005	<.5	<.5	<.5	873	4090	.10
CH-6879	6/2/2005	E.3	<.5	<.5	905	4040	.10
CH-6673	6/1/2005	<.5	<.5	<.5	864	4040	.10
CH-6878	6/2/2005	<.5	<.5	<.5	891	4040	.10
CH-755	6/7/2005	<.5	<.5	M	847	4040	.10
CH-SP-71	6/8/2005	<.5	<.5	<.5	831	4080	.10
CH-6881	6/6/2005	<.5	M	<.5	837	4040	.10
CH-6883	6/8/2005	<.5	<.5	<.5	827	4040	.01