Water Quality in the Potomac River Basin

Maryland, Pennsylvania, Virginia, West Virginia and the District of Columbia, 1992–96

U.S. Department of the Interior
U.S. Geological Survey

Circular 1166

A COORDINATED EFFORT

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Front: The Potomac River at Great Falls, Virginia, *by James Gerhart, U.S. Geological Survey*
Back, left: The Potomac River at Washington, D.C., *by James Gerhart, U.S. Geological Survey*
Back, right: Confluence of the Shenandoah (left) and Potomac Rivers at Harpers Ferry, W.Va., *by James Gerhart, U.S. Geological Survey*

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Water Quality in the Potomac River Basin, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia, 1992–96

By Scott W. Ator, Joel D. Blomquist, John W. Brakebill, Janet M. Denis, Matthew J. Ferrari, Cherie V. Miller, and Humbert Zappia

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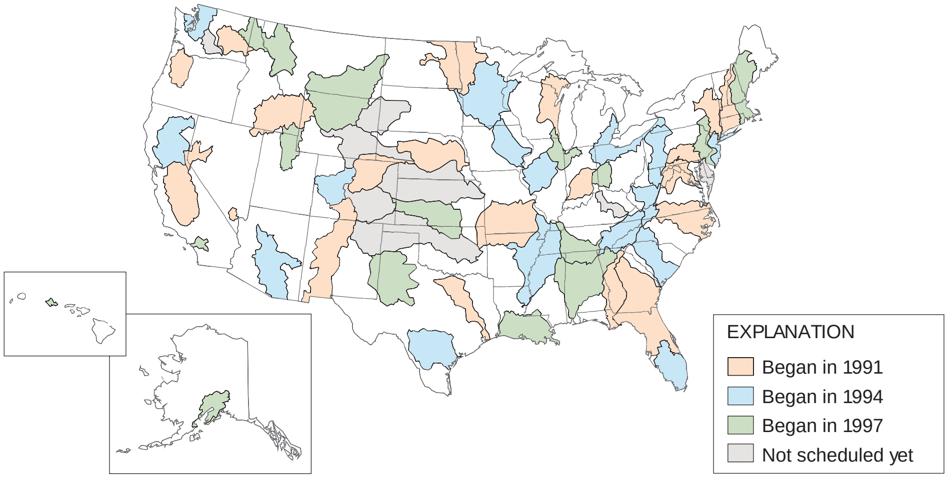
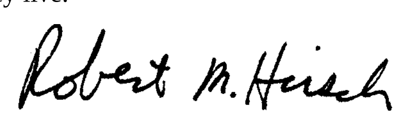


Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and because of the significant costs associated with decisions involving land and water management, conservation, and regulation. In 1991, the U.S. Congress appropriated funds for the U.S. Geological Survey (USGS) to begin the National Water-Quality Assessment (NAWQA) Program to help meet the continuing need for sound, scientific information on the areal extent of water-quality problems, how these problems are changing with time, and an understanding of the effects of human actions and natural factors on water quality conditions.

The NAWQA Program is assessing the water-quality conditions of more than 50 of the Nation's largest river basins and aquifers, known as Study Units. Collectively, these Study Units cover about one-half of the United States and include sources of drinking water used by about 70 percent of the U.S. population. Comprehensive assessments of about one-third of the Study Units are ongoing at a given time. Each Study Unit is scheduled to be revisited every decade to evaluate changes in water-quality conditions. NAWQA assessments rely heavily on existing information collected by the USGS and many other agencies as well as the use of nationally consistent study designs and methods of sampling and analysis. Such consistency simultaneously provides information about the status and trends in water-quality conditions in a particular stream or aquifer and, more importantly, provides the basis to make comparisons among watersheds and improve our understanding of the factors that affect water-quality conditions regionally and nationally.

This report is intended to summarize major findings that emerged between 1992 and 1995 from the water-quality assessment of the Potomac River Basin Study Unit and to relate these findings to water-quality issues of regional and national concern. The information is primarily intended for those who are involved in water-resource management. Indeed, this report addresses many of the concerns raised by regulators, water-utility managers, industry representatives, and other scientists, engineers, public officials, and members of stakeholder groups who provided advice and input to the USGS during this NAWQA Study-Unit investigation. Yet, the information contained here may also interest those who simply wish to know more about the quality of water in the rivers and aquifers in the area where they live.



Robert M. Hirsch, Chief Hydrologist

"Potomac NAWQA studies are contributing valuable information on water quality/land use issues vital to effective management of the Chesapeake Bay ecosystem."

—Dr. Emery Cleaves, Director, Maryland Geological Survey, Baltimore, Maryland

"As one involved in sharing information with both the public and other agencies addressing water resources issues in the Shenandoah River Basin, the Potomac NAWQA study has been quite helpful. This particular publication, summarizing a considerable amount of water quality data through informative graphics and excellent maps, should serve as a convenient reference to others interested in knowing more about our valuable water resources."

—Thomas Mizell, Virginia Department of Environmental Quality, Harrisonburg, Virgina.

Nutrients and pesticides in streams and ground water
A regional perspective

Although nitrogen and phosphorus occur naturally and are essential for the growth of plants and animals, excessive nutrients in water can adversely affect human health and the environment. Elevated concentrations of nitrogen and phosphorus in streams and ground water of the Potomac River Basin often result from human activities such as manure and fertilizer applications.
(p. 6)

Nutrient inputs to the Potomac River Basin are related to land use. Agricultural areas receive the largest amounts of nutrients because manure and fertilizer applications comprise 45 percent of nitrogen and 93 percent of phosphorus inputs.
(p. 6)

In most waters of the Potomac River Basin, concentrations of nutrients do not pose a threat to human health or wildlife.
(p. 7)

Elevated nitrogen concentrations in streams and ground water are common in areas of intensive row cropping, such as the northeastern part of the Potomac River Basin, and areas underlain by carbonate bedrock, such as the Great Valley.
(p. 8)

Organic nitrogen and phosphorus concentrations are typically low, except in streams during high flows.
(p. 9)

Tributary streams draining agricultural areas yield the greatest quantities of nitrogen to the Potomac River; streams draining agricultural and urban areas yield the greatest quantities of phosphorus.
(p. 9)

Pesticides can make water unfit to drink and cause adverse ecological effects in streams. Commonly used pesticides are present in ground water in the Potomac River Basin, but in most cases at concentrations that are not threatening to human health.
(p. 10)

More pesticides were detected in streams than in ground water, but only rarely at concentrations threatening to aquatic life.
(p. 11)

Pesticides were commonly detected in agricultural areas of the Potomac River Basin, particularly in areas of intense crop production such as the corn-producing northeastern counties and in the Great Valley. Samples from forested areas rarely contained detectable pesticides.
(p. 12-13)

Pesticides were frequently present in streams in urban areas; insecticide concentrations were greatest in urban streams.
(p. 13)

Maximum concentrations of most pesticides occur in streams during the spring and early summer months, coincident with their application to fields, although atrazine and metolachlor are present year round in streams in agricultural areas.
(p. 14)

Spring floods carry large amounts of nutrients and pesticides. A June 1996 flood on the Potomac River at Washington, D.C., carried an estimated 3,300 pounds of atrazine and 3,300,000 pounds of nitrogen.
(p. 14)

Higher concentrations of agricultural chemicals are found in streams in the Great Valley than in other agricultural areas, presumably because carbonate bedrock permits relatively rapid movement of these chemicals through ground water to streams.
(p. 15)

Organic contaminants and metals in streams

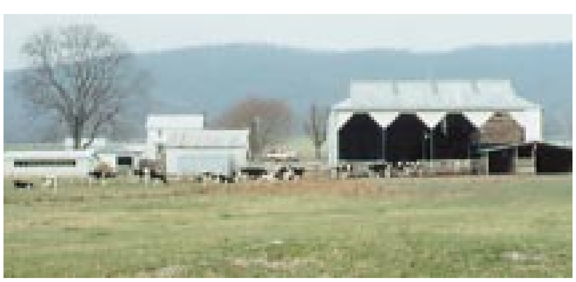
Chlorinated organic compounds, mercury, and lead are present in streambed sediment at concentrations that have some potential to adversely affect aquatic life.
(p. 16)

Although its use was banned in 1988, chlordane was detected in streambed sediment from 13 of 26 sites, including 4 sites at which concentrations pose a high potential for adverse effects on aquatic life.
(p. 17)

The use of DDT was banned in 1972 but it was detected in streambed sediment at most sites, although concentrations typically pose little risk to aquatic life.
(p. 17)

Mercury from an industrial plant in Waynesboro, Va., possibly over a period of decades, has caused elevated concentrations of mercury in sediments downstream from the plant in the Shenandoah River, a major Potomac tributary.
(p. 18)

The organic compounds and metals present in streambed sediment have been incorporated into the food chain.
(p. 18)



Photograph by James Gerhart, U.S. Geological Survey

Radon in ground water

Radon is present in ground water throughout the Potomac River Basin.
(p. 20)

The Federal drinking-water standard for radon is currently under review by the U.S. Environmental Protection Agency; however, radon levels in 69 percent of ground-water samples were greater than a previously proposed standard of 300 picocuries per liter.

(p. 20)

Radon in ground water is related to rock type, and levels are highest in eastern parts of the basin underlain by crystalline and siliciclastic rocks.
(p. 20)

Recent water-quality trends and outlook

Despite an estimated 44-percent increase in population in the Potomac River Basin from 1970 to 1990, total phosphorus concentrations in the Potomac River at Washington, D.C., have decreased since 1979, and nitrogen concentrations have apparently stabilized.
(p. 21)

Different forms of nitrogen show differing patterns in long-term trends in the Potomac River at Washington, D.C.; ammonia plus organic nitrogen concentrations have decreased, whereas nitrate concentrations have increased.
(p. 21)

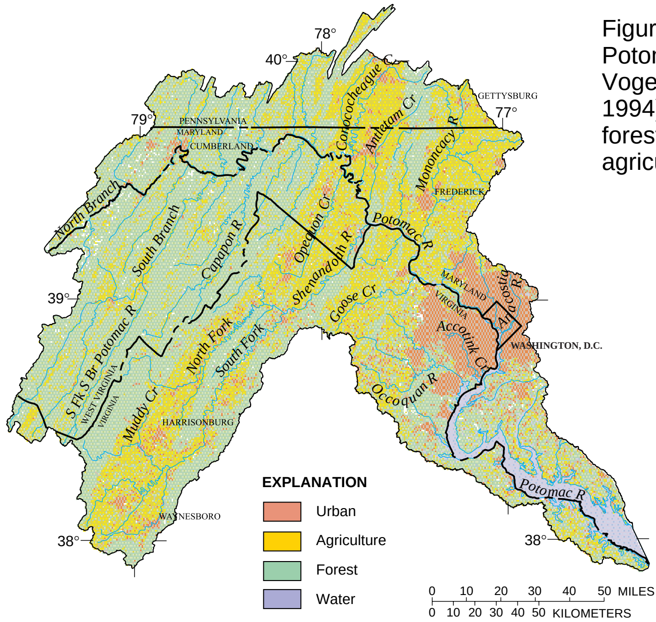


Figure 1. Generalized land use in the Potomac River Basin (modified from Vogelmann and others, 1997; and Hitt, 1994). The basin is predominantly forested, with smaller areas of agriculture and urban development.

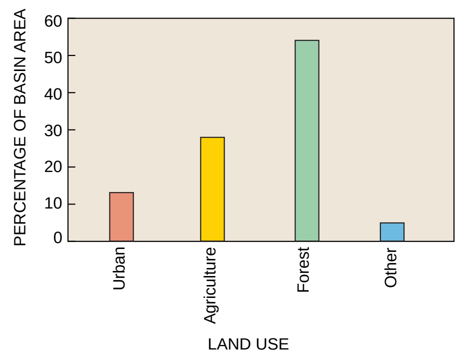
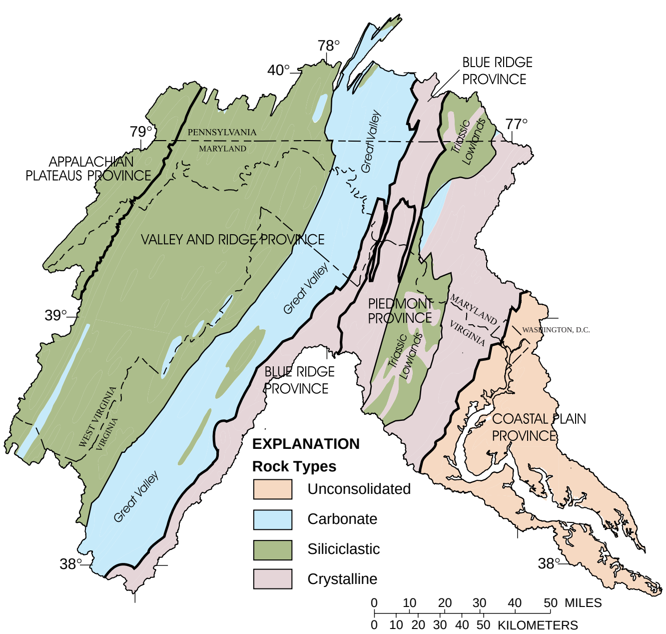


Figure 2. Major land use in the Potomac River Basin, 1990-94 (modified from Vogelmann and others, 1997; and Hitt, 1994).



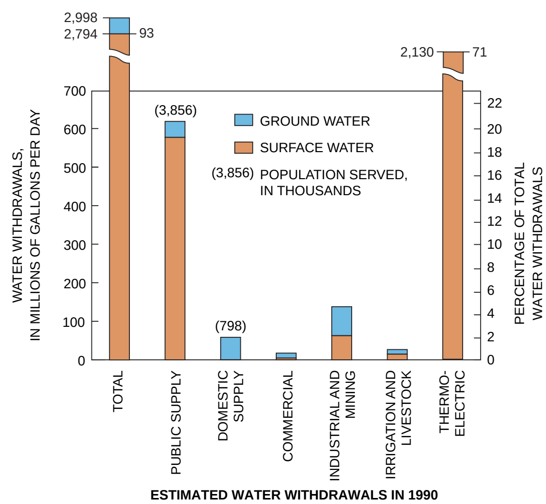


Figure 3. Generalized geology and physiography in the Potomac River Basin (modified from Fenneman and Johnson, 1946; Milici and others, 1963; Cardwell and others, 1968; Cleaves and others, 1968; King and Beikman, 1974; and Berg, 1980). Unconsolidated deposits occur mainly in the Coastal Plain and in isolated areas of alluvial deposits along stream channels in the Valley and Ridge. Crystalline rocks underlie only the Piedmont and Blue Ridge in the central and eastern parts of the basin. The entire basin west of the Blue Ridge is underlain by sedimentary rocks; these rocks are mainly siliciclastic, with areas of extensive carbonate rocks, particularly in the Great Valley.

Figure 4. Freshwater withdrawals in the Potomac River Basin (data from H.A. Perlman, U.S. Geological Survey, written commun., 1993). Most of the surface water withdrawn from the Potomac River Basin is used for the generation of electricity and for public supply. Ground water in the basin is used mainly for domestic and public supply. Water is also withdrawn from the basin for various commercial, industrial, and agricultural purposes.

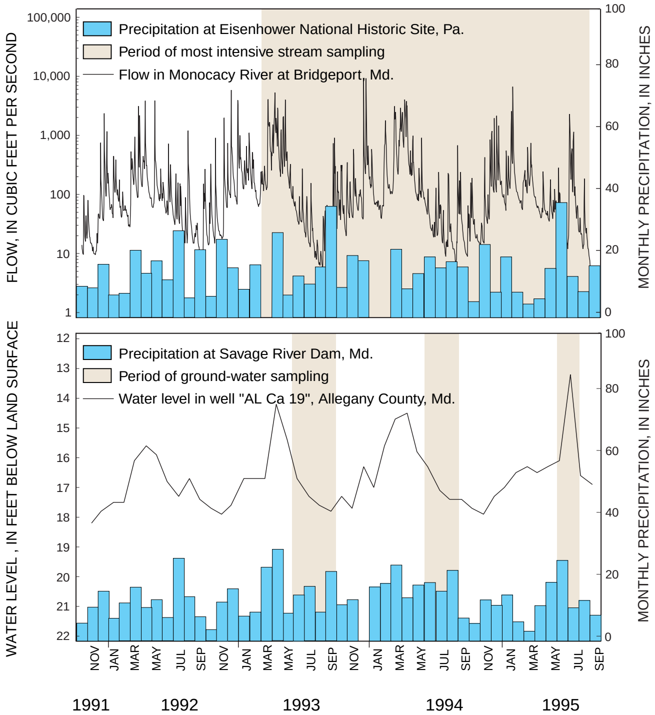


Figure 5. Streamflow, ground-water levels, and precipitation at selected sites in the Potomac River Basin. Streamflow and ground-water levels in the basin typically vary seasonally with rates of precipitation and evapotranspiration.

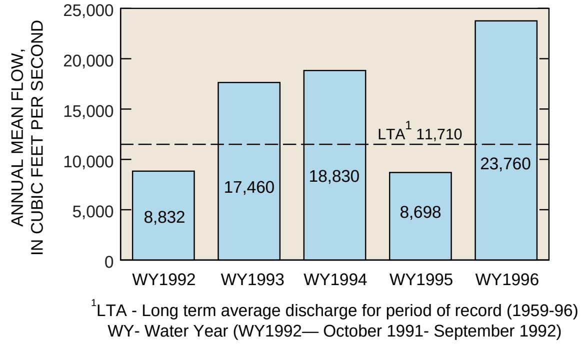


Figure 6. Mean annual streamflow of the Potomac River at Washington, D.C. Streamflow can vary considerably from year to year. Flow of the Potomac River at Washington, D.C., did not exceed flood level in 1992 or 1995; however, occasional flooding did occur in 1993, 1994, and 1996 and locally on some tributaries throughout the study period. Floods occurred mostly during the months of winter and early spring. Near-drought conditions occurred for short periods in the late summer or fall of 1992, 1993, and 1995.

Hydrologic conditions affect the quality of streams and ground water in the Potomac River Basin. Fertilizers, pesticides, and other chemicals that are applied to the land surface may infiltrate to ground water or run off to streams during rainfall depending on the season, soil properties, and the intensity and duration of precipitation. During dry periods, flow in most streams of the Potomac River Basin is sustained by discharge from ground water (fig. 7) and streamwater quality is similar to that of ground water. When flows are elevated during storms, streams of the basin typically become concentrated in chemicals that are washed from the land (fig. 8), although streams in some areas may become diluted.

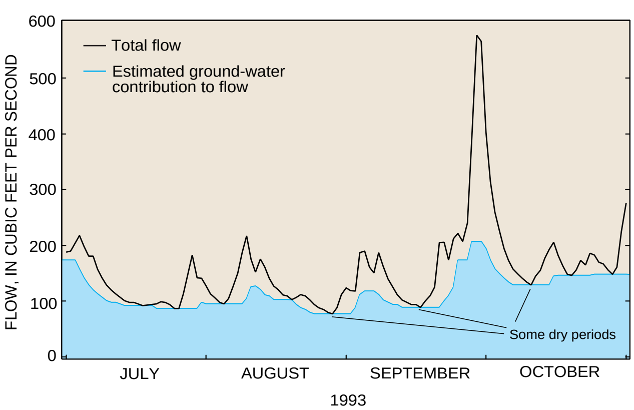


Figure 7. Total streamflow and estimated ground-water contribution to flow in the South Branch Potomac River near Springfield, W. Va., during part of 1993. Ground water contributes virtually all flow to the river during dry periods but some of the flow during wetter periods.

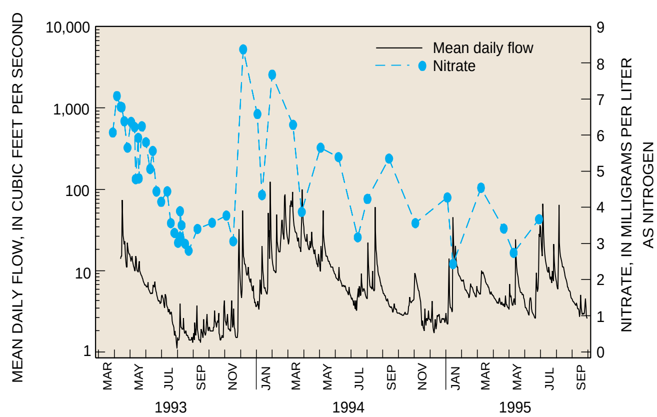


Figure 8. Streamflow and nitrate concentrations in Muddy Creek at Mount Clinton, Va. Nitrate concentrations are typically higher during periods of high flow than during drier periods.

In the Potomac River Basin, the quality of streams and ground water is affected by a variety of natural and human processes. Several major types of chemicals found in water in the basin include nutrients, trace elements, pesticides, chlorinated industrial compounds, and volatile organic compounds. Agricultural and urban land-use practices broadly characterize the distribution of these sources, because most contamination results from the disposal of human and animal wastes or from the use and disposal of other chemical compounds. Water, sediment, and tissue samples were collected throughout the basin and analyzed for nutrients, pesticides, metals, or other potential contaminants that are associated with urban and agricultural sources.

Much of the analysis done by the NAWQA Program within the Potomac River Basin focused on nutrients and pesticides because these compounds are of primary concern to environmental managers within the basin. Elevated concentrations of nutrients and pesticides can render water unsafe to drink and can have adverse environmental effects. In 1987, Maryland, Pennsylvania, Virginia, the District of Columbia, and the Federal government established a goal of reducing nutrient loads to Chesapeake Bay. The Potomac River is the second largest tributary to Chesapeake Bay, and information from the NAWQA Program can be used to monitor progress toward this goal. Only a small amount of data was available for pesticides in the Potomac River Basin prior to the NAWQA Program. Data collection was designed to fill this gap in information.

Nutrients (Nitrogen and Phosphorus)

Although nitrogen and phosphorus occur naturally, elevated concentrations of these nutrients in streams and ground water of the Potomac River Basin often result from human activities. Major sources of nitrogen and phosphorus to the basin in 1990 included commercial fertilizers and manure. Atmospheric deposition from the combustion of fossil fuels accounts for an additional 32 percent of nitrogen inputs. Municipal wastewater-treatment plants are locally important sources of nutrients to many streams, but they contributed about 12 percent of nitrogen and 4 percent of phosphorus inputs to the basin in 1990 (fig. 9).

Nutrient inputs to the Potomac River Basin are related to land use. The Great Valley (fig.3), which is 45 percent cropland, received the largest

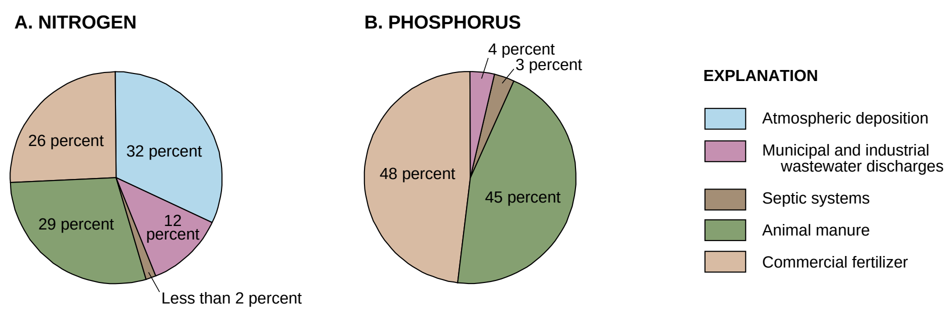


Figure 9. Major inputs of (A) nitrogen and (B) phosphorus to the Potomac River Basin, 1990. Most nitrogen and phosphorus inputs are derived from commercial fertilizers and manure, although a large percentage of nitrogen is derived from atmospheric deposition as well (Blomquist and others, 1996).

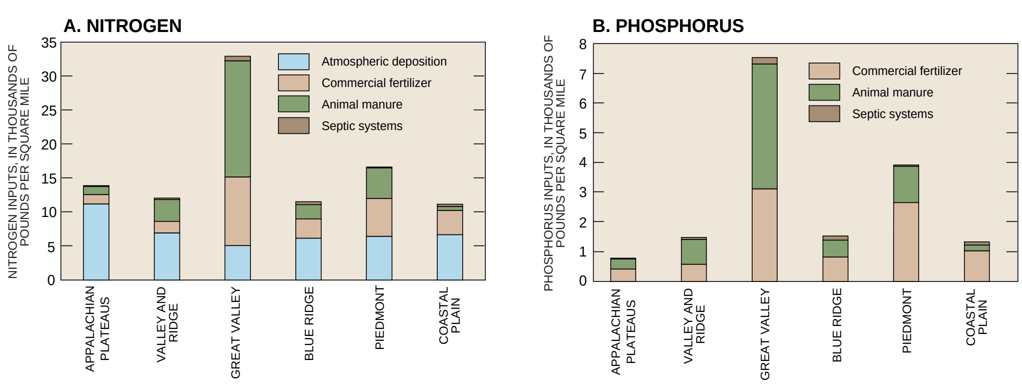


Figure 10. Inputs of (A) nitrogen and (B) phosphorus from non-point sources to areas of the Potomac River Basin, 1990 (modified from Blomquist and others, 1996).

estimated inputs from non-point sources of both nitrogen and phosphorus per unit area in 1990, followed by the Piedmont (including the Triassic Lowlands), which is 43 percent agricultural and 25 percent urban (Vogelmann and others, 1997; Hitt, 1994). Inputs to these areas were mostly attributed to commercial fertilizers and manure. Dominantly forested areas of the basin received smaller inputs of nitrogen (mostly from atmospheric deposition) and phosphorus per unit area in 1990. (fig. 10).

In most waters of the Potomac River Basin, concentrations of nutrients do not pose a threat to human health or wildlife. A Maximum Contaminant Level[1] (MCL) of 10 milligrams per liter (mg/L) as nitrogen has been established for nitrate (U.S. Environmental Protection Agency, 1994a). Drinking water containing nitrate in excess of this concentration may cause health problems in infants and small children. Nitrate concentrations in sampled streams of the Potomac River Basin were generally well below the MCL, even during high flows. Ground water in agricultural areas of the basin underlain by carbonate rock, however, is particularly susceptible to nitrate contamination (Ferrari and Ator, 1995). Nearly 25 percent of ground-water samples from domestic wells in such areas contained nitrate in excess of 10 mg/L. Excessive nitrogen or phosphorus in streams can cause eutrophication, a condition whereby aquatic plants and algae are overproduced. This algae can smother larger plants, consume dissolved oxygen, block sunlight from the water, and produce toxins that are harmful to other aquatic life (Allaby, 1989). To control eutrophication, the U.S. Environmental Protection Agency (1986) recommends that total phosphorus concentrations in flowing waters not exceed 0.1 mg/L, a concentration exceeded in only 12 percent of samples from small streams in the Potomac River Basin at low flow but in a greater percentage of samples from larger streams at varying flow conditions.

Nutrients are present in waters of the Potomac River Basin in many forms, often at concentrations suggestive of human-derived sources (figs. 11, 12). Maximum natural or “background” concentrations of nutrients in ground water of the basin are estimated at 0.4 mg/L (as nitrogen) for nitrate, 0.1 mg/L (as nitrogen) for

[1]MCLs are standards for levels of contaminants in finished public water supplies and are not directly applicable to untreated streams or ground water. MCLs are cited in this report for reference only.

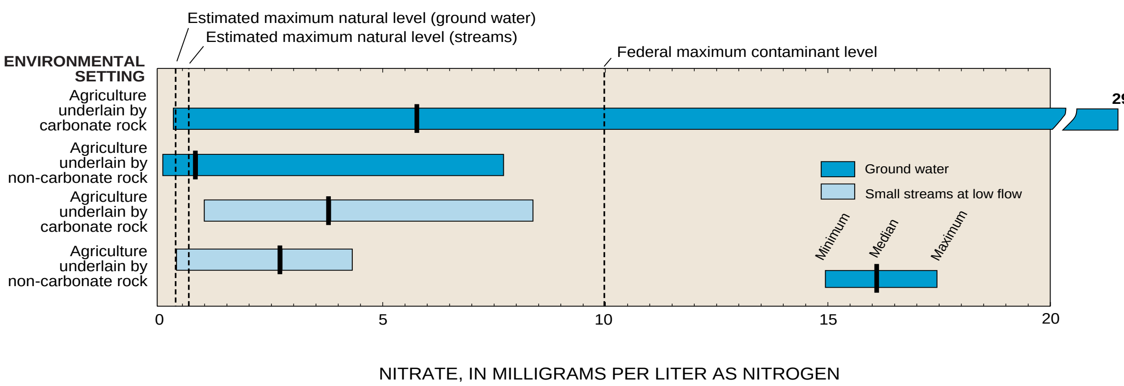


Figure 11. Among samples from small streams at low flow and ground water in the Potomac River Basin, the highest nitrate concentrations were found in areas of agriculture and carbonate bedrock.

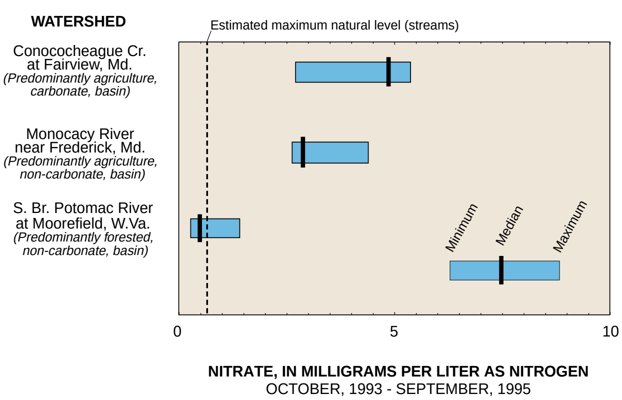


Figure 12. Time-series data show a wide variation in nitrate concentrations in selected Potomac River tributaries from 1993 through 1995, but concentrations typically are highest in those tributaries draining agricultural land and carbonate bedrock.

ammonia, and 0.07 mg/L (as phosphorus) for orthophosphate, the most common form of dissolved phosphorus in natural waters (Ator and Denis, 1997). On the basis of data from across the United States, maximum natural concentrations of nutrients in streams have been estimated at 0.6 mg/L for nitrate and 0.1 mg/L for ammonia (Mueller and others, 1995).

Elevated nitrogen concentrations in streams and ground water are common in the Potomac River Basin in areas of intensive row cropping and carbonate bedrock. Nitrate is the most common form of nitrogen in waters of the basin. Nitrate concentrations may vary considerably during the year at any given location because of seasonal variations in precipitation and inputs, but they generally exceed natural concentrations more often in streams and ground water in agricultural areas of the basin than in areas with other land uses. This is particularly evident in areas underlain by carbonate bedrock, where natural waters are more susceptible to such contamination (figs. 11, 12). Elevated nitrate concentrations in streams and ground water in some urban areas indicate that urban sources also contribute nutrients to the basin, although relatively few samples were collected in these areas during this study (Ator and Denis, 1997; Miller and others, 1997). Because nitrogen sources are typically surficial, concentrations are often greater in shallower than in deeper ground water (Blomquist and others, 1996). This is not evident from the data, however, likely because mostly shallow wells were sampled.

Nitrate concentrations that exceed natural concentrations are more common in streams and ground water in agricultural areas in the northeastern part of the Potomac River Basin than in other agricultural areas that contain lesser percentages of row cropping (fig. 13) (Ator and Denis, 1997; Miller and others, 1997). In 1992, row crops accounted for less than 20 percent of agricultural land in most counties of the basin, but as much as 47 percent of such land in counties in the northeast-

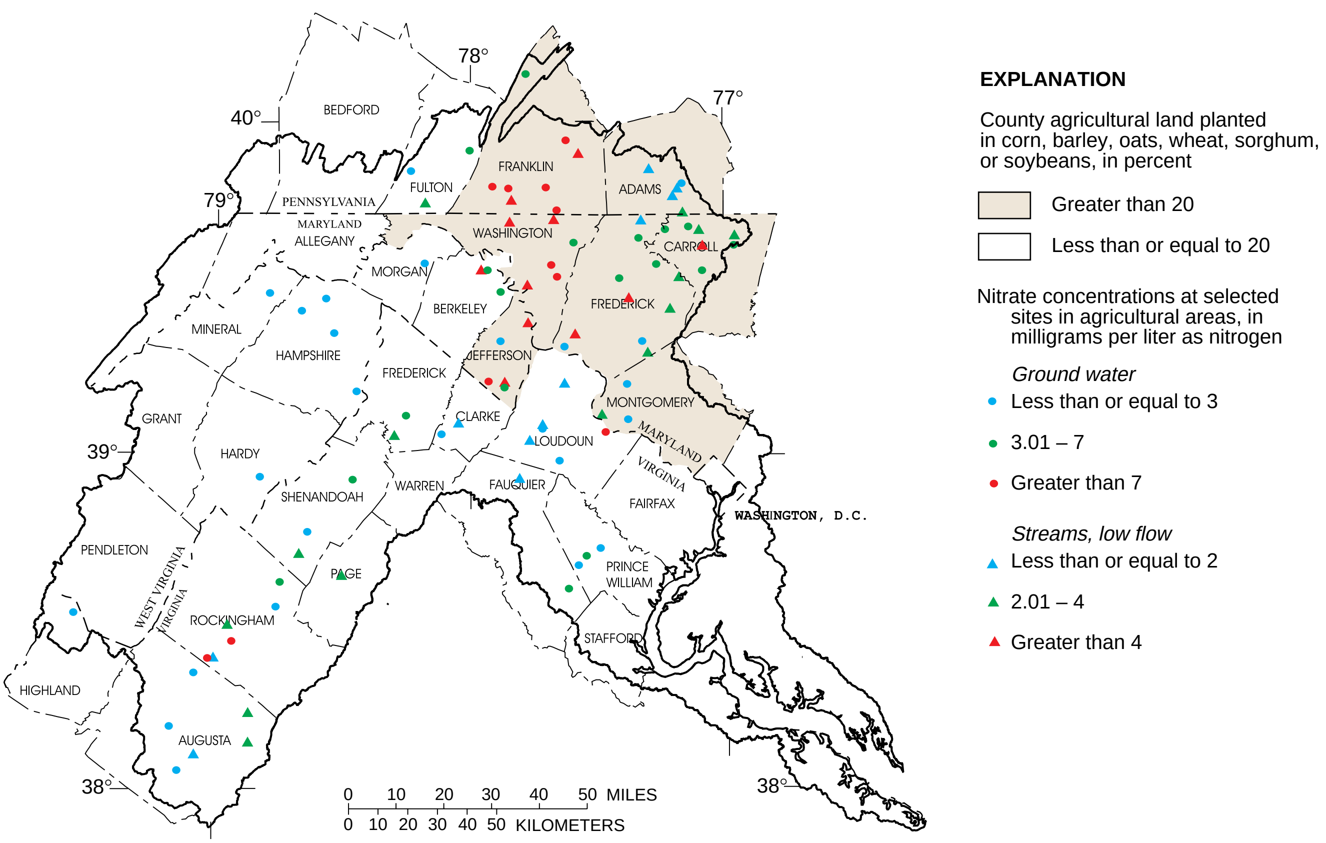


Figure 13. Within agricultural areas, most elevated nitrate concentrations in ground water and in small streams at low flow were found in counties with the highest percentages of agricultural land devoted to row crops.

ern part (U.S. Department of Commerce, 1995). Nitrogen is typically applied in greater quantities to crops in the form of fertilizer and manure than to pastures in the form of manure.

Ammonia concentrations are typically lower than nitrate concentrations but occasionally exceed natural concentrations. Elevated ammonia concentrations in small streams during low flow in carbonate areas were likely related to agricultural and urban land uses (Miller and others, 1997). Ammonia in ground water in forested areas may form from nitrogen that is deposited from the atmosphere or from organic nitrogen in leaves and other natural debris (Ator and Denis, 1997).

Organic nitrogen and phosphorus concentrations are typically low in waters of the basin, except in streams during high flows. Organic nitrogen (fig. 14) and phosphorus concentrations can be elevated for short periods in streams during high flow, but they were detected at low concentrations or were undetectable in most ground-water samples.

Streams draining primarily agricultural or urban areas yield the greatest quantities of nutrients to the Potomac River. Although the Shenandoah River contributes the greatest loads of total nitrogen and phosphorus among streams at which data were collected over time, Conococheague Creek, Muddy Creek, and the Monocacy River, which drain primarily agricultural watersheds, yield the largest loads of total nitrogen per square mile. Accotink Creek, an urban stream, yields the largest loads of total phosphorus per square mile, followed by Muddy and Conococheague Creeks and the Monocacy River (fig. 15). Phosphorus is less soluble than most forms of nitrogen and is often bound to stream sediment. Accotink Creek yields the most sediment per square mile among Potomac tributaries at which data were collected over time (Lizarraga, in press).

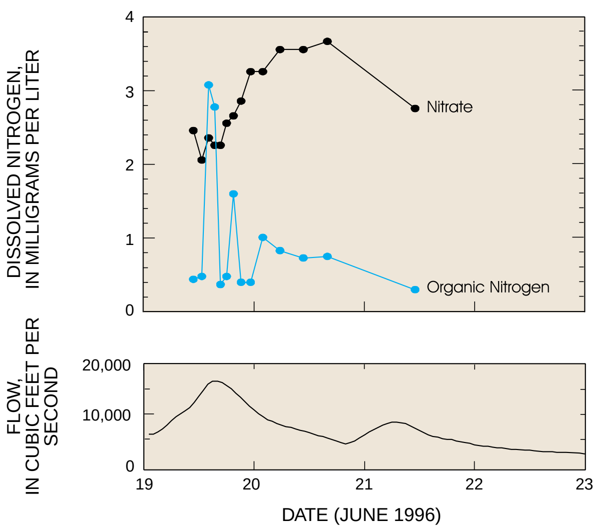


Figure 14. Organic nitrogen concentrations were elevated for a short time during high flow in Conococheague Creek in June 1996 but quickly decreased as the flow subsided. Concentrations of nitrate, a much more soluble form of nitrogen, were slightly depressed during the high flow.

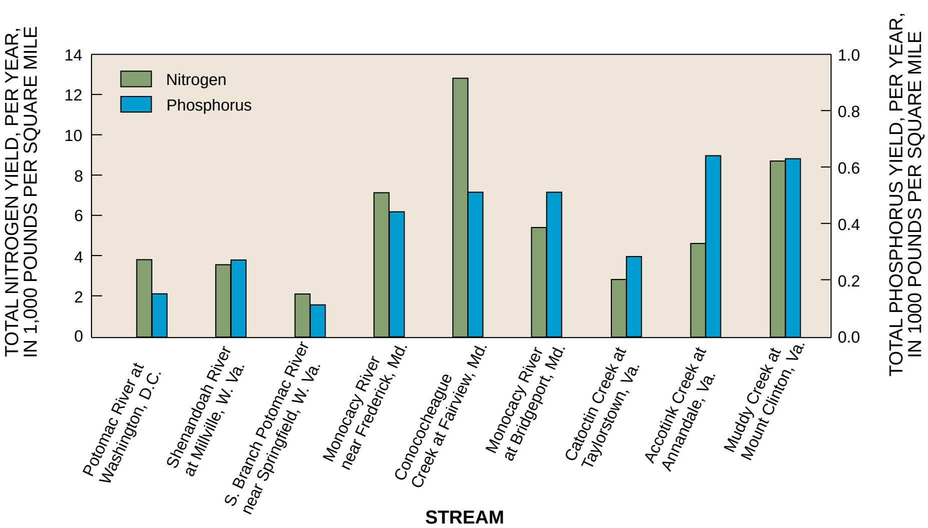


Figure 15. Estimated yields of nitrogen and phosphorus for selected streams in the Potomac River Basin, 1994-95 (Lizarraga, in press). The Monocacy River and Conococheague and Muddy Creeks, which drain primarily agricultural watersheds, and Accotink Creek, which drains a small urban watershed, yield the greatest amounts of nitrogen and phosphorus per square mile to the Potomac River.

Pesticides

Each year, 4.94 million pounds of synthetic organic pesticides are applied to agricultural lands within the Potomac River Basin, including 2.88 million pounds of herbicides, 1.09 million pounds of insecticides, and 0.97 million pounds of fungicides. Additionally, 1.24 million pounds of oil and 0.47 million pounds of sulfur are used primarily on apples and peaches to control insects and fungi, respectively. Pesticides are also used for non-agricultural purposes such as maintenance of golf courses, lawns, and gardens; defoliation of rights-of-way; and control of disease-carrying or defoliating insects. Application rates for these uses are not as well documented.

Cornfields and apple orchards receive nearly 75 percent of agricultural pesticides applied in the Potomac River Basin (table 2). Apples receive the heaviest average rate of pesticide application, followed by potatoes and peaches. The agricultural areas with the lowest average rates of pesticide application are pastures and hayfields.

Commonly used pesticides are present in ground water of the Potomac River Basin, typically at low concentrations. Pesticide compounds were detectable[2] in ground-water samples from throughout the basin, although concentrations rarely

Table 1: Major agricultural pesticides used in the Potomac River Basin and results of pesticide analyses
[F, fungicide; H, herbicide, I, insecticide; A, alfalfa; Ap, apples; C, corn; Ch, cherries; O, other hay; P, pasture; Pe, peaches; S, soybeans; T, tobacco; W, wheat; D, detected; N, not detected, ---, not analyzed]

Pesticide (Trade names[1])	Type	Estimated amount applied[2] (lb/yr)	Estimated acres treated	Major target crops	Sample result	
					Ground water	Streams
Atrazine (AAtrex, Gesaprim)	H	697,000	492,000	C	D	D
Metolachlor (Dual, Pennant)	H	539,000	323,000	C, S	D	D
Captan (Clomitane, Captanex)	F	319,000	37,600	Ap, Pe	---	---
Alachlor (Lasso, Alanox)	H	295,000	165,000	C, S	N	D
Chlorpyrifos (Dursban, Lorsban)	I	281,000	253,000	C, A, Ap	D	D
2,4-D (Weed-B-Gon, Chloroxone)	H	205,000	376,000	P, O, C, W	N	D
Mancozeb (Dithane DF, Nemispor)	F	202,000	43,300	Ap	---	---
Simazine (Aquazine, Princep)	H	168,000	126,000	C, Ap, Pe	D	D
Cyanazine (Bladex, Fortrol)	H	167,000	113,000	C	N	D
Metiram (Carbatene, Polyram DF)	F	148,000	8,230	Ap, Pe	---	---
Paraquat (Cyclone, Total)	H	133,000	336,000	C, A, Ap, S	---	---
Carbofuran (Furadan, Curaterr)	I	132,000	143,000	C, A, S	N	D
Butylate (Genate Plus, Sutan)	H	121,000	28,000	C	N	D
Glyphosate (Roundup, Rattler)	H	120,000	108,000	C, P, S, Ap	---	---
Ziram (Corozate, Thionic)	F	109,000	16,000	Ap, Pe	---	---
Azinphos-methyl (Guthion, Carfene)	I	88,000	49,800	Ap, Pe	N	D
EPTC (Eptam, Alirox)	H	83,300	19,700	C, A	D	D
Dicamba (Banvel, Metambane)	H	77,100	253,000	P, C, O	N	N
Pendimethalin (Prowl, Stomp)	H	73,700	79,300	C, S, T	N	D
Methomyl (Lannate, Methomex)	I	67,800	75,000	Ap, C, W	N	N

[1]Use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Government.
[2]Amount of active ingredient (Gianessi and Puffer, 1990, 1992a, 1992b).

exceeded 1 microgram per liter (µg/L). Atrazine was the most commonly detected pesticide in ground water, in 34 percent of samples (fig. 16). Simazine, metolachlor, and prometon were also detected in at least 15 percent of samples, and 10 other compounds (p,p'-DDE, EPTC, metribuzin, tebuthiuron, DCPA, pebulate, dichlorbenil, dicamba, terbacil, and propoxur) were detected in less than 10 percent of samples. Deethylatrazine (a byproduct of atrazine degradation) was detected in nearly all ground-water samples that contained detectable atrazine, often at higher concentrations.

A wider variety of pesticides was detected more frequently in small streams than in ground-water samples. Pesticides were commonly detected in samples from small streams of the basin that were collected during periods of low flow in late summer, although concentrations were usually less than 1 µg/L. Atrazine (fig. 17), metolachlor, simazine, and prometon were each detected in more than half of these samples. In addition, tebuthiuron, diazinon, and carbaryl were each detected in at least 10 percent of samples, and 18 other pesticide compounds were detected in less than 10 percent of the samples. Only atrazine and metolachlor were measured at concentrations greater than 1 µg/L. Deethylatrazine was detected in 67 percent of samples from small streams at low flow and in 86 percent of such samples that contained detectable atrazine.

Concentrations of pesticides in streams and ground water of the Potomac River Basin are usually not threatening to human health or most ecosystems, based on current standards and understanding. Established MCLs (U.S. Environmental Protection Agency, 1994a) for atrazine (3 µg/L), simazine (4 µg/L), and alachlor (2 µg/L) were only occasionally exceeded in stream samples collected during this study of the Potomac River Basin, most commonly during storms. The MCL of 70 µg/L for 2,4-D was never exceeded. There are currently no established drinking-water criteria for the other pesticides in common use in the basin, although established lifetime health-advisory levels (U.S. Environmental Protection Agency, 1996) for cyanazine and diazinon were infrequently exceeded. Although criteria for the protection of aquatic life do not reflect all possible effects of pesticides in streams and have not been established for many compounds, degradation products, and mixtures, established criteria (International Joint Commission Canada and United States, 1977; Canadian Council of Resource and Environment Ministers, 1991; U.S. Environmental Protection Agency, 1991a) were exceeded for atrazine, chlorpyrifos, cyanazine, diazinon, malathion, methylazinphos, and metolachlor. Aquatic-life criteria were exceeded almost exclusively in samples collected during storms in May,

[2]Using methods employed by the NAWQA Program, most pesticide compounds were detectable in water samples at concentrations as low as 0.001 µg/L to 0.01 µg/L.

Table 2: Pesticide application to major crops in the Potomac River Basin

Crop	Estimated acres[1]	Estimated amounts of pesticides used (lb/yr)[2]				Most heavily applied pesticide
		Fungicides	Herbicides	Insecticides	Total	
Corn	416,000	2,500	2,090,000	354,000	2,450,000	Atrazine
Apples	50,000	812,000	110,000	372,000	1,300,000	Captan
Alfalfa	247,00	0[3]	102,000	212,000	314,000	Chlorpyrifos
Soybeans	157,000	583	275,000	38,400	314,000	Metolachlor
Pasture	1,510,000	0[3]	149,000	0[3]	149,000	2,4-D
Peaches	8,790	79,600	11,300	31,900	123,000	Captan
Other Hay	545,000	0[3]	73,800	1,260	75,000	2,4-D
Wheat	123,000	1,880	21,000	22,400	45,300	2,4-D
Potatoes	1,220	9,310	6,410	13,600	29,400	Mancozeb
Cherries	1,600	16,600	721	2,090	19,400	Captan

[1]Based on 1992 agricultural census data (U.S. Department of Commerce, 1995).
[2]Based on Gianessi and Puffer, 1990, 1992a, 1992b.
[3]No reported use.

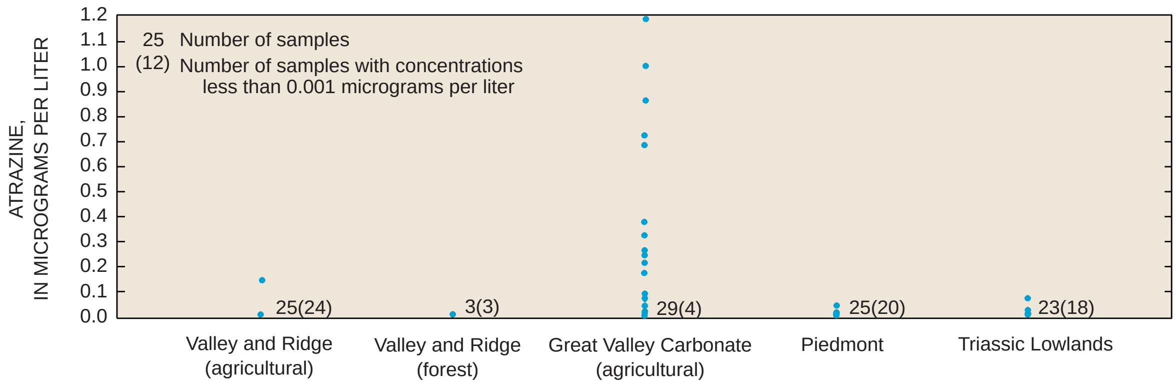


Figure 16. Concentrations of atrazine in ground water in sampled areas of the Potomac River Basin. Atrazine was most commonly detected in ground water in agricultural areas of the Great Valley.

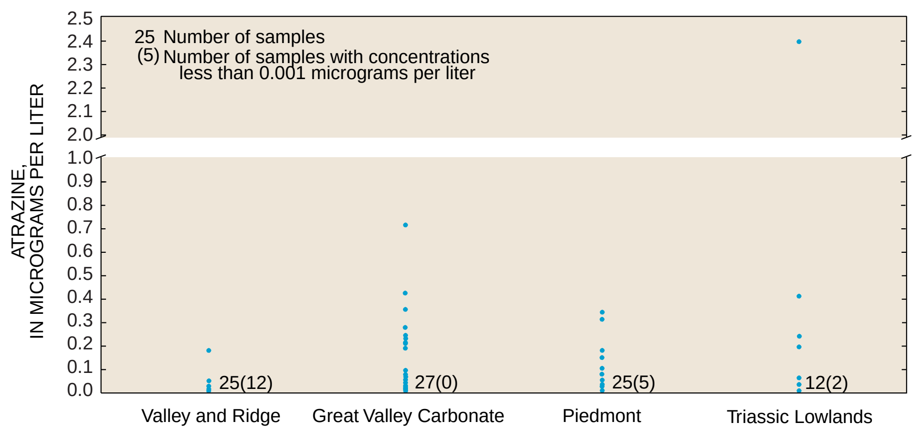


Figure 17. Concentrations of atrazine in small streams during low flow in sampled areas of the Potomac River Basin. The highest concentrations of atrazine were typically detected in streams of the Great Valley, although the highest concentration was detected in the Triassic Lowlands.

June, or July from Accotink Creek, the Monocacy River, or Muddy Creek. These streams drain predominantly urban or agricultural areas and were among the most intensely sampled for pesticides within the Potomac River Basin by the NAWQA Program.

Pesticides were commonly detected in streams and ground water in agricultural areas of the Potomac River Basin; samples from forested areas rarely contained detectable pesticides. Much of the agriculture in the basin is in the Great Valley, Piedmont, and Triassic Lowlands (fig. 3). In carbonate areas of the Great Valley, atrazine (figs. 16, 17), deethylatrazine, simazine, prometon, and metolachlor were each detected in more than half of the samples from ground water and small streams. Pesticides were also commonly detected in ground water and streams of the Piedmont and Triassic Lowlands. In the mostly forested Valley and Ridge, however, detections of pesticide compounds in streams were much less frequent, and there were virtually no detections in ground water. Six compounds (atrazine, deethylatrazine, p,p'-DDE, metribuzin, prometon, and simazine) were each detected in a single ground-water sample from the Valley and Ridge, and dichlorbenil was detected in four samples. Only atrazine, deethylatrazine, metolachlor, prometon, simazine, and tebuthiuron were detected in small-stream samples from the Valley and Ridge.

Pesticide concentrations in streams and ground water of the Potomac River Basin are greatest in areas of intense crop production – particularly in the corn-producing northeastern counties and in the Great Valley. Pesticide concentrations in ground water and small streams were typically higher in samples from the more heavily cropped areas than other agricultural areas (fig. 18). Among larger streams, the highest incidence of detections and elevated concentrations of atrazine and metolachlor also occurred predominantly in these areas, particularly in the Monocacy River and Opequon, Conococheague, and Antietam Creeks.

Streams in the Potomac River Basin are affected by pesticide applications in urban as well as agricultural areas. Many pesticides have been detected in samples from Accotink Creek, which drains a small, urban watershed near Washington, D.C. Herbicides detected at this site include atrazine, metolachlor, MCPA, oryzalin, and prometon. Simazine was detected most often and at the highest concentrations, occasionally exceeding the MCL of 4 µg/L. Insecticides—including diazinon, carbaryl, and chlorpyrifos—were also detected, year-round. Samples from Accotink Creek contained the highest concentrations of the insecticides diazinon and malathion measured in the Potomac River Basin and the highest concentrations of oryzalin and MCPA measured by the NAWQA Program. Pesticides found in Accotink Creek are generally used on rights-of-way, turf, golf courses, and for landscaping, and as additives to asphalt and other building materials.

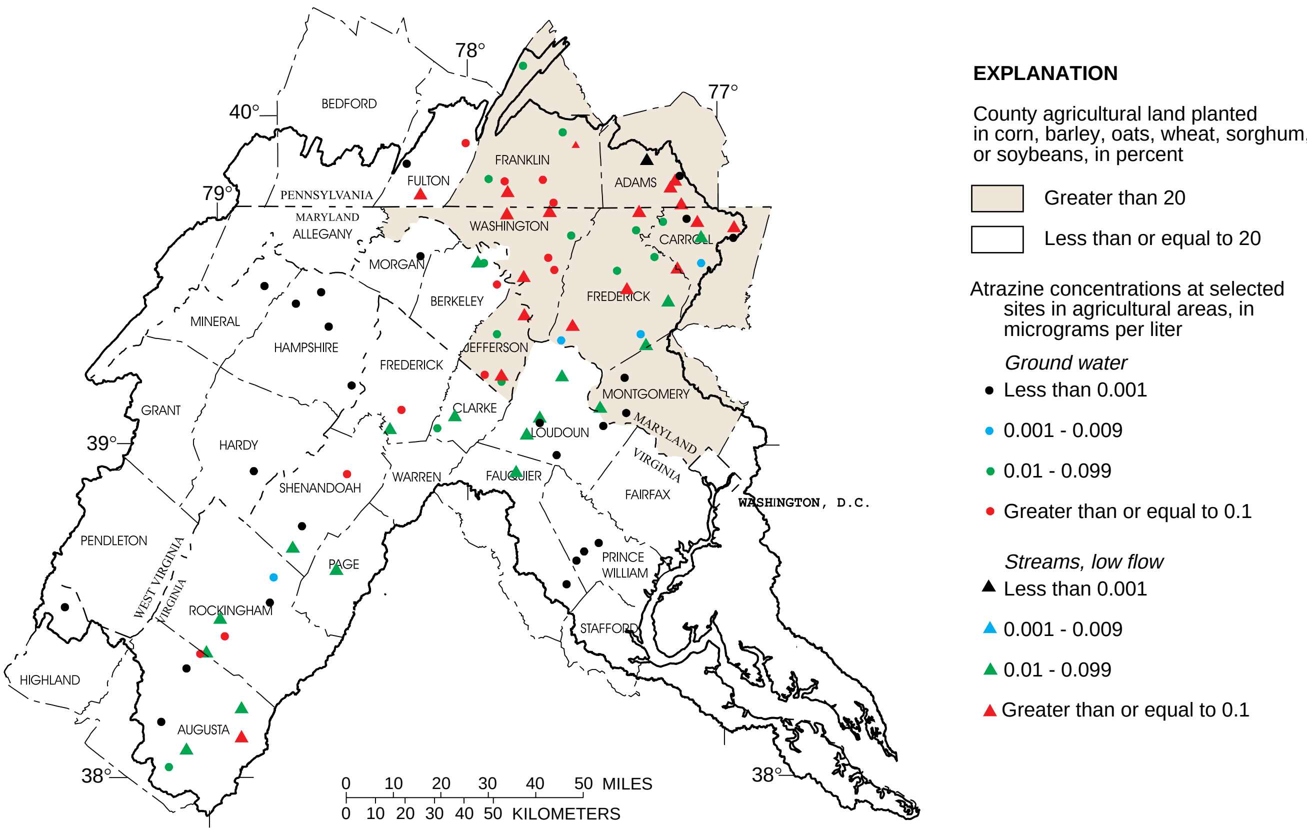


Figure 18. Within agricultural areas, most elevated atrazine concentrations in ground water and in small streams at low flow were found in counties with the highest percentages of agricultural land devoted to row crops.

Maximum concentrations of most pesticides occur in streams during the spring and early summer months, although atrazine and metolachlor are present year round in agricultural areas. The Monocacy River at Bridgeport, Md., for example, drains 173 square miles, almost 80 percent of which is agricultural. Pesticide concentrations in this stream are related to flow, but the major controlling factor is the seasonal application (fig. 19). During a storm in May 1994, concentrations of alachlor (3.1 µg/L), atrazine (25 µg/L), cyanazine (3.0 µg/L), and metolachlor (23 µg/L) in the Monocacy River were the highest measured in any water sample during this study. Other pesticides frequently detected in the Monocacy River included simazine, prometon, and linuron. Of the 45 pesticides for which samples from this site were analyzed, 19 were detected at least once during the period of most intensive sampling in 1994. Pesticide concentrations in the Potomac River also were highest in the spring, during the time of applications. Concentrations declined through the summer months and were nearly undetectable in late fall and winter.

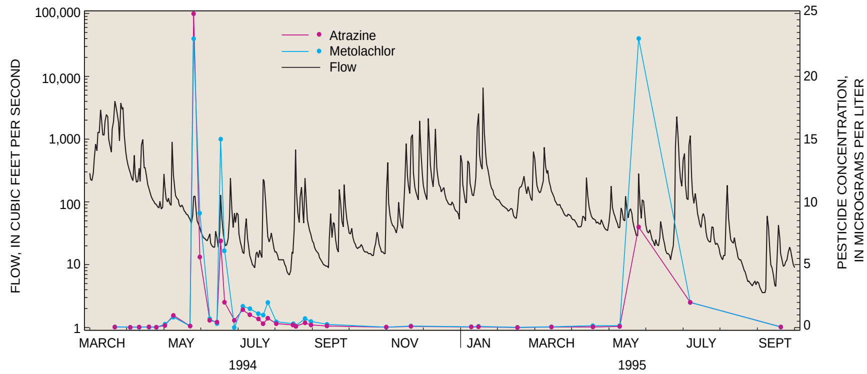


Figure 19. In the Monocacy River at Bridgeport, Md., atrazine and metolachlor were present at detectable concentrations during most of the year but concentrations were typically highest during the late spring following application.

Three major floods occurred in the Potomac River Basin in 1996 and had different effects on water quality because they occurred during different seasons (fig. 20). Record high flow for a single day occurred in January in the Potomac River at Washington, D.C., due to intense rainfall and rapid snowmelt caused by unseasonably warm weather following a blizzard. In June, basins of the Monocacy River and Conococheague Creek, which are dominantly agricultural, received intense rainfall over a 5-day period. Flow from the June storm in the Monocacy River at Bridgeport, Md., reached a level expected to occur only once in 200 years. Intensive rainfall from a tropical storm caused flooding in September in the mostly agricultural Shenandoah River Basin and points west.

Nitrogen loads in the Potomac River at Washington, D.C., were greater during the January flood than during June or September. Record flow, including runoff from previously frozen land, carried an estimated 18 million pounds of nitrogen, including large amounts of ammonia and organic nitrogen which are typically associated with manure and wastewater discharges.

The Potomac River at Washington, D.C., carried 25 times as much atrazine during the June flood as in September, even though the flow was three times greater in September. Over a 5-day period, the river carried an estimated 3,300 pounds of atrazine and 3.3 million pounds of nitrogen. On two consecutive days following the June storm, atrazine was measured in the river at concentrations greater than the MCL of 3 g/L.Pesticides and fertilizers are generally applied to the land in the spring, whereas nitrogen may be applied in the form of manure throughout the year.

Long-term impacts of the unprecedented flooding within the Potomac River Basin during 1996 have yet to be determined; however, the USGS is currently studying aquatic vegetation downstream in the Potomac estuary, and State and local governments are planning to sample drinking-water sources for pesticides more frequently during peak application periods.

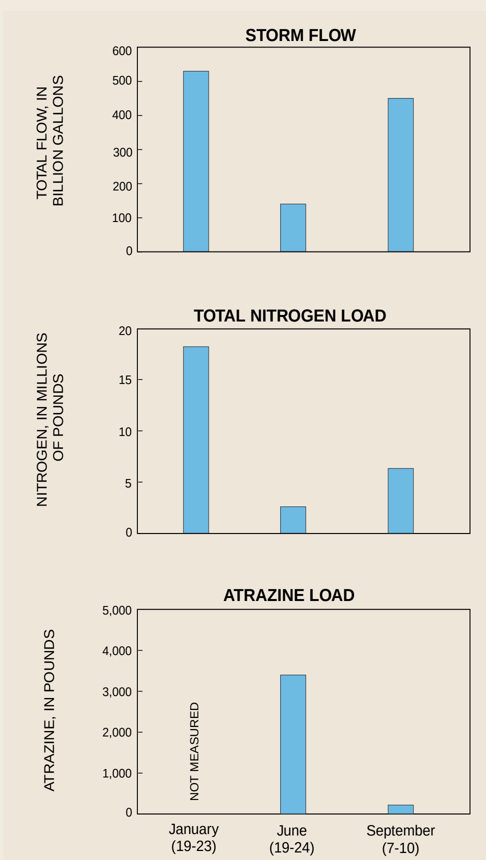


Figure 20. Three major floods in the Potomac River Basin during 1996 had different effects on water quality in the Potomac River at Washington, D.C., because they occurred at different times of the year.

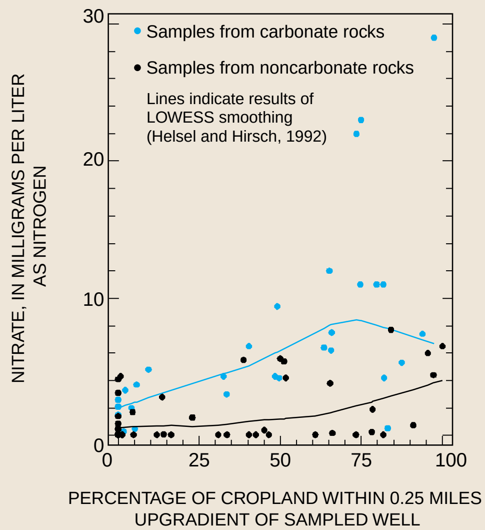


Figure 21. Nitrate concentrations in ground-water samples from the Potomac River Basin increase with increasing percentages of cropland, but are typically higher in samples from carbonate rocks like those of the Great Valley than in samples from rocks of other types.

Within the Potomac River Basin, streams and ground water in the Great Valley show the greatest water-quality effects from agricultural sources (fig. 21) **because the valley is intensely used for crop and animal production and because carbonate bedrock permits rapid transportation of constituents to ground water and streams.** Much of the Great Valley is underlain by carbonate rock which commonly contains open conduits (solution channels) created and enlarged by the action of acidic water moving through rock fractures. Rain is naturally acidified by the dissolution of carbon dioxide in the atmosphere and can be further acidified by the introduction of nitric and sulfuric acids into the atmosphere from the combustion of fossil fuels. Chemicals at the land surface in agricultural areas such as the Great Valley can be quickly and easily carried to ground water through conduits in bedrock. Once chemical constituents reach the ground water in carbonate rocks, they may move quickly with ground-water flow to streams, springs, or water-supply wells. Nutrient and pesticide concentrations in ground water of carbonate areas are often highly variable because the ground water responds so quickly to precipitation and the application of fertilizers and pesticides. In addition, soils derived from carbonate rocks tend to contain little organic carbon and therefore have a reduced ability to bind to organic chemicals, such as pesticides (Barbash and Resek, 1996).

Photograph by James Gerhart, U.S. Geological Survey

Chlordane,[3] DDT,[4] PCBs,[5] mercury, and lead are present in streambed sediment and aquatic tissues in the Potomac River Basin (fig. 22). Each of these compounds or metals can directly impair aquatic organisms living in or near the streambed and can be detrimental to the health of humans or other animals through the food chain. Lead, mercury, chlordane, and DDT have been designated as “toxics of concern” to the Chesapeake Bay (U.S. Environmental Protection Agency, 1991b,c).

[3]Chlordane concentrations presented are the sum of trans-chlordane, cis-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane.

[4]DDT concentrations presented are the sum of o,p’-DDT, p,p’-DDT, o,p’-DDD, p,p’-DDD, o,p’-DDE, p,p’-DDE.

[5]PCB concentrations presented are the sum of all PCB congeners.

Screening thresholds for organic compounds and trace metals in streambed sediment

A three-tiered system is used for screening measured concentrations of potentially toxic compounds in streambed sediment. Concentrations in tier 1 (greater than the upper screening value) have a high probability of causing adverse effects on aquatic life; concentrations in tier 2 (between the upper and lower screening values) have an intermediate probability of causing adverse effects on aquatic life; and concentrations in tier 3 (less than both screening values) have a low probability of causing adverse effects on aquatic life (Gilliom and others, in press). Screening levels for mercury, lead, DDT (Long and others,1995) and chlordane (Long and Morgan, 1990) are the ERL (effects range - low) and ERM (effects range - median) developed for bottom sediments in estuarine waters. Screening levels for PCBs are the PEL (Probable Effect Level) and TEL (Threshold Effect Level) developed by the Florida Department of Environmental Protection (1994). Because these values were developed for screening purposes, measurements within tiers 1 and 2 do not indicate that adverse effects have occurred at particular sampling sites.

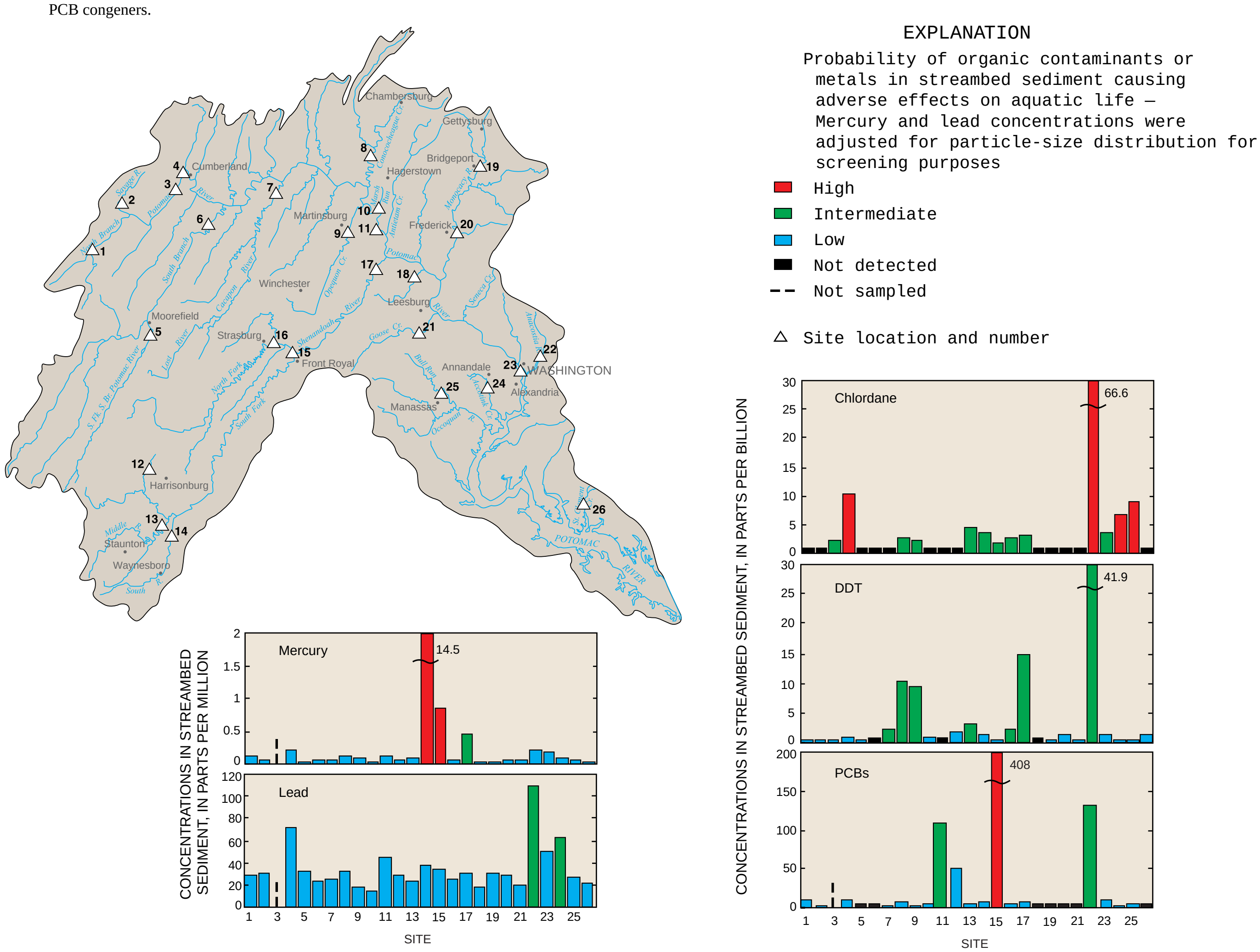


Figure 22. Chlordane, DDT, PCBs, lead, and mercury were detected in streambed sediment at many sites throughout the Potomac River Basin. Many concentrations were greater than screening levels, indicating that there is some potential for these contaminants to adversely affect aquatic life.

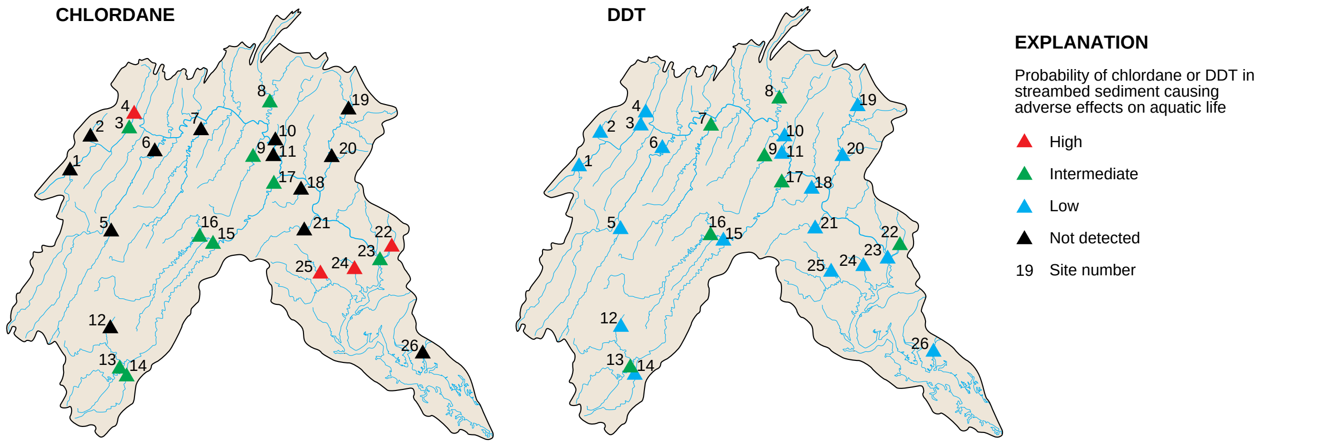


Figure 23. Chlordane and DDT were frequently found in streambed sediment in the Potomac River Basin, even though these insecticides are now banned. The greatest chlordane concentrations were measured near the Washington, D.C., urban areas and Cumberland, Md.; whereas the greatest DDT concentrations were measured in streams in the Great Valley.

The use of chlordane, DDT, and PCBs has been banned or restricted for nearly two decades. The occurrence of these compounds in streambed sediment indicates a persistent potential for toxic effects from regional and point sources of contamination in parts of the Potomac River Basin

Streambed sediment

Chlorinated organic compounds and trace metals are present in streambed sediment of the Potomac River and its tributaries at concentrations that have some potential to adversely affect aquatic life. Sediment from 14 of 25 sites contained chlordane, DDT, PCBs, lead, or mercury at concentrations that pose an intermediate probability of causing adverse effects on aquatic life; concentrations at six sites indicate a high probability of causing adverse effects on aquatic life.

Chlordane was detected in streambed sediment from 13 of 26 sites in the Potomac River Basin, even though most uses of chlordane were banned in 1978 and a total ban was implemented in 1988 (U.S. Environmental Protection Agency, 1991c, 1992, 1994a). Chlordane is a synthetic organic compound that was primarily applied to soil surrounding building foundations as an insecticide to control termites and ants. For this application, chlordane was developed to adhere to soil particles and to degrade slowly—offering long-term protection from pests. These chemical properties, however, render chlordane a persistent problem in many streams in the Potomac River Basin.

At least a moderate potential for occasional adverse effects to aquatic organisms exists at all sites where chlordane was detected in streambed sediment. Seven of these sites are in the Great Valley (fig. 23). Although the Great Valley is largely agricultural (including row crops, pasture, and orchards), several urban and industrial centers extend through the valley from Waynesboro, Va., to Chambersburg, Pa. Chlordane in this region could be derived from a wide variety of sources and applications.

Concentrations of chlordane in streambed sediment indicate a high probability for adverse effects on aquatic biota at four sites downstream from urban areas (fig. 23). The maximum concentration (66.6 ppb, parts per billion) was measured in a sample from the Anacostia River (site 22) in a tidal area near Washington, D.C. This concentration was more than 10 times the upper screening threshold. The second highest concentration was measured in sediment from the North Branch Potomac River, at a site downstream from a heavily industrialized area of Cumberland, Md.

DDT was detected in streambed sediment from 23 of 26 sites sampled in 1992 and 1996. DDT is an insecticide used to control mosquitoes and other pests. Its use was banned in 1972 because of its harmful effects on birds and other wildlife and its potential to cause cancer and damage the human nervous system, liver, kidney, and skin (U.S. Environmental Protection Agency, 1992). Its widespread occurrence in the Potomac River Basin two decades since its ban is attributable to both widespread use and chemical stability.

Although DDT was present at a large proportion of sampled sites, concentrations at most sites indicate little potential for adverse effects on aquatic biota. DDT concentrations in sediment at seven sites indicate a moderate potential for adverse effects on aquatic life. Of these, five are in the Great Valley. The application of DDT to orchards has been identified as one potential source of DDT in several streams in the central Great Valley (Gerhart and Blomquist, 1995). As with chlordane, sediment from the Anacostia River near Washington, D.C. (fig. 23) had the highest concentration of DDT (41.9 ppb).

PCB concentrations in sediment from the South Fork Shenandoah River at Front Royal, Va., indicate a high potential for adverse effects on aquatic life. The high levels of PCBs at this site are attributable to a textile plant immediately upstream (Virginia Water Control Board, 1992). This plant has been closed since 1989, when the PCB releases were discovered. Other high levels of PCBs were measured in sediment from the Potomac River at Shepherdstown, W. Va. (site 11), but no local sources have been identified (Gerhart and Blomquist, 1995).

Mercury was detected in all streambed sediment samples from the Potomac River Basin and poses a potential threat to aquatic life at six sites (Gerhart and Blomquist, 1995). Although it occurs naturally in trace amounts in the Earth's crust, mercury may be introduced as a contaminant to the environment as a consequence of human activities. Mercury is used in the manufacture of paints, paper, and vinyl chloride, and it can also be found in batteries and fungicides.

High levels of mercury at three sites are directly attributable to a long-term industrial source of mercury contamination on the South River in Waynesboro, Va. (fig. 24). In 1977, mercury was found in soils at the Waynesboro plant, where it was used in industrial processes until 1950. Mercury contamination may have continued at this site for several decades prior to its discovery (Brooks, 1977). This potentially long-term source has led to measurable mercury contamination as far as 171 miles downstream, near Harpers Ferry, W.Va. (fig. 24). It is possible that the Waynesboro plant is a contributing source of mercury measured as far downstream as Washington, D.C., although more detailed study would be necessary to make this link.

Lead was detected in streambed sediment at all 25 sampled sites in the Potomac River Basin. The highest lead concentration (110 ppm, parts per million) was measured in sediment collected from the Anacostia River near Washington, D.C., which also contained the highest concentrations of chlordane and DDT. Sediment from two other sites in the Washington, D.C., area and one in Cumberland, Md., contained lead at concentrations indicating a moderate potential for adverse effects on aquatic life.

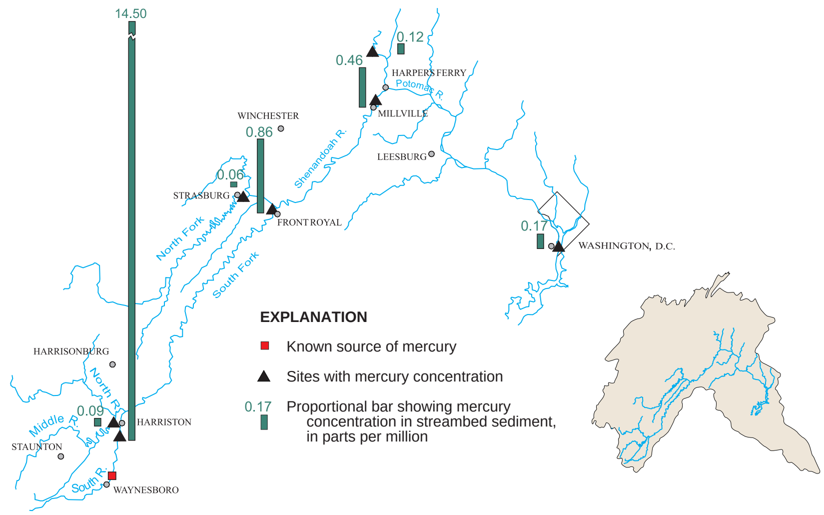


Figure 24. Mercury contamination from an industrial source in Waynesboro, Va. (possibly lasting over a period of decades), has led to widespread contamination of the South Fork Shenandoah and Shenandoah Rivers (to about 171 river miles downstream). It is possible that contamination from this source has spread as far downstream as the Potomac River at Washington, D.C.

Each of the sediment samples containing lead at concentrations potentially harmful to aquatic life were collected in urban and industrial areas. Although lead occurs naturally in trace amounts, many potential sources of lead contamination exist, including batteries, vehicle emissions, solder, and corroding brass, pipes, and plumbing. Other sources include paints, gasoline, and lead shot, although uses of lead for these purposes has been restricted. Sediment in urban areas may accumulate lead from any of these sources.

Aquatic tissues

Contaminants present in streambed sediment are bioavailable and have been incorporated into the food chain. Chlordane, DDT, PCBs, mercury, and lead were detected in Asiatic clam *(Corbicula fluminea)* tissue and fish tissue samples collected in 1992 and 1996 (Zappia, 1996). Organochlo-

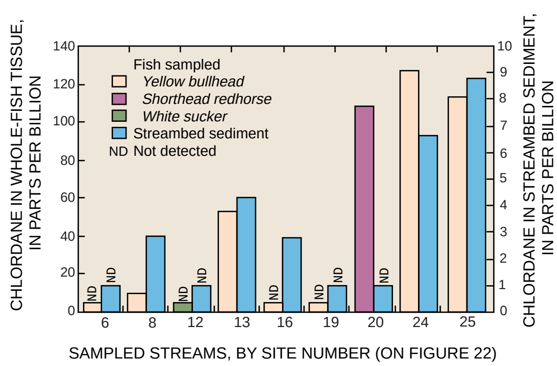


Figure 25. Chlordane concentrations in whole-fish samples of bottom-feeding fish are correlated with concentrations in streambed sediment (Gerhart and Blomquist, 1995). These sediments apparently serve as a source of chlordane in the food chain. One sample of shorthead redhorse (a carp-like fish) shows chlordane contamination near Frederick, Md., where none exists in the streambed sample. This contamination may be from exposure to contamination in other locations or from historical exposure.

rine compounds were detected less frequently in clam tissue than in streambed sediment, as chlordane and DDT were detected in only 3 of 16 sites and PCBs were detected in 4 sites (table 3). Chlordane was generally found in higher concentrations in whole-fish tissue than in clams.

Streambed sediment apparently serves as a source of chlordane to the food chain, because chlordane concentration in fish tissue is correlated with concentration in sediment (fig. 25).

Chlordane concentrations in fish tissue pose a threat to fish-eating wildlife at two sites in the Potomac River Basin. Whole-fish tissues from two streams in Virginia, Bull Run (site 25) and Accotink Creek (site 24), contained chlordane at concentrations exceeding the National Academy of Sciences, National Academy of Engineering (NAS/NAE) (1973) recommended maximum concentration for the protection of fish-eating wildlife. These sites are in the heavily urbanized Washington, D.C., area. A human health advisory including chlordane currently exists for the consumption of fish caught in Washington, D.C., waters, "due to PCBs and other compounds" (Hamid Karimi, District of Columbia Department of Consumer and Regulatory Affairs, written commun., 1994). Possible effects of chlordane on human health include cancer, dizziness, headache, fatigue, and convulsions. No Asiatic clam samples contained chlordane at concentrations threatening to humans or wildlife.

No Asiatic-clam or whole-fish samples contained PCBs at concentrations threatening to human health or wildlife, although human health advisories have been issued for some streams. Asiatic clams from the South Fork Shenandoah River at Front Royal, Va. (site 15), contained the highest measured concentration of PCBs in the basin. Human-health advisories for PCBs in fish exist in this part of the South Fork Shenandoah River. Human-health advisories also exist for other reaches of the North Fork, South Fork, and mainstem Shenandoah River and for Washington, D.C., waters (Emily Jones, Commonwealth of Virginia, Department of Game and Inland Fisheries, written commun., 1996; Hamid Karimi, District of Columbia Department of Consumer and Regulatory Affairs, written commun., 1994).

Mercury was detected in tissue samples from nine sites, including four sites in the Shenandoah River watershed downstream from the contamination source in Waynesboro, Va. Mercury was detected in Asiatic clams from seven sites, but no concentrations exceeded the FDA action level for the protection of human health in edible-shellfish tissue. The highest measured concentration of mercury in Asiatic clams (0.71 ppm) was detected at site 14, downstream from Waynesboro, Va. Mercury was also detected at five sites (8, 13, 16, 19, and 20) in fish livers, although FDA action levels and NAS/NAE criteria are not applicable to fish livers.

The Virginia Department of Health has established warnings to restrict consumption of fish from the South River and the South Fork of the Shenandoah River because of concentrations of mercury in fish tissue (Vickie Odell, Virginia Department of Health, written and oral commun., 1997).

Table 3. Summary of chlordane, DDT, PCB, lead and mercury concentrations in Asiatic clam tissues and relation to standards for the protection of human health

[ppb, parts per billion; also equivalent to micrograms per kilogram]

Compound or metal	Number of sites where detected (16 sites sampled)	Minimum detected concentration (ppb)	Maximum detected concentration (ppb)	U.S. Food and Drug Administration action level[1] (ppb)	Number of sites exceeding standard
Chlordane	3	8.8	31.1	300	0
DDT	3	5.1	12.9	5,000	0
PCBs	4	140	162	2,000	0
Lead	14	300	1,200	no standard	--
Mercury	7	89	710	1,000	0

[1] U.S. Food and Drug Administration, 1992.

All samples of Asiatic clams (*Corbicula fluminea*) contained chlordane, DDT, and PCB at concentrations well below the U.S. Food and Drug Administration action levels for protection of human health. Mercury concentrations approached the FDA action level in a sample from the South River near Waynesboro, where the greatest concentration was measured in streambed sediment .

Table 4. Summary of chlordane, DDT, and PCB concentrations in whole-fish tissue and relation to criteria for the protection of fish-eating wildlife

[ppb, parts per billion, also equivalent to micrograms per kilogram]

Compound	Number of sites where detected (8 sites sampled)	Minimum detected concentration (ppb)	Maximum detected concentration (ppb)	NAS/NAE recommended maximum concentration for the protection of fish-eating wildlife[1] (ppb)	Number of sites exceeding standard
Chlordane	4	9.6	127	100	2
DDT	4	6.4	12	1,000	0
PCBs	5	75	146	500	0

[1] National Academy of Sciences, National Academy of Engineering, 1973.

Two samples of bottom-feeding fish contained chlordane at concentrations greater than the NAS/NAE recommended maximum concentration for the protection of fish-eating wildlife. These samples, collected in 1992, show a persistence in the food chain because chlordane use was restricted in 1978 and banned in 1988.

Radon is present in ground water throughout the Potomac River Basin. The Federal drinking-water standard for radon is currently under review by the U.S. Environmental Protection Agency; however, radon levels in 69 percent of ground-water samples were greater than a previously proposed standard of 300 picocuries per liter. Of 104 ground-water samples, 103 contained detectable levels of radon and levels ranged from among the lowest to among the highest in the Nation.

A colorless, odorless, radioactive gas, radon forms naturally in rocks and soils through the radioactive decay of radium, a product of uranium decay. Radon commonly enters buildings through foundation cracks and may dissolve in ground water and be carried into buildings served by water supply wells. Radon from ground water is released into household air when water is used for showering, washing, and other everyday purposes. According to the U.S. Surgeon General, exposure to airborne radon is second only to cigarette smoking as a cause of lung cancer. The risk of cancer increases with exposure to increasing levels of airborne radon (U.S. Environmental Protection Agency, 1994b).

Radon activities in ground water of the Potomac River Basin are related to rock type. Ground-water radon activities[6] are highly variable in all areas but are typically higher in areas underlain by crystalline rocks of the Piedmont than in areas underlain by carbonate rocks (figs. 26, 27). Crystalline rocks of predominantly granitic composition, like many of those in the Piedmont, contain more uranium, on average, than do carbonate rocks (Faure, 1986). The part of the Piedmont west of the Triassic Lowlands is an exception; ground-water radon activities in this area are typically lower than in carbonate areas. This area contains some granitic rocks, but many of the crystalline rocks of this area are not predominantly granitic like those of the rest of the Piedmont. Rocks of this type contain much less uranium, on average, than do granitic or carbonate rocks (Faure, 1986).

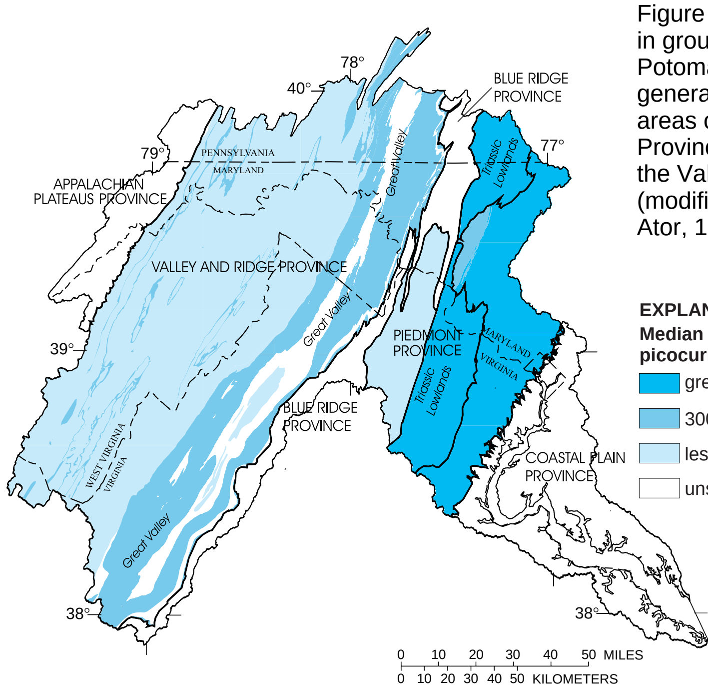


Figure 26. Radon activities in ground water in the Potomac River Basin are generally higher in sampled areas of the Piedmont Province than in those of the Valley and Ridge (modified from Lindsey and Ator, 1996).

Ground-water radon activities in the Triassic Lowlands are among the highest detected in the basin. The rocks of the Triassic Lowlands are mainly siliciclastic and extend south from the area of Gettysburg, Pa., to the west of Washington, D.C., through Maryland and Virginia. Ground-water samples from these rocks contained radon activities comparable to those measured in samples from the primarily granitic rocks of the Piedmont (figs. 26, 27).

Ground-water radon activities in the Valley and Ridge are generally very low. The Valley and Ridge covers most of the basin from the area of western Maryland through eastern West Virginia and is underlain primarily by siliciclastic rocks. Unlike samples from the siliciclastic rocks of the Triassic Lowlands, however, samples from these rocks typically contained very little radon (figs. 26, 27).

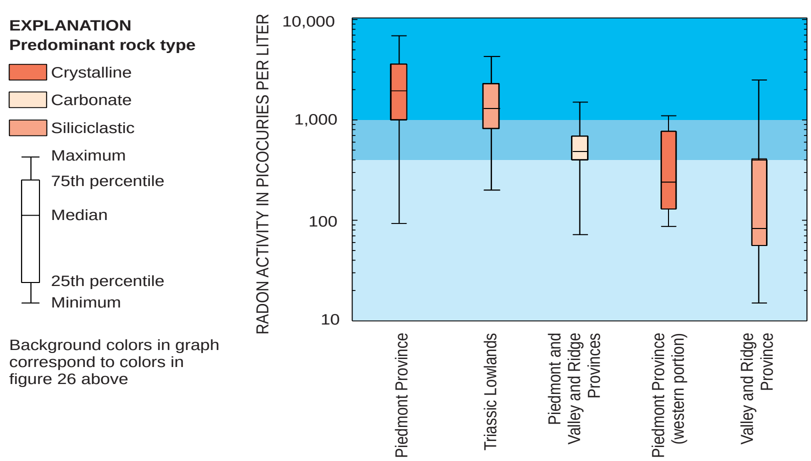


Figure 27. Radon activities in ground water vary widely within each sampled area of the Potomac River Basin but are generally higher in sampled areas of the Piedmont Province than in those underlain by carbonate rocks (modified from Lindsey and Ator, 1996).

[6]Amounts of radioactive elements (such as radon) are often reported in terms of activities rather than concentrations.

The quality of water in aquifers and streams of the Potomac River Basin likely will continue to be stressed by population growth and associated pressures well into the 21st century. Basin population will increase by an estimated 19 percent to 6.2 million between the years 2000 and 2020 (Carlton Haywood, Interstate Commission on the Potomac River Basin, oral commun., 1998). Analysis of data collected by the NAWQA Program suggests that, although water quality in the basin is improving in some respects, water managers will continue to wrestle with several long-term water-quality problems while addressing the pressures and consequences of population growth and associated land-use changes.

Despite an estimated 44 percent increase in population in the Potomac River Basin from 1970 to 1990, total phosphorus concentrations in the Potomac River at Washington, D.C., have decreased since 1979, and nitrogen concentrations have apparently stabilized (fig. 28). Large-scale water-quality-management practices such as improving municipal wastewater-treatment facilities and widespread implementation of phosphate-detergent bans and agricultural best-management practices (BMPs) are apparently working effectively to curb nutrient concentrations in the Potomac River.

Different forms of nitrogen show conflicting patterns in long-term trends in the Potomac River at Washington, D.C., which complicates the forecasting of trends in nutrient concentrations (fig. 28). Improved treatment of municipal wastewater is likely to decrease discharges of both ammonia and organic nitrogen significantly but increase nitrate discharge to streams. Agricultural BMPs that minimize field runoff and increase infiltration to ground water may cause similar nitrate increases in surface water by diverting nitrogen through the ground-water system prior to its discharging to streams. These practices may delay the movement of nitrogen to streams by years or even decades (Focazio and others, in press) as well as increase contamination of ground water by nitrogen and other agricultural chemicals. Much of the ground water underlying agricultural lands in the Potomac River Basin already contains elevated concentrations of nitrate and detectable concentrations of herbicides; and small streams at base flow contain concentrations of nitrate and pesticides similar to those found in ground water. At this point, it is impossible to predict the long-term effect(s) that BMPs may have on ground-water quality or resulting effects on the Potomac River and its tributaries.

Contamination by pesticides and industrial compounds will likely persist in the Potomac River Basin for years to come. Chlordane and DDT, two long-banned insecticides, were detected in tissues and sediment and will likely remain present at low concentrations in urban and suburban areas for the foreseeable future. Mercury and PCBs will likely continue to be carried downstream in sediments of the Shenandoah River from their industrial sources until the reservoir of the contaminants is depleted. Many newly developed pesticides and industrial compounds are being released into the environment. The occurrence of these compounds can be tracked only with continued monitoring initiatives.

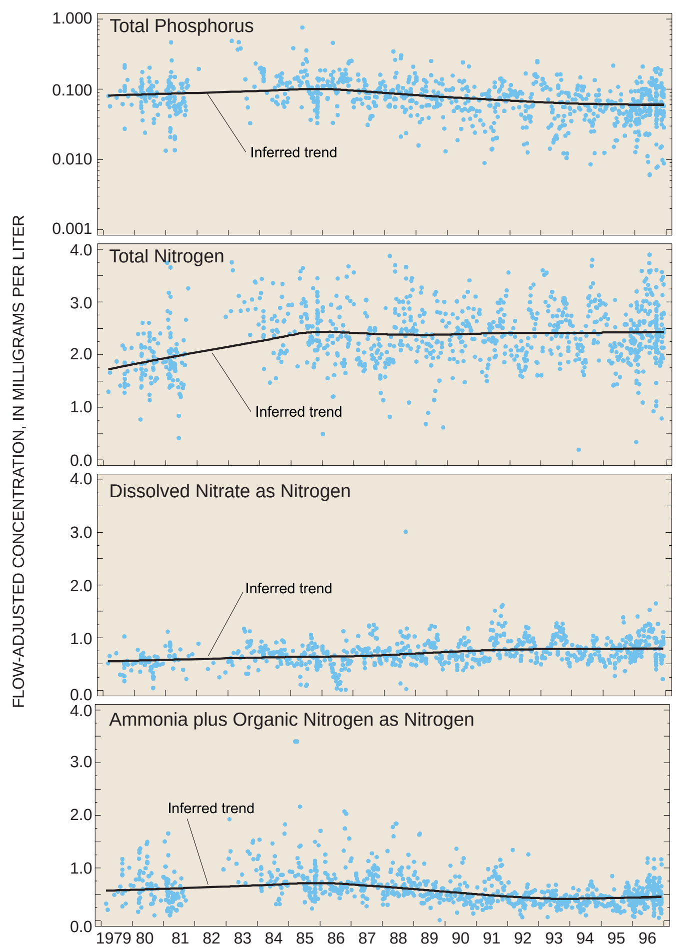


Figure 28. Flow-adjusted nutrient concentrations in the Potomac River at Washington, D.C., 1979-96. Total phosphorus concentrations have decreased over this period. Recent trends in nitrogen concentrations are more complicated; ammonia plus organic nitrogen concentrations have decreased, whereas nitrate concentrations have increased, resulting in apparently stable total nitrogen concentrations since about 1985

Seven major water-quality characteristics were evaluated for selected stream sites in each NAWQA Study Unit. Summary scores for each characteristic were computed for all sites that had adequate data. Scores for each routine monitoring site in the Potomac River Basin (fig. 29) were compared with scores for all sites sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water, and semivolatile organic compounds, organochlorine pesticides, and PCBs in sediment. (Methods used to compute rankings and evaluate aquatic-life criteria are described by Gilliom and others, in press.)

EXPLANATION

Ranking of stream quality relative to all NAWQA stream sites - Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more aquatic life criteria were exceeded.

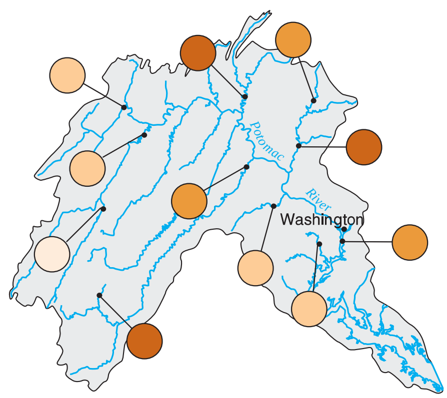
Greater than the 75th percentile (among the highest 25 percent of NAWQA stream sites)

Between the median and the 75th percentile

Between the 25th percentile and the median

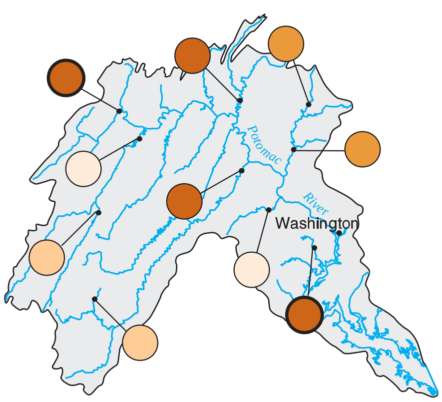
Less than the 25th percentile (among the lowest 25 percent of NAWQA stream sites)

NUTRIENTS in water



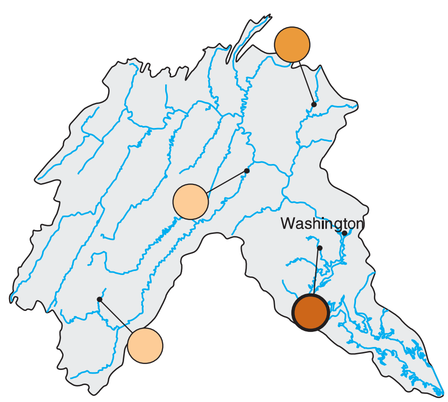
Among sites at which long-term data were collected, nutrient concentrations in the Potomac River Basin were consistently highest in streams draining mostly agricultural areas, particularly in Conococheague and Muddy Creeks and the Shenandoah River, which drain areas underlain by carbonate rocks. Nutrient concentrations in these streams and the Monocacy River ranked among the highest in the Nation, although no applicable criteria for the protection of aquatic life were exceeded.

ORGANOCHLORINE PESTICIDES and PCBs in streambed sediment and aquatic tissues



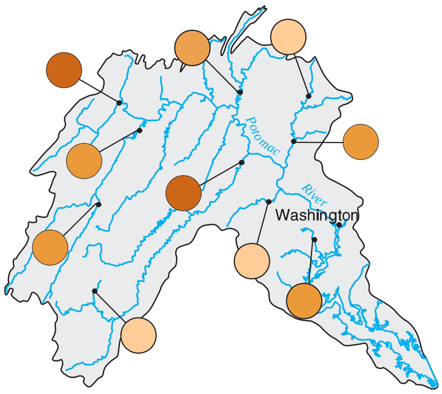
PCBs or organochlorine pesticides were detected in streambed sediment or aquatic tissues at all sampled sites and the levels of these compounds at four sites rank among the highest in the Nation. Chlordane concentrations in streambed sediment at sites on the North Branch Potomac River and Accotink Creek exceeded threshold levels that indicate a potential to cause adverse effects on aquatic organisms. Further sampling would be necessary to determine possible dangers of consuming fish from these sites (for more information, see pages 16-19).

PESTICIDES in water



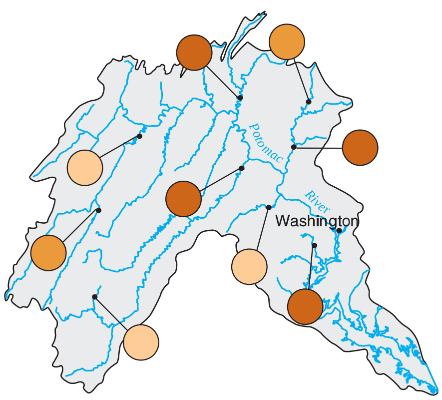
Accotink Creek, which drains a small urban basin near Washington, D.C., had the highest concentrations of pesticides measured in the Potomac River Basin and ranked among the highest observed, nationwide. Agricultural basins (particularly cropped) also contribute relatively large amounts of pesticides to the Potomac River, but less so than Accotink Creek. Concentrations of pesticides at these sites are similar to many sites across the Nation. Similar concentrations of herbicides were detected among agricultural and urban sites, but insecticide concentrations were higher at the urban site. Aquatic-life criteria were exceeded only in Accotink Creek.

TRACE ELEMENTS in streambed sediment



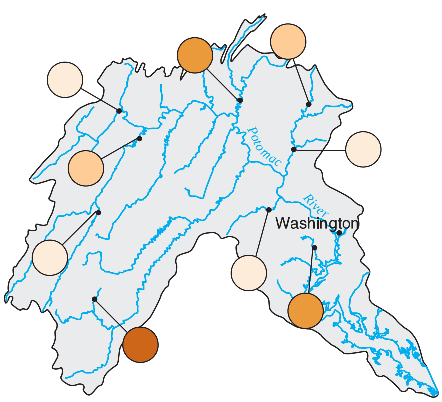
Trace element concentrations in streambed sediment were among highest in the Nation at two of ten sampled sites in the Potomac River Basin. Relatively high concentrations of mercury and zinc were detected in the North Branch Potomac River at Cumberland, Md. This site drains a coal-mining region as well as nearby urban and industrial land. Mercury concentrations in the Shenandoah River at Millville, W. Va., were greater than seven times the National median (for more information, see page 18).

SEMIVOLATILE ORGANIC COMPOUNDS in streambed sediment



Concentrations of semivolatile organic compounds (SVOCs) in streambed sediment were among the highest in the Nation at four sites in the Potomac River Basin. Two of these sites are near urban areas and the others, the Shenandoah River and Conococheague Creek, drain mixed urban and agricultural areas. Criteria for the protection of aquatic life were not exceeded.

FISH COMMUNITY DEGRADATION



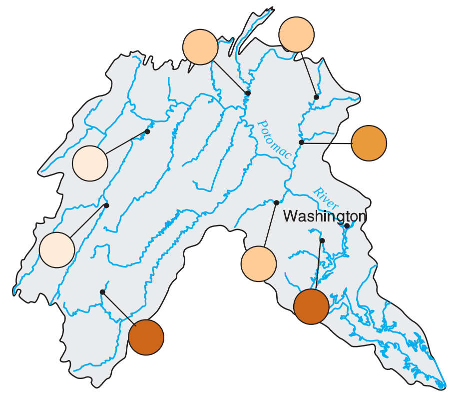
Of nine sites in the Potomac River Basin at which fish communities were analyzed, only Muddy Creek, in an agricultural setting, was highly degraded relative to sites nationwide. A high percentage of fish found at this site are pollution tolerant. Fish communities at two other sites were degraded to a lesser degree but were also among the most degraded in the Nation. One of these sites, Conococheague Creek, drains an agricultural area and the other, Accotink Creek, drains an urban area near Washington, D.C.

CONCLUSIONS

Elevated concentrations of nutrients and pesticides in streams of the Potomac River Basin are among the highest in the Nation at several sites and are generally related to agricultural or urban land in the contributing watersheds. Stream habitat and fish communities are also most degraded in streams draining intensively agricultural or urban areas.

Concentrations of PCBs, organochlorines, trace elements, and SVOCs in streambed sediment or aquatic tissues at several sites are also among the highest measured by the NAWQA Program. The most affected streams, including the North Branch Potomac, Shenandoah, and Monocacy Rivers, as well as Accotink Creek, typically drain intensely agricultural or urban areas. Criteria for the protection of aquatic life were exceeded at some of these sites.

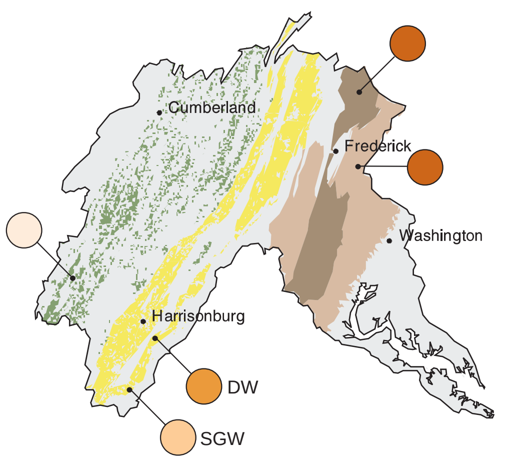
STREAM HABITAT DEGRADATION



Stream habitats at Muddy and Accotink Creeks were among the most degraded in the Nation. A majority of sites in the Potomac River Basin at which stream habitats were assessed exhibited moderate to high habitat degradation with typically lower bank stability, increased bank erosion, and lower densities of riparian vegetation than at less degraded sites.

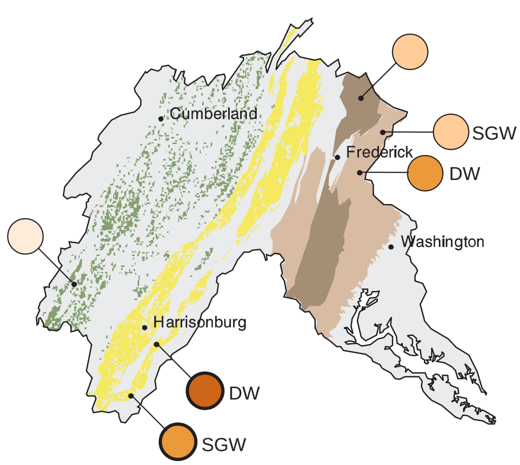
Five major water-quality characteristics were evaluated for ground-water studies in each NAWQA Study Unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that had adequate data. Scores for each aquifer and shallow ground-water area in the Potomac River Basin were compared with scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer also are compared to established drinking-water standards and criteria for protection of human health. (Methods used to compute rankings and evaluate standards and criteria are described by Gilliom and others, in press.)

RADON



The occurrence of radon in ground water is dependent on a number of geologic and hydrologic factors, especially bedrock composition. Ground-water radon levels in the crystalline and siliciclastic rocks of the Piedmont and Triassic Lowlands in the eastern part of the basin are among the highest observed nationwide. Radon activities in carbonate rocks of the Great Valley are also relatively high, but activities in the western part of the Valley and Ridge are among the lowest in the Nation.

NITRATE



Nitrate concentrations in ground water in carbonate rocks underlying agricultural areas of the basin are among the highest in the Nation; nearly 25 percent of samples contained nitrate at concentrations exceeding the Federal drinking-water standard. Nitrate concentrations in the Piedmont area of the basin are also relatively high compared to other drinking-water sources across the Nation, although no samples exceeded the drinking-water standard. Nitrate concentrations in the Triassic Lowlands and under agricultural lands in the Valley and Ridge are relatively low.

EXPLANATION

Shallow drinking-water aquifers

- Great Valley Carbonate, agricultural areas
- Valley and Ridge, agricultural areas
- Piedmont
- Triassic Lowlands

Ranking of ground-water quality relative to all NAWQA ground-water studies —

DW indicates ranking compared to drinking-water aquifers (only), nationwide

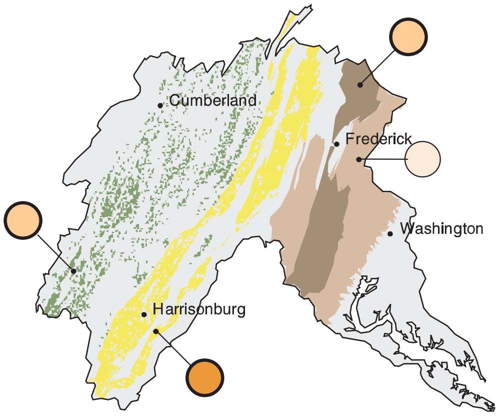
SGW indicates ranking compared to shallow ground-water (only), nationwide

No label indicates comparison to DW and SGW

Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more standards or criteria were exceeded.

- **Greater than the 75th percentile** (among the highest 25 percent of NAWQA ground-water studies)
- **Between the median and the 75th percentile**
- **Between the 25th percentile and the median**
- **Less than the 25th percentile** (among the lowest 25 percent of NAWQA ground-water studies)

DISSOLVED SOLIDS



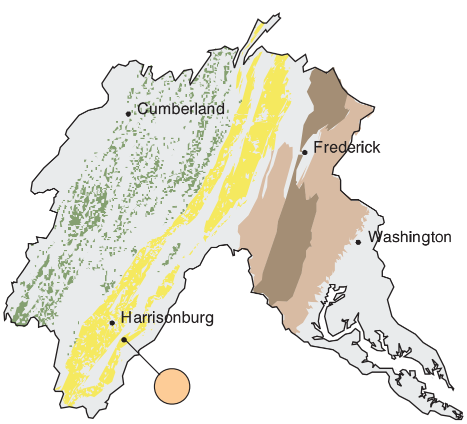
Concentrations of dissolved solids in ground water in carbonate aquifers underlying agricultural areas of the basin are among the highest in the Nation; 10 percent of samples exceeded the Federal drinking-water standard. Dissolved solids concentrations in other sampled areas of the Potomac River Basin are generally lower, although the drinking-water standard was exceeded in 14 percent of the samples from the Triassic Lowlands and 4 percent from the Valley and Ridge.

CONCLUSIONS

In general, the presence of pesticides, nitrate, and dissolved solids in ground water is related to agricultural land use—particularly in areas underlain by carbonate rocks. Potential urban sources of nitrate, pesticides, and VOCs were not investigated.

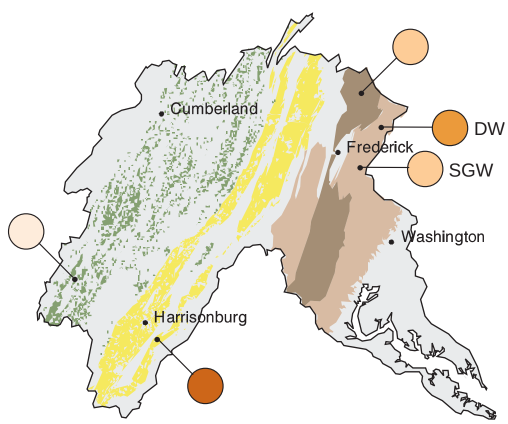
Radon occurrence in ground water is related to rock type. Igneous and metamorphic rocks of granitic composition (and sedimentary rocks derived from granitic rocks) tend to contain more uranium (Faure, 1986) and, therefore, higher activities of radon than rocks of other types. Uranium is often concentrated in carbonate rocks as well.

VOLATILE ORGANIC COMPOUNDS



Concentrations of volatile organic compounds (VOCs) in agricultural areas of the Great Valley are among the lowest in the Nation. Only 6 percent of the samples contained detectable VOCs, and no Federal drinking-water standards were exceeded. No other area of the Potomac River Basin was sampled for VOCs as part of the NAWQA Program.

PESTICIDES



Pesticide concentrations in agricultural areas of the Great Valley Carbonate are among the highest in the Nation; 85 percent of samples contained detectable pesticides. Ground water in the Piedmont also contains relatively high levels of pesticides. By contrast, pesticides were detected in only 12 percent of wells in agricultural areas of the Valley and Ridge.

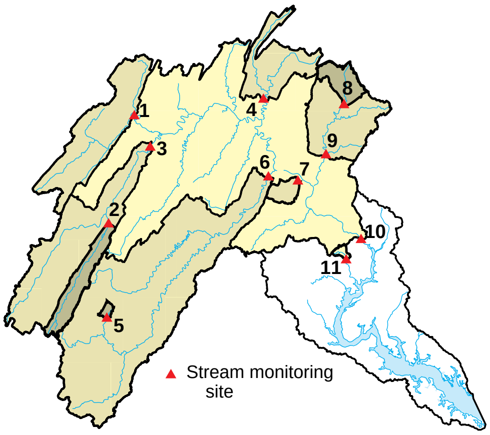


Figure 29. Stream chemistry was monitored at 11 sites in the basin (see table 5). Of these sites, four (sites 5, 6, 8, and 11) were also monitored more intensively for pesticides, and two (sites 5 and 11) were monitored more intensively for ecology.

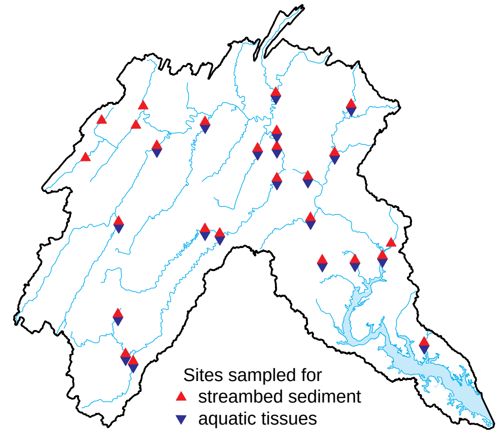
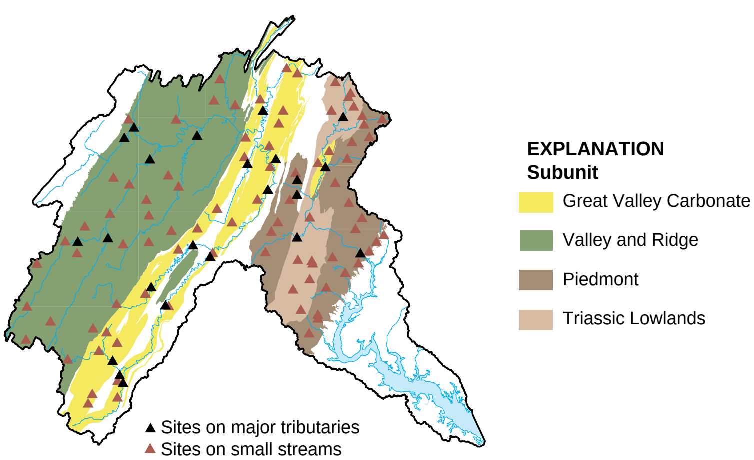


Figure 30. Streambed sediment was sampled at 26 sites in the basin. Of these sites, 21 were also sampled for aquatic tissues (Asiatic clams or yellow bullhead).

Table 5. Basic surface-water monitoring sites in the Potomac River Basin

Number (see fig. 29)	Name	Drainage area (square miles)	Principal land use(s)
1	North Branch Potomac River near Cumberland, Md.	875	Forested
2	South Fork South Branch Potomac River near Moorefield, W. Va.	283	Forested, agricultural
3	South Branch Potomac River near Springfield, W. Va.	1,470	Forested, agricultural
4	Conococheague Creek at Fairview, Md.	494	Agricultural
5	Muddy Creek at Mount Clinton, Va.	14.2	Agricultural
6	Shenandoah River at Millville, W. Va.	3,040	Agricultural
7	Catoctin Creek at Taylorstown, Va.	89.6	Forested
8	Monocacy River at Bridgeport, Md.	173	Agricultural
9	Monocacy River near Frederick, Md.	817	Agricultural
10	Potomac River at Chain Bridge at Washington, D.C.	11,600	Forested, agricultural
11	Accotink Creek near Annandale, Va.	23.5	Urban



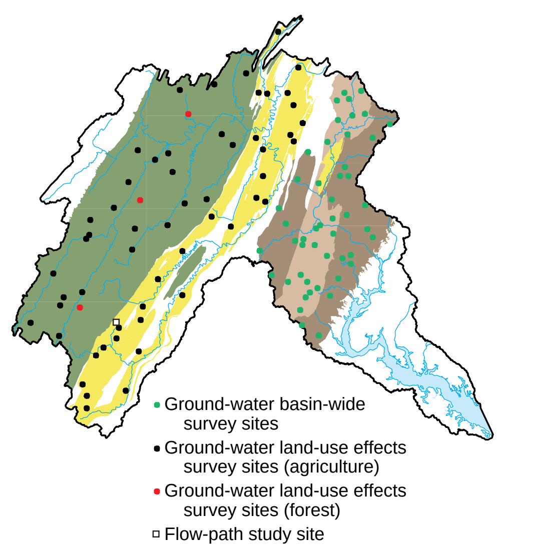


Figure 31. Stream-chemistry and ecological studies were done at 89 small streams in four subunits of the basin. A synoptic study of water chemistry was also done at 23 larger streams throughout the basin.

Figure 32. Ground-water samples were collected at 48 sites in two subunits and at 57 sites in specific land uses in two other subunits. Multiple samples were collected from ground water and streams at a small-scale flow-path study site.

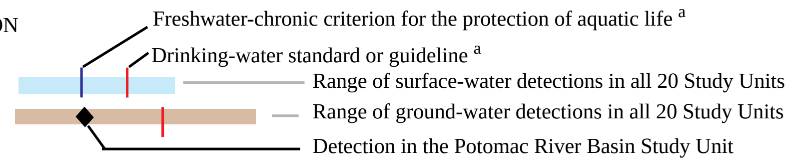
Study component[1]	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream chemistry				
Streambed-sediment survey	Concentrations of trace elements and organic compounds in sediment were measured to determine their occurrence and spatial distribution in sediments in streams of the basin.	Depositional zones of the Potomac River and selected tributaries.	22 4 (see fig. 30)	1 (in 1992) 1 (in 1996)
Basic sites	Concentrations of major ions, suspended sediment, organic carbon, and nutrients were measured in water samples collected monthly and during selected high flows to describe the occurrence of those compounds in streams over time.	Streams of the basin, at or near sites where streamflow is measured continuously.	11 (see fig. 29, table 5)	About 14 samples per year, (1993-95)
Intensive sites	Concentrations of pesticides were measured in water samples collected during selected high flows and weekly during a growing season to determine the timing of transportation of such compounds to streams.	Subset of basic sites, including streams draining predominantly agricultural or urban areas.	4 (see fig. 29, table 5)	About 24 samples per year, (1993-95)
Synoptic study of major tributaries	Concentrations of major ions, nutrients, pesticides, and suspended sediment were measured in water samples collected during stable, intermediate flow to relate the occurrence and spatial distribution of those chemical compounds to potential sources in contributing watersheds.	Selected tributaries of the Potomac River draining watersheds of greater than about 100 square miles.	23 (see fig. 31)	1 (in 1994)
Synoptic studies of small streams	Concentrations of nutrients, pesticides, suspended sediment, and major ions were measured in water samples collected during low flows to determine the occurrence and spatial distribution of those compounds in streams across the basin and relate the stream chemistry to land use and other watershed characteristics.	Small streams draining watersheds of less than 37 square miles.	25 39 25 (see fig. 31)	1 (in 1993) 1 (in 1994) 1 (in 1995)
Stream ecology				
Contaminants in aquatic tissues	Concentrations of organic compounds in whole fishes and clams and concentrations of trace metals in fish livers and clams were measured to determine the occurrence and spatial distribution of metals and organic compounds that can accumulate in aquatic tissues.	Subset of streambed-sediment-survey sites.	17 4 (see fig. 30)	1 (in 1992) 1 (in 1996)
Intensive ecological assessments	Fish, macroinvertebrates, and algae were identified and counted and quantitative assessments of stream habitat were conducted to determine the variability of biological communities and habitat representing primary ecological regions of the basin on a small scale.	Subset of intensive sites.	2 (see fig. 29, table 5)	1 reach per site per year, (1993-95)
Ecological synoptic studies	Fish, macroinvertebrates, and algae were identified and counted and quantitative assessements of stream habitat were conducted to determine the habitat and community structure of aquatic species in representative streams across the basin.	Sites sampled during synoptic studies of small streams.	25 39 25 (see fig. 31)	1 (in 1993) 1 (in 1994) 1 (in 1995)
Ground-water chemistry				
Basin-wide survey	Concentrations of nutrients, pesticides, organic carbon, radon, uranium, tritium, and major ions were measured in water samples to describe the chemistry of ground water in the Piedmont and Triassic Lowlands (fig. 3).	Randomly selected subset of previously existing shallow (mostly less than 300 feet deep) wells.	48 (see fig. 32)	1 (in 1994)
Land-use effects survey	Concentrations of nutrients, pesticides, organic carbon, radon, uranium, tritium, and major ions were measured in water samples to describe the chemistry of ground water within particular land-use settings and relate the differences in ground-water chemistry to natural and human factors.	Randomly selected subset of previously existing shallow (mostly less than 300 feet deep) wells within agricultural or forested areas.	54 (agriculture) 3 (forest) (see fig. 32)	1 (29 in 1993) 1 (25 in 1995) 1 (3 in 1995)
Flow-path study	Concentrations of nutrients, pesticides, organic carbon, radon, uranium, tritium, and major ions were measured in water samples to relate their occurrence and distribution on a small scale to land use and other factors and evaluate their transport from the land surface to ground water and from ground water to streams.	Streams and shallow (mostly less than 50 feet deep) wells installed along an approximate line of ground-water flow within a small (less than 2 square miles) watershed.	29 (see fig. 32)	1 - 10 (1993–1995)

[1]Gerhart and Brakebill, 1997; Gilliom and others, 1995.

The following tables summarize data collected for NAWQA studies from 1992-95 by showing results for the Potomac River Basin Study Unit compared to the NAWQA national range for each compound detected. The data were collected at a wide variety of places and times. In order to represent the wide concentration ranges observed among Study Units, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1,000), rather than the precise number. The complete data set used to construct these tables is available upon request.

Concentrations of herbicides, insecticides, volatile organic compounds, and nutrients detected in ground and surface waters of the Potomac River Basin Study Unit. [mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; %, percent; <, less than; - -, not measured; trade names may vary and are used for identification purposes only]

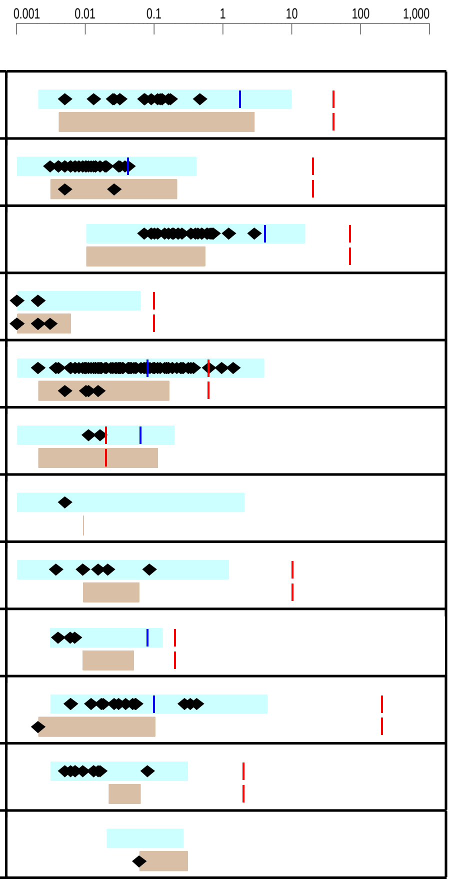
EXPLANATION



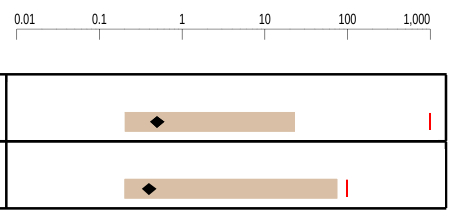
Herbicide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.001, 0.01, 0.1, 1, 10, 100, 1,000)
Acetochlor	11% 0%	
Alachlor (Lasso)	18% 0%	
2,6-Diethylaniline (Alachlor metabolite)	<1% 0%	
Atrazine (AAtrex, Gesaprim)	76% 46%	
Deethylatrazine[c] (Atrazine metabolite)	62% 41%	
Benfluralin (Balan, Benefin, Bonalan)	1% 0%	
Butylate (Sutan, Genate Plus, butilate)	<1% 0%	
Cyanazine (Bladex, Fortrol)	21% 0%	
DCPA (Dacthal, chlorthal-dimethyl)	1% <1%	
Dicamba (Banvel, Mediben, dianat)	0% 1%	
Dichlorprop (2,4-DP, Seritox 50, Kildip)	1% 0%	
Diuron (Karmex, Direx, DCMU)	14% 0%	
EPTC (Eptam)	1% <1%	
Linuron (Lorox, Linex, Sarclex)	9% 0%	
MCPA (Agritox, Agroxone)	2% 0%	
Metolachlor (Dual, Pennant)	66% 17%	
Metribuzin (Lexone, Sencor)	9% 2%	
Napropamide (Devrinol)	<1% 0%	
Oryzalin (Surflan, Dirimal, Ryzelan)	6% 0%	
Pebulate (Tillam)	0% <1%	
Pendimethalin (Prowl, Stomp)	13% 0%	
Prometon (Gesagram, prometone)	59% 7%	
Propachlor (Ramrod, propachlore)	<1% 0%	
Simazine (Aquazine, Princep, Gesatop)	79% 38%	
Tebuthiuron (Spike, Perflan)	7% 4%	
Terbacil[c] (Sinbar)	4% <1%	
Triclopyr (Garlon, Grazon, Crossbow)	4% 0%	
Trifluralin (Treflan, Trinin, Elancolan)	<1% <1%	

Insecticide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.001, 0.01, 0.1, 1, 10, 100, 1,000)
Azinphos-methyl[c] (Guthion, Gusathion)	3% 0%	
Carbaryl[c] (Sevin, Savit)	24% 0%	

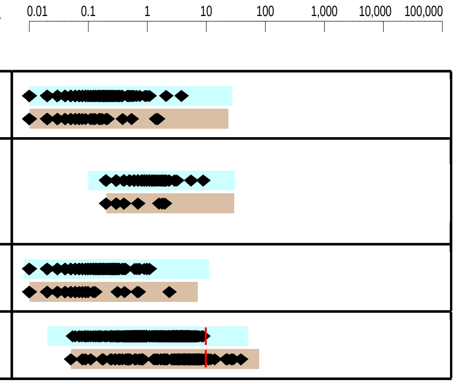
Insecticide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
Carbofuran[c] (Furadan, Curaterr)	5% 0%	
Chlorpyrifos (Dursban, Lorsban)	8% <1%	
2,4-D (2,4-PA)	20% 0%	
p,p'-DDE (*p,p'*-DDT metabolite)	<1% <1%	
Diazinon	24% 1%	
Dieldrin (Panoram D-31, Octalox)	1% 0%	
Ethoprop (Mocap, Prophos)	<1% 0%	
Fonofos (Dyfonate)	1% 0%	
gamma-HCH	<1% 0%	
Malathion (maldison, malathon, Cythion)	4% <1%	
Methyl parathion (Penncap-M)	2% 0%	
Propoxur (Baygon, Blattanex, Unden)	0% 1%	



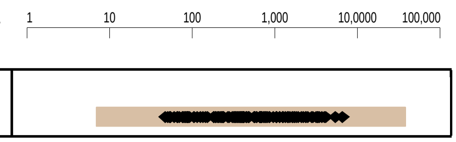
Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
Methylbenzene (Toluene)	- - 6%	
total Trihalomethanes	- - 6%	



Nutrient (Trade or common name)	Rate of detection [b]	Concentration, in mg/L
Dissolved ammonia	87% 88%	
Dissolved ammonia plus organic nitrogen as nitrogen	77% 10%	
Dissolved phosphorus as phosphorus	86% 52%	
Dissolved nitrite plus nitrate	99% 74%	



Other	Rate of detection [b]	Concentration, in pCi/L
Radon 222	- - 99%	



Herbicides, insecticides, volatile organic compounds, and nutrients not detected in ground and surface waters of the Potomac River Basin Study Unit.

Herbicides

2,4,5-T

2,4,5-TP (Silvex, Fenoprop)

2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone)

Acifluorfen (Blazer, Tackle 2S)

Bentazon (Basagran, Bentazone, Bendioxide)

Bromacil (Hyvar X, Urox B, Bromax)

Bromoxynil (Buctril, Brominal)

Chloramben (Amiben, Amilon-WP, Vegiben)

Clopyralid (Stinger, Lontrel, Reclaim, Transline)

Dacthal mono-acid (Dacthal metabolite)

Dinoseb (Dinosebe)

Ethalfluralin (Sonalan, Curbit)

Fenuron (Fenulon, Fenidim)

Fluometuron (Flo-Met, Cotoran, Cottonex, Meturon)

MCPB (Thistrol)

Molinate (Ordram)

Neburon (Neburea, Neburyl, Noruben)

Norflurazon (Evital, Predict, Solicam, Zorial)

Picloram (Grazon, Tordon)

Pronamide (Kerb, Propyzamid)

Propanil (Stam, Stampede, Wham, Surcopur, Prop-Job)

Propham (Tuberite)

Thiobencarb (Bolero, Saturn, Benthiocarb, Abolish)

Triallate (Far-Go, Avadex BW, Tri-allate)

Insecticides

3-Hydroxycarbofuran (Carbofuran metabolite)

Aldicarb sulfone (Standak, aldoxycarb, aldicarb metabolite)

Aldicarb sulfoxide (Aldicarb metabolite)

Aldicarb (Temik, Ambush, Pounce)

Disulfoton (Disyston, Di-Syston, Frumin AL, Solvirex, Ethylthiodemeton)

Methiocarb (Slug-Geta, Grandslam, Mesurol)

Methomyl (Lanox, Lannate, Acinate)

Oxamyl (Vydate L, Pratt)

Parathion (Roethyl-P, Alkron, Panthion, Phoskil)

Phorate (Thimet, Granutox, Geomet, Rampart)

Propargite (Comite, Omite, Ornamite)

Terbufos (Contraven, Counter, Pilarfox)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

cis-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

Volatile organic compounds

1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA)

1,1,1-Trichloroethane (Methylchloroform)

1,1,2,2-Tetrachloroethane

1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113)

1,1,2-Trichloroethane (Vinyl trichloride)

1,1-Dichloroethane (Ethylidene dichloride)

1,1-Dichloroethene (Vinylidene chloride)

1,1-Dichloropropene

1,2,3-Trichlorobenzene (1,2,3-TCB)

1,2,3-Trichloropropane (Allyl trichloride)

1,2,4-Trichlorobenzene

1,2,4-Trimethylbenzene (Pseudocumene)

1,2-Dibromo-3-chloropropane (DBCP, Nemagon)

1,2-Dibromoethane (EDB, Ethylene dibromide)

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,2-Dichloroethane (Ethylene dichloride)

1,2-Dichloropropane (Propylene dichloride)

1,3,5-Trimethylbenzene (Mesitylene)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,3-Dichloropropane (Trimethylene dichloride)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

1-Chloro-2-methylbenzene (*o*-Chlorotoluene)

1-Chloro-4-methylbenzene (*p*-Chlorotoluene)

2,2-Dichloropropane

Benzene

Bromobenzene (Phenyl bromide)

Bromochloromethane (Methylene chlorobromide)

Bromomethane (Methyl bromide)

Chlorobenzene (Monochlorobenzene)

Chloroethane (Ethyl chloride)

Chloroethene (Vinyl Chloride)

Chloromethane (Methyl chloride)

Dibromomethane (Methylene dibromide)

Dichlorodifluoromethane (CFC 12, Freon 12)

Dichloromethane (Methylene chloride)

Dimethylbenzenes (Xylenes (total))

Ethenylbenzene (Styrene)

Ethylbenzene (Phenylethane)

Hexachlorobutadiene

Isopropylbenzene (Cumene)

Methyl *tert*-butyl ether (MTBE)

Naphthalene

Tetrachloroethene (Perchloroethene)

Tetrachloromethane (Carbon tetrachloride)

Trichloroethene (TCE)

Trichlorofluoromethane (CFC 11, Freon 11)

cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)

cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)

n-Butylbenzene (1-Phenylbutane)

n-Propylbenzene (Isocumene)

p-Isopropyltoluene (*p*-Cymene)

sec-Butylbenzene

tert-Butylbenzene

trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)

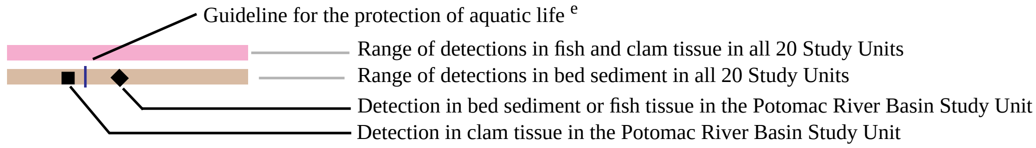
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)

Nutrients

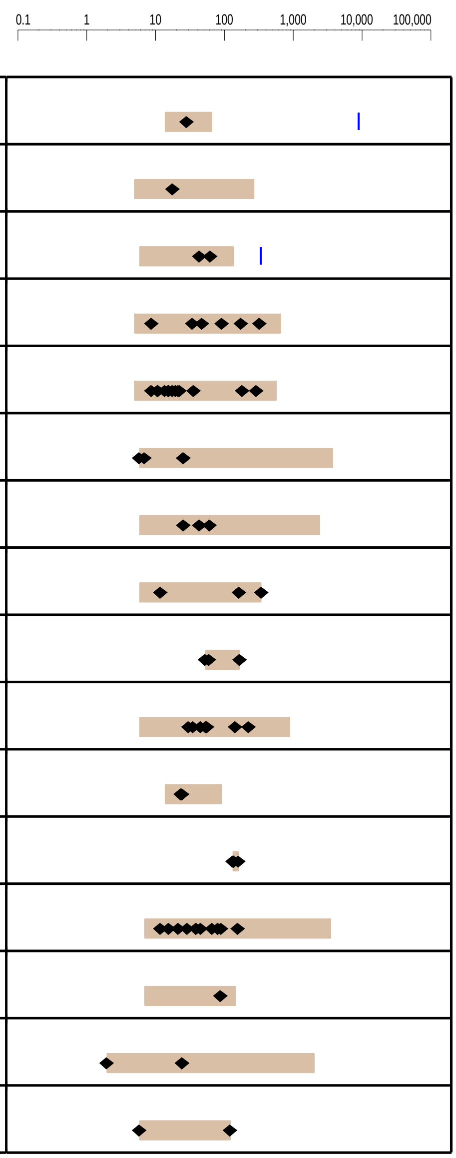
No non-detects

Concentrations of semivolatile organic compounds, organochlorine compounds, and trace elements detected in fish and clam tissue and bed sediment of the Potomac River Basin Study Unit. [µg/g, micrograms per gram; µg/kg, micrograms per kilogram; %, percent; <, less than; - -, not measured; trade names may vary]

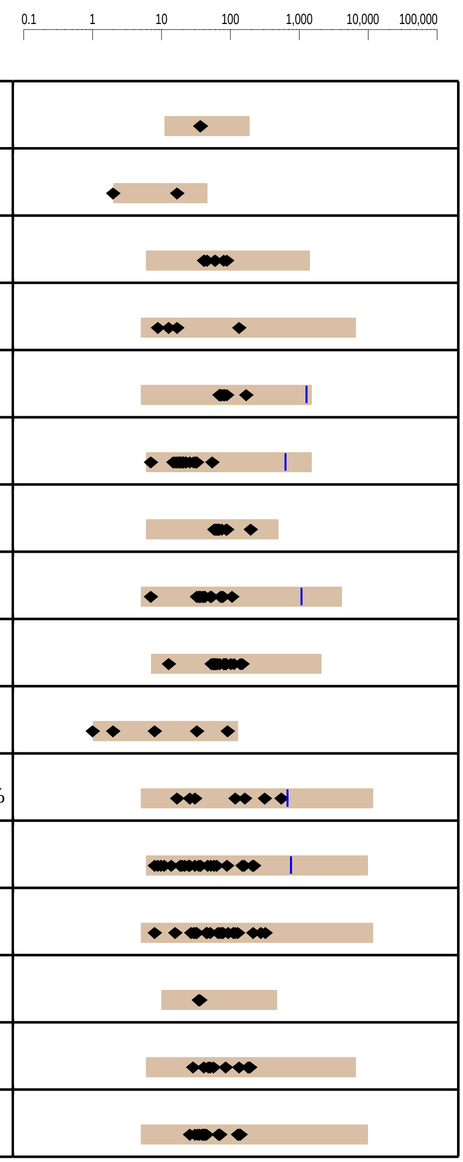
EXPLANATION



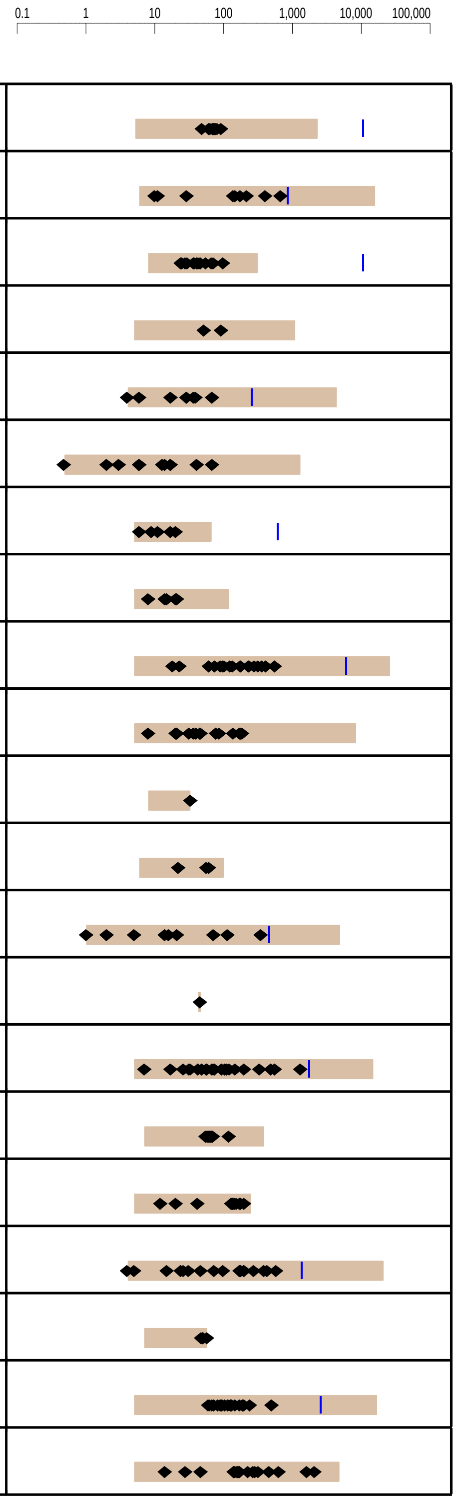
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
1,2,4-Trichlorobenzene	- - 20%	
1,2-Dimethylnaphthalene	- - 20%	
1,4-Dichlorobenzene	- - 33%	
1,6-Dimethylnaphthalene	- - 67%	
1-Methyl-9H-fluorene	- - 85%	
1-Methylphenanthrene	- - 80%	
1-Methylpyrene	- - 60%	
2,3,6-Trimethylnaphthalene	- - 43%	
2,4-Dinitrotoluene	- - 43%	
2,6-Dimethylnaphthalene	- - 100%	
2,6-Dinitrotoluene	- - 33%	
2-Chlorophenol	- - 50%	
2-Methylanthracene	- - 73%	
3,5-Dimethylphenol	- - 20%	
4,5-Methylenephenanthrene	- - 60%	
4-Bromophenyl-phenylether	- - 33%	



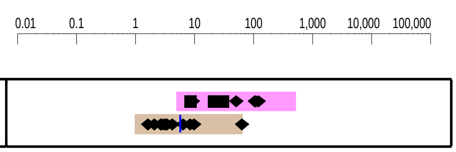
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
4-Chloro-3-methylphenol	- - 33%	
4-Chlorophenyl-phenylether	- - 33%	
9H-Carbazole	- - 75%	
9H-Fluorene	- - 67%	
Acenaphthene	- - 78%	
Acenaphthylene	- - 91%	
Acridine	- - 78%	
Anthracene	- - 90%	
Anthraquinone	- - 91%	
Azobenzene	- - 56%	
Benz[*a*]anthracene	- - 100%	
Benzo[*a*]pyrene	- - 96%	
Benzo[*b*]fluoranthene	- - 95%	
Benzo[*c*]cinnoline	- - 56%	
Benzo[*ghi*]perylene	- - 71%	
Benzo[*k*]fluoranthene	- - 95%	



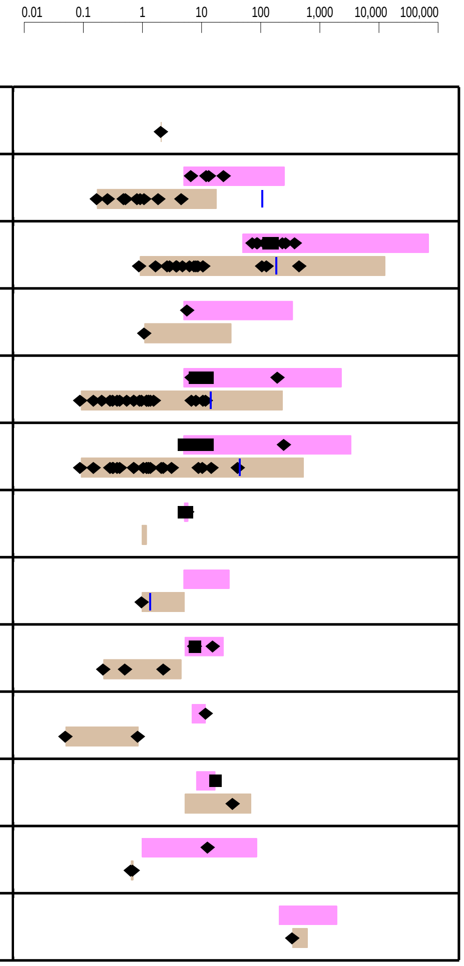
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
Butylbenzylphthalate	- - 86%	
Chrysene	- - 100%	
Di- *n* -butylphthalate	- - 100%	
Di- *n* -octylphthalate	- - 40%	
Dibenz[*a,h*] anthracene	- - 67%	
Dibenzothiophene	- - 80%	
Diethylphthalate	- - 100%	
Dimethylphthalate	- - 67%	
Fluoranthene	- - 100%	
Indeno[1,2,3- *cd*] pyrene	- - 82%	
Isophorone	- - 20%	
Isoquinoline	- - 50%	
Naphthalene	- - 69%	
N-Nitrosodi- *n* -propylamine	- - 20%	
Phenanthrene	- - 96%	
Phenanthridine	- - 81%	
Phenol	- - 94%	
Pyrene	- - 100%	
bis(2-Chloro-ethoxy)methane	- - 56%	
bis(2-Ethyl-hexyl)phthalate	- - 100%	
p-Cresol	- - 95%	



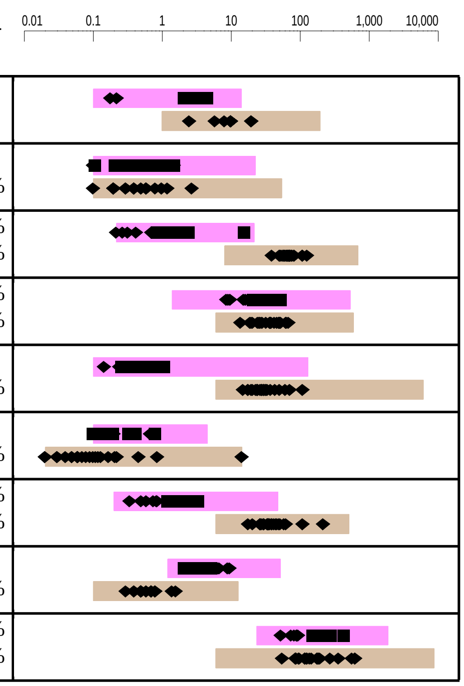
Organochlorine compound (Trade name)	Rate of detection [b]	Concentration, in µg/kg
total-Chlordane	26% 48%	



Organochlorine compound (Trade name)	Rate of detection [b]	Concentration, in µg/kg
Chloroneb (chlor-onebe)	- - 4%	
Dieldrin (Panoram D-31, Octalox)	13% 36%	
PCB, total	39% 68%	
DCPA (dacthal, chlo-rthal-dimethyl)	3% 4%	
p,p'-DDE	16% 88%	
total-DDT	26% 88%	
beta-HCH (*beta*-BHC, *beta*-hexachlo-	10% 0%	
gamma-HCH (lin-dane, *gamma*-BHC)	0% 4%	
Heptachlor epoxide	13% 12%	
Heptachlor (hep-tachlore, Velsicol)	3% 8%	
p,p'-Methoxychlor (Marlate)	3% 4%	
Pentachloroanisole	3% 8%	
Toxaphene (cam-phechlor)	0% 4%	



Trace element	Rate of detection [b]	Concentration, in µg/g
Arsenic	80% 48%	
Cadmium	96% 100%	
Chromium	100% 100%	
Copper	100% 100%	
Lead	72% 100%	
Mercury	56% 100%	
Nickel	100% 100%	
Selenium	96% 100%	
Zinc	100% 100%	



Semivolatile organic compounds, organochlorine compounds, and trace elements not detected in fish and clam tissue and bed sediment of the Potomac River Basin Study Unit.

Semivolatile organic compounds

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

2,2-Biquinoline

2-Chloronaphthalene

2-Ethylnaphthalene

C8-Alkylphenol

N-Nitrosodiphenylamine

Nitrobenzene

Pentachloronitrobenzene

Quinoline

Organochlorine compounds

Aldrin (HHDN, Octalene)

Endosulfan I (*alpha*-Endosulfan, Thiodan, Cyclodan, Beosit, Malix, Thimul, Thifor)

Endrin (Endrine)

Hexachlorobenzene (HCB)

Isodrin (Isodrine, Compound 711)

Mirex (Dechlorane)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

cis-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

delta-HCH (*delta*-BHC, *delta*-hexachlorocyclohexane, *delta*-benzene hexachloride)

o,p'-Methoxychlor

trans-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

Trace elements

No non-detects

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[a] Selected water-quality standards and guidelines (Gilliom and others, in press).

[b] Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by only counting detections equal to or greater than 0.01 µg/L to facilitate equal comparisons among compounds that had varying detection limits; a value of <1% signifies that there were only detection below, or <1% above, the 1µg/L level. Some herbicides and insecticides were not reliably detected as low as the 0.01µg/L level, so frequencies may be underestimated for some compounds. For other compound groups, all detections were counted and detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in all groups are summarized in Gilliom and others (in press).

[c] Detections of these compounds are reliable, but concentrations are determined with greater uncertainty than for the other compounds and are reported as estimated values (Zaugg and others, 1995).

[d] The guideline for methyl *tert*-butyl ether is between 20 and 40 µg/L; if the tentative cancer classification C is accepted, the lifetime health advisory will be 20 µg/L (Gilliom and others, in press).

[e] Selected sediment quality guidelines (Gilliom and others, in press).

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The terms in this glossary were compiled from numerous sources. Some definitions have been modified and may not be the only valid ones for these terms.

Ammonia - A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

Aquifer - A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Basin - *See* Drainage basin.

Bedrock - General term for consolidated (solid) rock that underlies soils or other unconsolidated material.

Bed sediment - The material that temporarily is stationary in the bottom of a stream or other watercourse.

Carbonate rocks - Rocks (such as limestone or dolostone) that are composed primarily of minerals (such as calcite and dolomite) containing the carbonate ion (CO_3^{2-}).

Community - In ecology, the species that interact in a common area.

Concentration - The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as micrograms per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Crystalline rocks - Rocks (igneous or metamorphic) consisting wholly of crystals or fragments of crystals.

Degradation products - Compounds resulting from transformation of an organic substance through chemical, photochemical, and(or) biochemical reactions.

Discharge - Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Dissolved constituent - Operationally defined as a constituent that passes through a 0.45-micrometer filter.

Drainage basin - The portion of the surface of the Earth that contributes water to a stream through overland runoff, including tributaries and impoundments.

Ecosystem - The interacting populations of plants, animals, and microorganisms occupying an area, plus their physical environment.

Evapotranspiration - A collective term that includes water lost through evaporation from the soil and surface-water bodies and by plant transpiration.

FDA action level - A regulatory level recommended by the U.S. Environmental Protection Agency for enforcement by the FDA when pesticide residues occur in food commodities for reasons other than the direct application of the pesticide. Action levels are set for inadvertent pesticide residues resulting from previous legal use or accidental contamination. Applies to edible portions of fish and shellfish in interstate commerce.

Fish community - *See* Community.

Ground water - In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat - The part of the physical environment where plants and animals live.

Health advisory - Nonregulatory levels of contaminants in drinking water that may be used as guidance in the absence of regulatory limits. Advisories consist of estimates of concentrations that would result in no known or anticipated health effects (for carcinogens, a specified cancer risk) determined for a child or for an adult for various exposure periods.

Herbicide - A chemical or other agent applied for the purpose of killing undesirable plants. *See also* Pesticide.

Infiltration - Movement of water, typically downward, into soil or porous rock.

Insecticide - A substance or mixture of substances intended to destroy or repel insects.

Invertebrate - An animal having no backbone or spinal column.

Karst - A type of topography that results from dissolution and collapse of carbonate rocks such as limestone and dolomite and characterized by closed depressions or sinkholes, caves, and underground drainage.

Load - General term that refers to a material or constituent in solution or suspension in transport; usually expressed in terms of mass or volume.

Maximum contaminant level (MCL) - Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCL's are enforceable standards established by the U.S.

Environmental Protection Agency.

Nitrate - An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Nutrient - Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Pesticide - A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents, or other "pests."

Phosphorus - A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Photosynthesis - Synthesis of chemical compounds by organisms with the aid of light. Carbon dioxide is used as raw material for photosynthesis and oxygen is a product.

Physiography - A description of the surface features of the Earth, with an emphasis on the origin of landforms.

Picocurie (pCi) - One trillionth (10^{-12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7 x 10^{10} radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm) or 0.037 dps.

Precipitation - Any or all forms of water particles that fall from the atmosphere, such as rain, snow, hail, and sleet.

Radon - A naturally occurring, colorless, odorless, radioactive gas formed by the disintegration of the element radium; damaging to human lungs when inhaled.

Siliciclastic rocks - Rocks such as shale and sandstone that are formed by the compaction and cementation of quartz-rich mineral grains.

Triazine herbicide - A class of herbicides containing a symmetrical triazine ring (a nitrogen-heterocyclic ring composed of three nitrogens and three carbons in an alternating sequence). Examples include atrazine, propazine, and simazine.

Triazine pesticide - *See* Triazine herbicide.

Uranium - A heavy silvery-white metallic element, highly radioactive and easily oxidized. Of the 14 known isotopes of uranium, ^{238}U is the most abundant in nature.

Watershed - *See* Drainage basin.

Water year - The continuous 12-month period, October 1 through September 30, in U.S. Geological Survey reports dealing with the surface-water supply. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as the “1980” water year.

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