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Water Quality in the New England Coastal Basins

Maine, New Hampshire, Massachusetts, and Rhode Island, 1999–2001

U.S. Department of the Interior
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Circular 1226

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http://water.usgs.gov/nawqa/nawqa_sumr.html

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Front cover: Ipswich River in Autumn (Photograph reprinted from Andrew Borsari, Photographer, and published with permission).
Back cover: Photograph left, sampling the fish community on the Nissitissit River, Brookline, N.H.; Photograph middle, collecting a surface-water sample on the Merrimack River at Lowell, Mass.; Photograph right, measuring water level from a public-supply well in Marion, Mass. (Photographs by K.W. Robinson, B.O. Stock, and S.M. Flanagan, U.S. Geological Survey)

Water Quality in the New England Coastal Basins, Maine, New Hampshire, Massachusetts, and Rhode Island, 1999–2001

By Keith W. Robinson, Sarah M. Flanagan, Joseph D. Ayotte, Kimberly W. Campo, Ann Chalmers, James F. Coles, and Thomas F. Cuffney

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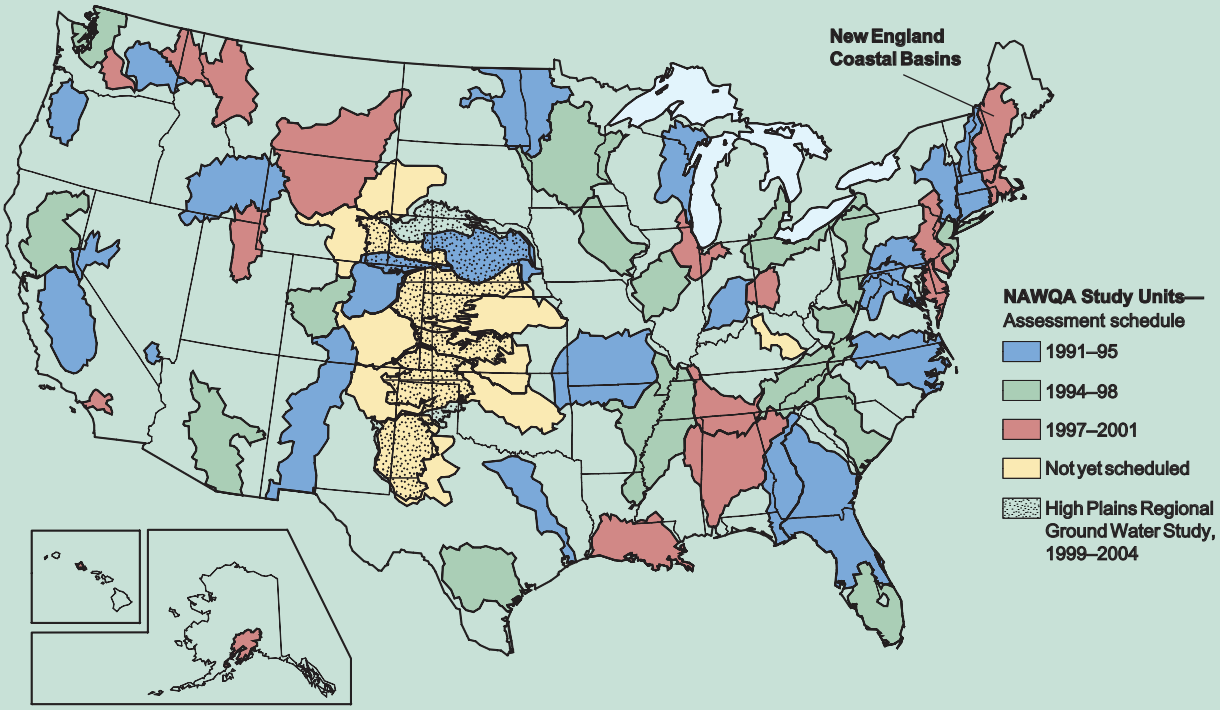
Contents

National Water-Quality Assessment Program

The quality of the Nation's water resources is integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and also suitable for industry, irrigation, and habitat for fish and wildlife. Recognizing the need for long-term, nationwide assessments of water resources, the U.S. Congress has appropriated funds since 1991 for the USGS to conduct the **National Water-Quality Assessment (NAWQA) Program**. Scientists in the NAWQA Program work with partners in government, research, and public interest groups to assess the spatial extent of water-quality conditions, how water quality changes with time, and how human activities and natural factors affect water quality. This information is useful for guiding water-management and protection strategies, research, and monitoring in different hydrologic and land-use settings across the Nation.



The New England Coastal Basins is one of 51 water-quality assessments initiated since 1991. Together, the 51 major river basins and aquifer systems, referred to as "Study Units," include water resources used by more than 60 percent of the population in watersheds that cover about half of the land area of the conterminous United States. Timing of the assessments varies because of the program's rotational design, in which one-third of all Study Units are intensively investigated for 3 to 4 years, with trends assessed every 10 years. As indicated on the map, the New England Coastal Basins is part of the third set of intensive investigations, which began in 1997.

What kind of water-quality information does the NAWQA Program provide?

Water-quality assessments by a single program cannot possibly address all of the Nation's water-resources needs and issues. Therefore, it is necessary to define the context within which NAWQA information is most useful.

- Total resource assessment—NAWQA assessments are long-term and interdisciplinary, and include information on water chemistry, hydrology, land use, stream habitat, and aquatic life. Assessments are not limited to a specific geographic area or water-resource problem at a specific time. Therefore, the findings describe the general health of the total water resource, as well as emerging water issues, thereby helping managers and decision makers to set priorities.
- Source-water characterization—Assessments focus on the quality of the available, untreated resource and thereby complement (rather than duplicate) Federal, State, and local programs that monitor drinking water. Findings are compared to drinking-water standards and health advisories as a way to characterize the resource.
- Compounds studied—Assessments focus on chemical compounds that have well-established methods of investigation. It is not financially or technically feasible to assess all the contaminants in our Nation's waters. In general, the NAWQA Program investigates those pesticides, nutrients, volatile organic compounds, and metals that have been or are currently used commonly in agricultural and urban areas across the Nation. A complete list of compounds studied is on the NAWQA Web site at *http://water.usgs.gov/nawqa*.
- Detection relative to risk—Compounds are measured at very low concentrations, often 10 to 100 times lower than Federal or State standards and health advisories. Detection of compounds, therefore, does not necessarily translate to risks to human health or aquatic life. However, these analyses are useful for identifying and evaluating emerging issues, as well as for tracking contaminant levels over time.
- Multiple scales—Assessments are guided by a nationally consistent study design and uniform methods of sampling and analysis. Findings thereby pertain not only to water quality of a particular stream or aquifer, but also contribute to the larger picture of how and why water quality varies regionally and nationally. This consistent, multiscale approach helps to determine if a water-quality issue is isolated or pervasive. It also allows direct comparisons of how human activities and natural processes affect water quality in the Nation's diverse environmental settings.

Introduction to this Report

"The New England Coastal Basins NAWQA study has been very valuable to the U.S. Environmental Protection Agency's New England regional water programs. The study has provided contaminated sediment data which will be incorporated into our National and regional sediment inventories; has highlighted the importance of arsenic in drinking water wells in New England; and has established relationships between land use and environmental quality of rivers and streams, including flow, nutrient status, and biological communities. The data from, and the monitoring approaches of, the study will help the USEPA in its monitoring and regulatory roles."

Matthew Liebman,
Environmental Biologist,
U.S. Environmental Protection Agency—New England

This report contains the major findings of a 1999–2001 assessment of water quality in the New England Coastal Basins. It is one of a series of reports by the National Water-Quality Assessment (NAWQA) Program that present major findings in 51 major river basins and aquifer systems across the Nation.

In these reports, water quality is discussed in terms of local, State, and regional issues. Conditions in a particular basin or aquifer system are compared to conditions found elsewhere and to selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms.

This report is intended for individuals working with water-resource issues in Federal, State, or local agencies, universities, public interest groups, or in the private sector. The information will be useful in addressing a number of current issues, such as the effects of agricultural and urban land use on water quality, human health, drinking water, source-water protection, hypoxia and excessive growth of algae and plants, pesticide registration, and monitoring and sampling strategies. This report is also for individuals who wish to know more about the quality of streams and ground water in areas near where they live and how that water quality compares to the quality of water in other areas across the Nation.

The water-quality conditions in the New England Coastal Basins summarized in this report are discussed in detail in other reports that can be accessed from *http://nh.water.usgs.gov/CurrentProjects/nawqa/nawqaweb.htm*. Detailed technical information, data and analyses, collection and analytical methodology, models, graphs, and maps that support the findings presented in this report in addition to reports in this series from other basins can be accessed from the national NAWQA Web site (*http://water.usgs.gov/nawqa*).

"Nubble Light in Winter"

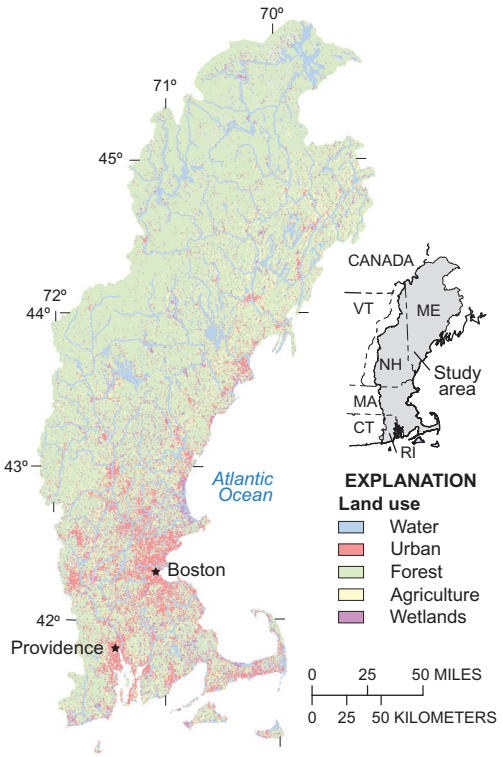
(Reprinted from Norman Eggert, Eggphoto/Images of New England, and published with permission.)

Summary of Major Findings

Stream and River Highlights

Human activities associated with past and current residential, commercial, and industrial land uses (collectively known as urban lands) are the primary factors affecting the chemical quality and health of aquatic ecosystems in streams of the New England Coastal Basins. Although concentrations of most chemical constituents monitored met water-quality guidelines, there are no guidelines for the mixtures of many industrial and household cleaners and fuel-related compounds (collectively called volatile organic compounds, or VOCs), pesticides, and nutrients in urban streamwater at generally low levels. Major findings for rivers and streams include the following:

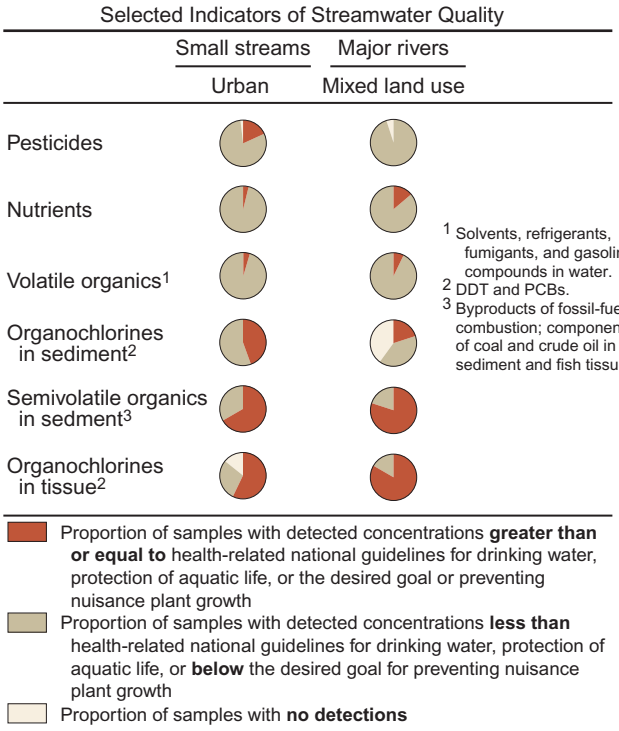
- Degradation of stream ecosystems appears to occur early in the process of watershed urbanization. For example, populations of macroinvertebrate species such as mayflies, stoneflies, and caddisflies, which are sensitive to urban contaminants and habitat disturbance, are reduced where as little as 3 percent of the land cover in the watershed is urban and population density is less than 300 people per square mile. Stream ecosystems are fully degraded where urban areas cover about 20 percent of the watershed and population densities are about 3,000 people per square mile (page 7).
- Rivers draining highly urbanized watersheds in the Boston and Providence areas contained concentrations of the trace elements arsenic, chromium, copper, cadmium, lead, mercury, and zinc in streambed sediments that exceeded guidelines for protection of aquatic life. Dominant sources of these trace elements include vehicular traffic and historical releases of these metals to the environment during the past two centuries from industrial and municipal wastewater (page 10).
- Environmentally persistent organic chemicals that had widespread and historical use, such as dichlorodiphenyltrichloroethane (DDT), chlordane, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs), were commonly detected in the streambed sediments of urban rivers at concentrations that could endanger the health of aquatic life (page 11).
- Concentrations of mercury were frequently greater in fish in forested watersheds in New Hampshire than in fish in highly urban watersheds near Boston. These findings indicate that mercury contamination is not limited to rivers that once received industrial and municipal wastes but rather is widespread because of mercury deposition from the atmosphere (page 14).
- VOCs from fuels and commonly used industrial and household products were frequently found in two heavily urbanized rivers near Boston. More than 75 percent of water samples from the Charles and Aberjona Rivers contained low concentrations of the gasoline additive methyl *tert*-butyl ether (MTBE), the disinfection by-product chloroform, and the solvent trichlorothene (TCE). Volatile organic compounds are transported to rivers in runoff from impervious surfaces and lawns and in contaminated ground water (page 17).
- Nitrogen concentrations in rivers increased with increasing percentages of urban lands in the watershed, ranging from about 0.4 mg/L (milligrams per liter) in the forested Kennebec River in Maine to more than 2.5 mg/L in the urbanized Aberjona River in Massachusetts. Primary urban sources of nitrogen include fertilizers, atmospheric deposition, and combined sewer overflows. Phosphorus concentrations in rivers also increase with increasing percentages of urban land and with the presence of permitted municipal wastewater discharges. The greatest mean phosphorus concentration occurred in the Merrimack River in Massachusetts, at a site downstream from nearly 50 permitted municipal wastewater discharges (page 22).



In the early to mid-1990s, the 23,000-square-mile New England Coastal Basins were primarily forested (72 percent), the remaining land being urban (8 percent), agriculture (6 percent), open water (6 percent), and wetlands (5 percent). Most of the 8.3 million people in the study area in 2000 lived along the coast.

Major Influences on Streams and Rivers

- Urbanization, including increasing amounts of impervious surfaces, population, and vehicles
- Historical releases of industrial and municipal wastewater
- Atmospheric deposition of contaminants, such as mercury and nitrogen



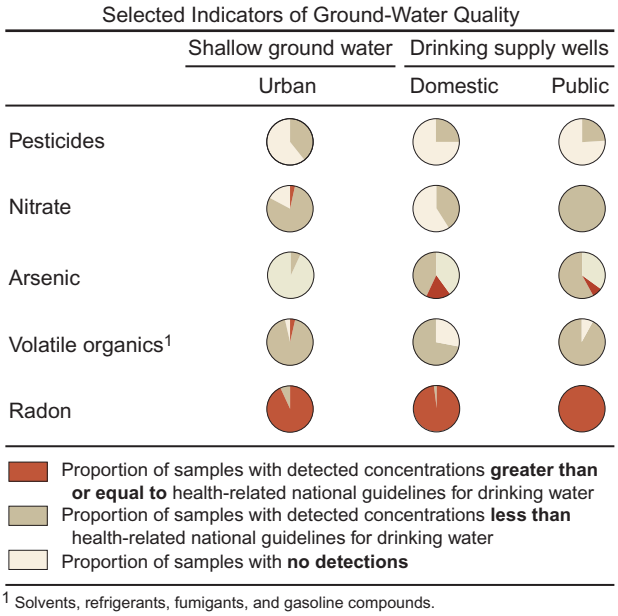
Ground-Water Highlights

Ground-water quality in the New England Coastal Basins generally meets existing Federal and State standards and guidelines for drinking water, with the exception of arsenic and radon. Concentrations of arsenic exceeded the U.S. Environmental Protection Agency (USEPA) drinking-water standard of 10 µg/L (micrograms per liter) in almost 20 percent of the domestic wells sampled, and concentrations of radon exceeded the USEPA standard of 300 pCi/L (picocuries per liter) in water from nearly all domestic and public-supply wells sampled. Major findings for ground water include the following:

- Low concentrations of VOCs frequently were detected in aquifers used for drinking water throughout the Study Unit. The gasoline additive MTBE, the most frequently detected VOC, occurred more widely in ground water in sand and gravel aquifers (80 percent of sampled wells), which tend to be vulnerable to surface contamination, than in bedrock aquifers (30 percent of sampled wells). None of the samples from wells used for drinking water exceeded drinking-water advisory concentrations for MTBE or drinking-water standards and guidelines for other VOCs (page 17).
- Elevated concentrations of arsenic are widespread in ground water from bedrock aquifers of the Study Unit. Overall, water samples from 17 percent of domestic wells completed in bedrock and from 3 percent of public water-supply wells completed in sand and gravel aquifers had concentrations that exceeded the USEPA drinking-water standard of 10 µg/L. Elevated concentrations of arsenic were most prevalent in water from bedrock aquifers in eastern New Hampshire and Maine, where a rapidly growing population is dependent on unregulated domestic bedrock wells for water supply. Concentrations of arsenic exceeded the drinking-water standard more frequently in calcareous metamorphic bedrock than in igneous and other metamorphic bedrock. Arsenic occurs naturally in the bedrock of the region (page 24).
- Radon was present in all but one of the sampled domestic and public water-supply wells in the Study Unit at concentrations that exceeded the proposed USEPA drinking-water standard of 300 pCi/L for drinking water. Concentrations of radon were greatest in water from igneous bedrock. Nationally, the highest concentration of radon measured by the NAWQA Program was from a domestic well in New Hampshire (page 26).

Major Influences on Ground-Water Quality

- Natural properties of bedrock and sand and gravel material
- Urbanization, including increasing amounts of impervious surfaces, population, and vehicles



Introduction to the New England Coastal Basins

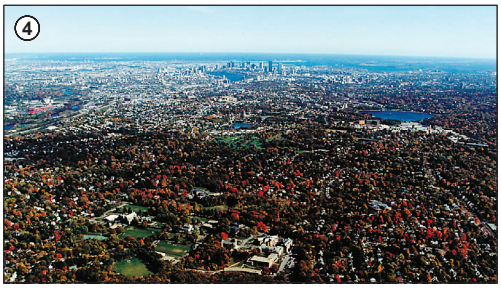
Environmental Setting

The New England Coastal Basins covers 23,000 square miles in Maine, New Hampshire, Massachusetts, and Rhode Island and includes river basins that drain to the coast between Casco Bay, Maine, and Block Island Sound, R.I. (fig. 1) (Ayotte and Robinson, 1997). Hydrology is dictated by the hilly to mountainous topography and forested landscape of the region. The largest rivers—the Kennebec, Androscoggin, Saco, and Merrimack—drain the northern two-thirds of the New England Coastal Basins. (For simplicity, this area will be referred to as the "basins.") These rivers originate in the mountainous and forested Northeastern Highlands **ecoregion** and flow southeasterly to coastal waters in the hilly plains of either the Northeastern Coastal Zone or the Laurentian Plains and Hills ecoregions (Omernik, 1987). The Charles and Blackstone Rivers—large rivers that drain the southern one-third of the basins—are entirely in the Northeastern Coastal Zone ecoregion

Surface waters in undeveloped areas are generally of high quality but are sensitive to atmospheric deposition of contaminants.

Urban sprawl can have a profound effect on water quality.

Untreated chemical wastes dumped decades ago are still in rivers today.



Although relatively small in land area (8 percent), urban lands have proportionally greater effect on water quality than any other land use.

Figure 1. Large rivers and lakes draining forested mountainous terrains dominate the northern two-thirds of the New England Coastal Bas

Monitoring of surface and ground waters by the New England Coastal Basins NAWQA study focused in the Northeastern Coastal Zone ecoregion to study the effects of urbanization on these waters. (Photograph 1 reprinted from N.H. Division of Travel and Tourism, and published with permission; photograph 2 by K.W. Robinson, U.S. Geological Survey; photograph 3 by B.O. Stock, U.S. Geological Survey; and photograph 4 reprinted from J.R. Melanson, Aero Photo, Inc., and published with permission.)

Words defined in glossary (p. 32) are in **bold** lettering when first used in text.

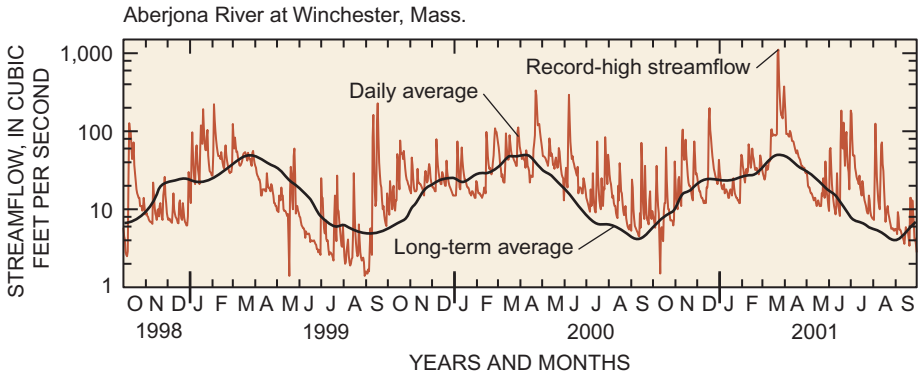


Figure 2. Rivers were sampled during 1999 to 2001 when flows were both below and above the long-term (1961–97) average.

and flow through the densely populated metropolitan areas of Boston, Mass., and Providence, R.I. Virtually no major streams drain Cape Cod and the nearby offshore islands in the Atlantic Coastal Pine Barrens ecoregion, which are composed of sandy plains.

The geology of the basins consists of fractured, crystalline bedrock that is typically covered by glacial deposits that resulted from the last glaciation from 12,000 to 5,000 years ago. The more than 400 individual geologic units in the basins are generally grouped by their age, formation, and mineral composition into aquifers of metamorphic and igneous rocks having varying amounts of calcium carbonate (Robinson and others, 2002; Montgomery and others, 2002). The glacial deposits consist of clay, silt, sand, and gravel, which are found along stream valleys and coastal plains. Sand and gravel glacial deposits serve as important aquifers for public water supplies in the basins. Till is the most dominant glacial deposit, covering most of the bedrock in the upland areas (Flanagan and others, 1999).

Hydrologic Conditions

Cold winters and relatively cool summers characterize the climate of the basins. Average annual precipitation ranges from 42 inches in the coastal areas to more than 60 inches in the White Mountains. Monthly precipitation in Boston during the 1998–2001 sampling period ranged from zero to 10 inches. Flows in rivers are typically greatest in April as the result of the combination of snowmelt and spring storms (Flanagan and others, 1999). Overall, flows of rivers in the basins were below normal in 1999 and near normal in 2000 and 2001. Although no severe regional droughts or floods occurred in the basins during this period, record high streamflows were measured in some rivers, such as the Aberjona River (fig. 2).

Water Use

Nearly 70 percent of the 1.43 billion gallons of freshwater used each day in the basins is withdrawn from rivers and reservoirs (fig. 3). This water is used primarily for drinking or household purposes, but also for thermoelectric power generation, industrial processes, and irrigation. Major cities, such as Boston, Providence, and Portland, Maine, rely on reservoirs for drinking-water supplies. Another 149 million gallons of water is piped each day from the Quabbin Reservoir, which is outside the New England Coastal Basins, to supplement Boston's water needs.

Ground water accounts for about 30 percent of total freshwater use and is an important source of drinking water for public and domestic (household) use. About 173 million gallons of water is pumped each day from **sand and gravel aquifers**, which are the only source of public-supplied water to many towns and cities, especially in the Atlantic Coastal Pine Barrens ecoregion. About 74 million gallons of water is pumped each day from bedrock aquifers for domestic supplies; these aquifers are the sole source of drinking water for many residents in New Hampshire and Maine (Flanagan and others, 1999).

Effects of Population Growth and Urbanization on Water Quality

From 1990 to 2000, the population of the New England Coastal Basins increased 6.8 percent, from 7.78 million people to 8.31 million. Much of

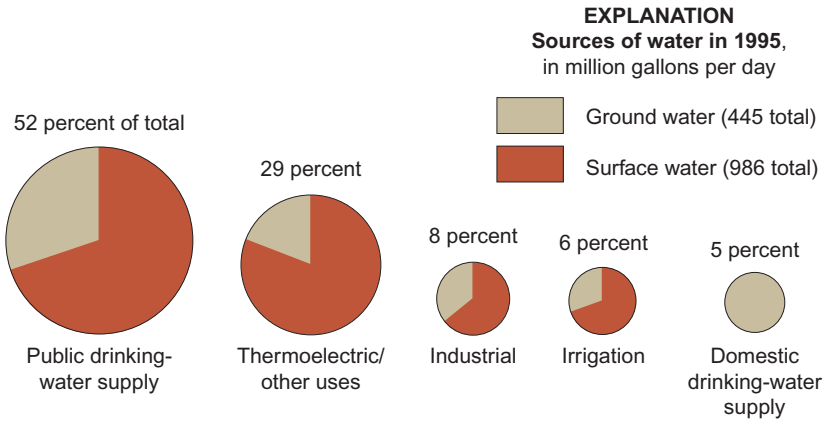


Figure 3. More than 50 percent of all surface water and ground water used each day in the basins is for drinking water and household supplies.

the population growth occurred in rural and outlying suburban areas from Providence northward through the Boston metropolitan area and into southern New Hampshire and Maine. For example, urban land area expanded about 10 to 20 percent in many towns in eastern Massachusetts between 1985 and 1999 (Massachusetts Executive Office of Environmental Affairs, 2002). Simultaneously, 7 percent of forests in New Hampshire were converted to urban land (Sundquist and Stevens, 1999). Because the population in the basins is expected to grow—at a rate of 9 percent in Massachusetts and Rhode Island to 16 percent in New Hampshire—from 2000 to 2025 (U.S. Census Bureau, 2002), conversion of forested and agricultural lands into urban lands will continue throughout the rural areas of the basins.

As in other parts of the Nation, population growth and urban development in a watershed can increase the amount of impervious surfaces, stormwater runoff, sedimentation, applications of fertilizers and **pesticides** in landscaped areas, municipal and industrial wastewater discharge, and vehicular emissions—all of which can greatly affect water quality. Excessive amounts of nutrients, oxygen-demanding substances, and sediments, as well as degraded riparian habitat, are common water-quality concerns in urbanized rivers of the basins.

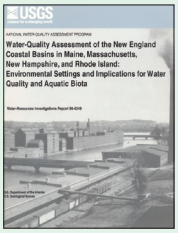
Water quality also is affected by other human and land-use activities. For example, dam building at the outlets of lakes and along streams since the 17th century has blocked the migration of native fish, degraded natural habitat, and trapped fine sediments and associated contaminants, such as phosphorus, that can result in nutrient-enriched lakes and ponds. Stormwater runoff from agricultural and silvicultural (forest) lands can lead to increased nutrients, pesticides, and sediments entering nearby surface waters. In addition, precipitation associated with westerly weather patterns originating in power-generating States outside of New England transports sulfur, nitrogen, and mercury to New England surface waters (Sowles, 2001; U.S. Environmental Protection Agency, 1999a; Robinson and others, 2003).

River water and biological quality varies throughout the basins. In the Northeastern Highlands ecoregion, water quality generally is suitable for most uses, with local degradation in urban and agricultural areas and downstream from permitted wastewater discharges. Consequently, many rivers in the Northeastern Highlands support native and nonnative trout and other cold-water fish. In contrast, water quality in the more urbanized Northeastern Coastal Zone ecoregion commonly is degraded, and most rivers contain nonnative, warm-water fish such as smallmouth and largemouth bass.

Ground water in the sand and gravel aquifers in the basins commonly underlies urban and agricultural lands in river valleys and coastal areas. As a result, the ground water is vulnerable to contamination from applications of fertilizers and pesticides, leaky sewerlines, malfunctioning septic tanks, road salt, and spills and leaks of chemicals near the land surface. The coarse-grained aquifer material allows these contaminants to move downward rapidly with little opportunity for filtration or chemical degradation.

The potential for contamination of water in bedrock aquifers varies greatly, depending on the type of bedrock and the interconnection of the fractures and joints in rock to the land surface and overlying sediments. Natural contaminants, such as arsenic and radon, are common in certain bedrock aquifers of the basins (Ayotte and others, 1999).

Many streams have been dammed to create ponds that were used as a source of power for the mills built along waterways during the past two centuries. (Photograph reprinted from Werner Horn, Photographer, and published with permission.)



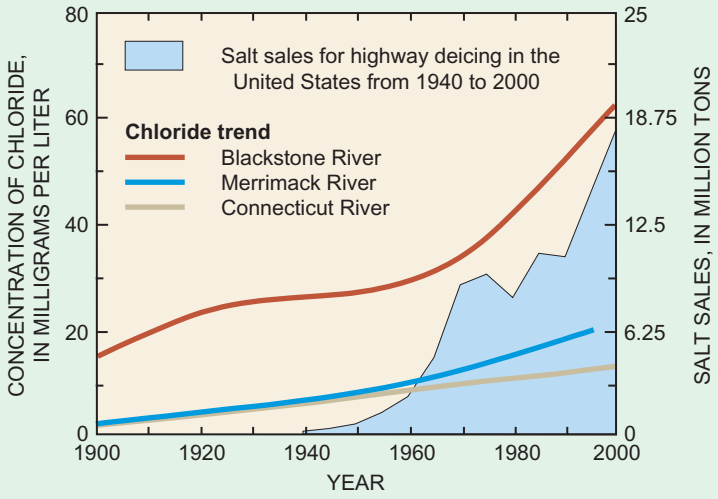
A detailed description of the New England Coastal Basins is in the following report:

Water-quality assessment of the New England Coastal Basins in Maine, Massachusetts, New Hampshire, and Rhode Island: Environmental settings and implications for water quality and aquatic biota, by S.M. Flanagan and others; U.S. Geological Survey Water-Resources Investigations Report 98–4249 at **http://pubs.water.usgs.gov/wri984249**

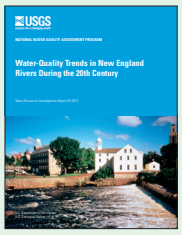
Water quality has changed in New England rivers

The damming of rivers and the historical disposal of untreated industrial, municipal, and domestic wastes from industry, cities, and homes made some of the rivers in the New England Coastal Basins among the most contaminated in the Nation during the early 20th century. Changing economies, environmental legislation, and improved treatment of sewage and industrial wastewaters have resulted in cleaner rivers today (2004) than 50 to 100 years ago. River-monitoring data collected since the 1960s show that phosphorus concentrations decreased in the Merrimack, Blackstone, and Connecticut Rivers because of bans on phosphate detergents, improved wastewater treatment, and reduced use of phosphorus fertilizer by farmers (Robinson and others, 2003). Continued urban development and associated human activities, however, will continue to affect water quality and aquatic life, as indicated by levels of other contaminants. For example, concentrations of chloride continue to increase in the Blackstone, Merrimack, and Connecticut Rivers because of increased applications of road deicing salt.

Photographs of the Nashua River, N.H., before (mid-1960s) and after (mid-1980s) treatment of municipal and industrial wastewater. (Reprinted from Nashua River Watershed Association, and published with permission.)



Chloride concentrations in the Blackstone, Merrimack, and Connecticut Rivers have increased steadily since the beginning of the 20th century.



A detailed description of water-quality trends during the 20th century is in the following report:

Water-quality trends in New England rivers during the 20th century, by K.W. Robinson and others; U.S. Geological Survey Water-Resources Investigations Report 03–4012 at
http://pubs.water.usgs.gov/wrir03-4012

Major Findings

Urbanization Results in Significant Degradation of Stream Ecosystems

The effect of expanding urban and suburban development on the biological, chemical, and physical characteristics of stream ecosystems is a concern to water-resource managers and the general public. Understanding how streams respond to urbanization was the focus of a study in the Boston metropolitan area in 2000 (see inset).

Effects on Aquatic Communities

Biological indicators of stream-ecosystem health, such as the presence of invertebrates and fish sensitive to contamination, commonly are used to evaluate the effects of contaminants and land-use disturbances such as urbanization. Data collected in 30 streams in the New England Coastal Basins showed that the number of contamination-sensitive aquatic insects, such as mayflies, stoneflies, and caddisflies (orders Ephemeroptera, Plecoptera, and Trichoptera, respectively, or **EPT taxa**), decreased with increasing urban intensity. The number of EPT taxa ranged from more than 20 species per stream in watersheds with 2 percent urban land, such as in the Little River in Maine, to 4 species in the highly urbanized Aberjona River in Massachusetts (draining 68 percent urban land). Overall, the quality of invertebrate communities in the streams declined with increasing urban intensity (fig. 4).

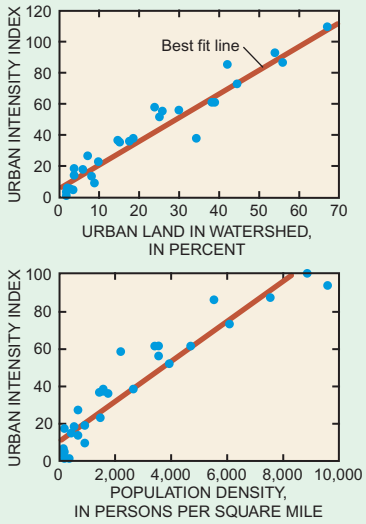
Similarly, the occurrence of fish preferring fast-flowing waters and the abundance of minnows (Cyprinidae) declined with increasing urban intensity. The number of fish that prefer fast-flowing waters decreased from nearly 800 fish in two streams in Maine to fewer than 100 in the Aberjona River near Boston. The decrease may be due, in large part, to frequent dams and ponds on streams in urban watersheds, which commonly eliminates the natural riffles in streams. The number of minnow species ranged from four in the least urbanized streams to none in the most urbanized streams. The presence or absence of fish in the minnow family is a good indicator of urbanization effects on stream ecosystem health because these fish naturally occur in streams throughout the basins.

In contrast to invertebrate and fish communities, the diversity of algae in streams—particularly diatom species—increased with urban intensity. In addition, the total number of algal species increased from fewer than 20 in the least urbanized streams to nearly 60 in the most urbanized streams. The increased diversity and number of algae species reflect readily available nutrients and other factors, such as increased water temperatures, in the more urban streams.

An example of residential development in a highly urbanized watershed near Boston, Mass. (Photograph by K.W. Robinson, U.S. Geological Survey.)

An integrated index of urban intensity is used to define urban effects on stream ecosystems

Biological, chemical, and physical characteristics were assessed in 30 streams in the Northeastern Coastal Zone ecoregion having watersheds ranging in size from 19 to 40 mi^2. These streams reflect both relatively pristine streams in New Hampshire and Maine and heavily urbanized streams near Boston. Each stream was ranked with an "urban intensity index" (ranging from 0 to 100) on the basis of 24 measures of urbanization, including the percentage of urban land within its watershed; human population density and its rate of change; the number of permitted wastewater discharges, toxic release sites, roads, and dams; and various socioeconomic factors related to housing, income, and population characteristics (McMahon and Cuffney, 2000). Population density of the 30 watersheds ranged from 170 to 9,600 people per square mile, and percentage of urban land in the watersheds ranged from 2 to 68 percent. The urban intensity index was a useful tool in both selecting streams to sample and in the interpretation of the stream data collected.



The urban intensity index is closely related to the population density and percentage of urban land in the watersheds studied.

Effects on Water Chemistry

Specific conductance, pH, and the concentrations of bicarbonate, nitrogen, and pesticides increased with increasing urban intensity. For example, specific conductance ranged from less than 100 µS/cm (microsiemens per centimeter) in streams throughout most of Maine and New Hampshire to more than 400 µS/cm in streams near Boston—indicating more dissolved chemicals in streams draining urban land. Dissolved inorganic nitrogen in streamwater ranged from less than 0.05 mg/L (**milligrams per liter**) in the least urbanized to greater than 4.0 mg/L in the most urbanized streams. Although the detection frequency and concentrations of pesticides increased with urban intensity, concentrations were very small—all less than 1 µg/L (micrograms per liter)—and none of the stream samples collected for this study contained pesticide concentrations that exceeded **guidelines for the protection of aquatic life**. The most commonly detected pesticides included the insecticides diazinon and carbaryl and the herbicides prometon and atrazine. Information on other sampling of pesticides and nutrients in streams of the basins is on pages 21 and 22, respectively.

Effects on Stream Habitat

The physical habitat of streams also change as land becomes more urbanized (fig. 4). Most notably, average daily water temperatures increased with increased urban intensity. This may be due to stormwater runoff from large amounts of impervious surfaces and the many natural and artificial ponds along streams in urban areas. Warmer stream temperatures help to explain decreases in concentrations and percent saturation of dissolved oxygen in the more urbanized streams, especially in summer. Concentrations of dissolved oxygen above 5 mg/L are critical to fish survival. The lowest measured concentration of dissolved oxygen was 3.5 mg/L in the urban Matfield River—below the State of Massachusetts **water-quality criteria** of 5.0 mg/L for Class B warm-water fisheries.

Average **stream depth** also changed with urbanization. Specifically, stream depth increased from 0.7 foot in the least urbanized streams to 2.0 feet in the most urbanized streams. The greater stream depth in the most urbanized watersheds is indicative of increased scouring of streambanks and soils as a consequence of urbanization.

In contrast to streams in other urban areas across the Nation, the flashiness of streams—the rapidity at which streamflow increases and then decreases in response to precipitation—did not

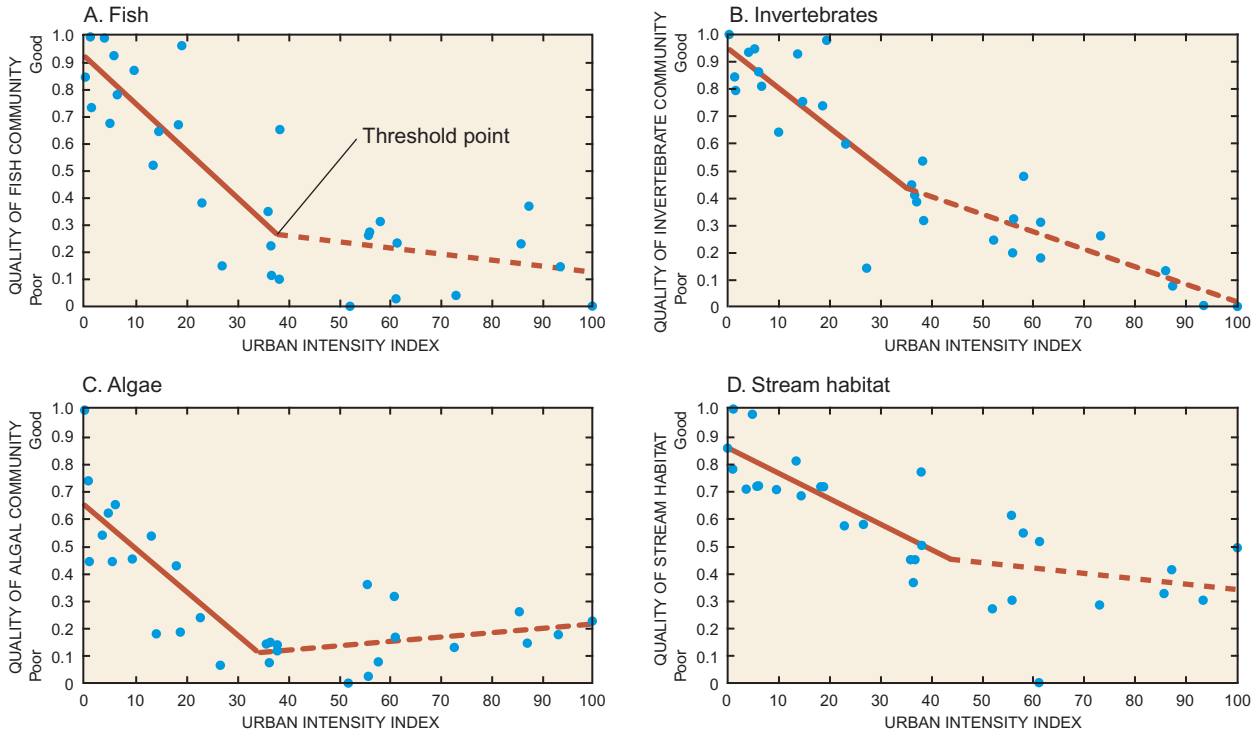
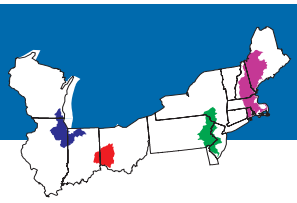


Figure 4. Most of the change in (A) fish, (B) invertebrates, (C) algae, and (D) stream habitat occurs in the early stages of urbanization, up to a certain threshold point, after which the change occurs at a slower rate. The threshold point is defined on the basis of two-slope linear regression analysis using a significance level of $\alpha = 0.05$. The two line symbols indicate that the slope of the line is significantly different before and after the threshold point. The values on the y-axis are a relative scale from 0 to 1 designed to represent the ecological conditions being measured.

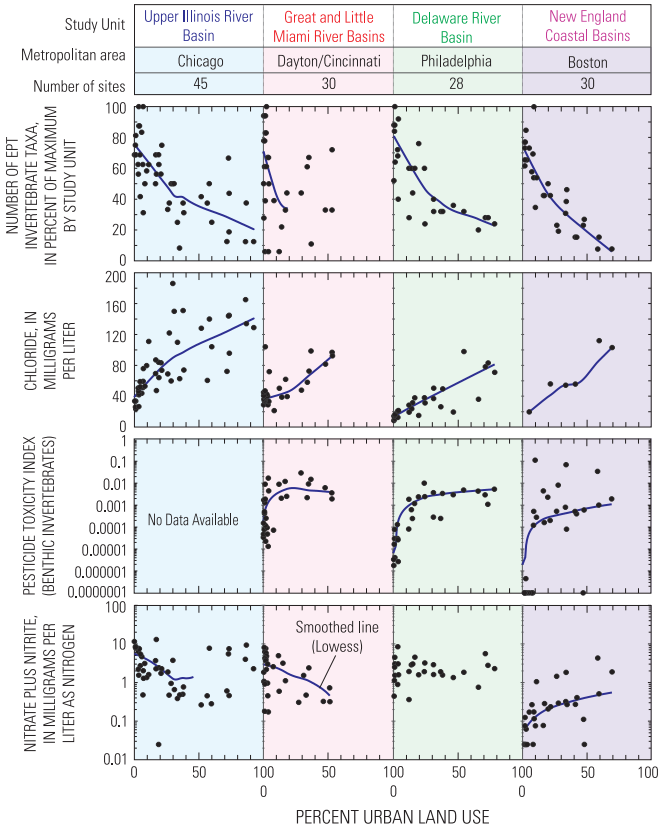


REGIONAL PERSPECTIVE—Stream Quality Degrades as Urbanization Increases in Four Major Metropolitan Areas

Urbanization can degrade water quality and affect sensitive aquatic life, according to a comparison of NAWQA findings among studies in the major metropolitan areas of Boston (New England Coastal Basins), Philadelphia (Delaware River Basin), Dayton and Cincinnati (Great and Little Miami River Basins), and Chicago (Upper Illinois River Basin). These studies, which compared conditions among streams in watersheds ranging from minimally to highly urbanized, showed declines in indicators of biological-community health—and increases in chemical indicators of human activity—with increases in percentage of urban land. For example, the number of benthic invertebrate species sensitive to pollution, such as the "EPT taxa" [mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera)], generally decreased with increasing urban-land percentage in all four metropolitan areas. The declines in EPT taxa were steepest from 0 to about 20 percent urban land, and with the exception of Dayton/Cincinnati, the decline continues with increased urbanization. The anomalous pattern in the Dayton/Cincinnati area may be associated, in part, with effects of high percentages of agricultural land in some of its less urbanized watersheds, as well as the absence of study sites with much more than 50 percent urban land.

Over space and time, invertebrate communities integrate the effects of many factors, including chemical changes, physical habitat alterations, and changes in types of food available to invertebrate consumers. Among the chemical changes noted with increasing urban land in the metropolitan areas studied were increased chloride concentrations and increased potential pesticide toxicity to benthic invertebrates. Chloride sources include municipal and industrial discharges, septic systems, and road-salt runoff. Other organic and inorganic chemicals may be associated with the chloride from these sources. The potential toxicity of the mixture of pesticides detected in stream water increased with increasing urban land percentage, according to the Pesticide Toxicity Index [a measure for ranking sites based on summed concentrations of detected pesticides and the toxicity of each pesticide to benthic invertebrates (Munn and Gilliom, 2001)]. The increase was especially pronounced at relatively low percentages of urban land. Contributing factors may include the amount, relative toxicity, and timing of pesticides—particularly insecticides—that are applied in urban settings.

Patterns of nitrate concentration with increasing urban land were not consistent among the four metropolitan areas. In fact, the only clear increase in nitrate concentrations with urbanization was in the Boston area. This is, in part, because nutrients in Boston-area streams are associated primarily with urban sources and are not affected by additional sources, such as fertilizers applied on agricultural land. Moreover, watersheds with minimal urban land in the Boston area are mainly forested, and nitrate concentrations in those streams are low (less than 0.1 mg/L). In contrast, nitrate concentrations in streams decreased with increasing urbanization in the Dayton/Cincinnati area and in minimally to moderately urban settings of the Chicago area, whereas in the Philadelphia area they neither increased nor decreased; fertilizers applied to crops contribute to the higher nitrate concentrations in some less urbanized watersheds in these settings. Sewage may be a factor contributing to the high nutrient concentrations in some highly urban Chicago streams.



Selected examples of biological and chemical indicators, in relation to urbanization. Smoothed lines are shown in plots for which Spearman rank correlations were statistically significant at a probability value of less than 0.05.

In summary, biological and chemical characteristics in streams respond to increases in urban land in their respective watersheds. The responses may differ in pattern and in rate, however, so approaches for monitoring the effects of urbanization on streams may need to be tailored to specific metropolitan areas. Findings of these NAWQA studies may help in developing and prioritizing optimal management strategies for a particular setting.

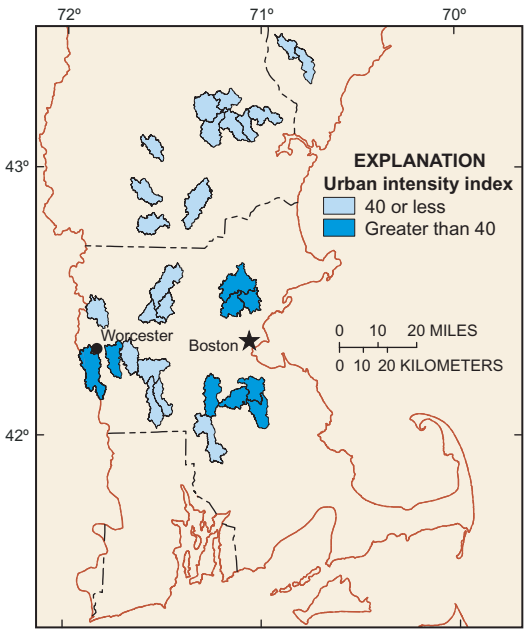


Figure 5. In the 30 watersheds studied, the quality of fish, invertebrate, and algae communities declined rapidly up to an urban intensity index of about 40 after which degradation was so severe that no further response to increasing urban intensity could be detected.

increase with increasing urban intensity in the basins. Flows in urban streams are commonly flashy because of rapid runoff of stormwater from impervious surfaces such as roads, parking lots, and rooftops. The large number of natural and artificial ponds and wetlands along stream channels in the basins, however, most likely help to minimize the effect of impervious surfaces on streamflow characteristics in this region. Preventing an increase in the flashiness of streamflows can be advantageous to maintaining healthy stream ecosystems because increased flashiness can lead to erosion of sediment and the disturbance of substrates and other stream habitat features that are important for fish and aquatic insects.

Management Considerations

NAWQA findings show that the biological, chemical and physical characteristics of streams all play a role in the types and quality of aquatic ecosystems found in those streams. Determining which measures of stream health are influencing other measures and their relative importance requires careful sampling and data analysis.

NAWQA findings also help to define the timing of degradation as related to watershed development. Changes in invertebrate, fish, and algal communities in streams draining the New England Coastal Basins appear to occur early in the process of watershed urbanization. For example, populations of EPT taxa are reduced in streams draining watersheds with as little as 3 percent urban land and a population density of less than 300 people/mi^2 (people per square mile). Changes in fish, invertebrate, and algae communities and stream habitat continued in streams up to an urban intensity index of about 40 (corresponding to about 20 percent urban land and a population density less than 3,000 people/mi^2), at which point the changes occur at a noticeably lower rate. Streams that are at or near this "threshold" include Elizabeth Brook, Fort Pond Brook, Stony Brook, and Sudbury River in Massachusetts, and Beaver Brook in New Hampshire—all watersheds that currently are experiencing significant population growth. Streams that have an urban intensity index over 40 were associated with degraded stream ecosystems; these include the Quinsigamond, Saugus, Matfield, and Aberjona Rivers in eastern Massachusetts (fig. 5). These streams drain older urban centers.

The information above can be used to understand where water-quality management actions are likely to have the greatest benefits and where stream restoration/protection resources should be implemented. Thresholds can be useful for prioritizing and managing stream restoration and protection. For example, efforts to improve the quality of a stream in a watershed with an urban intensity index above 40 may not be as successful as protecting a stream in a watershed having an urban intensity index less than 40. Although an urban intensity threshold of 40 is a fairly uniform indicator of a highly degraded stream ecosystem in the New England Coastal Basins, thresholds should be used only as a general planning tool. A thorough understanding of the individual stream ecosystem associated with a particular river is necessary to target management actions that would have the greatest benefits for that stream.

Many Trace Elements and Organic Contaminants were Detected in Streambed Sediments

Streambed-sediment samples from 14 New England Coastal Basins rivers contained 43 different trace elements, 27 different polycyclic aromatic hydrocarbon compounds (PAHs), and a variety of organochlorine compounds such as PCBs and DDT. Concentrations of many of these trace elements and organic compounds, which originate from natural and manmade sources (see Additional Information box), were greater in rivers draining highly urbanized watersheds in and near Boston and Providence than in rivers draining the outlying suburban and rural areas. At some sites, the concentrations detected may be posing a potential health risk to aquatic life (Chalmers, 2002). Sediments serve as a necessary habitat for many aquatic biota, but they also act as a depository for many persistent and potentially toxic contaminants.

Concentrations of seven of the detected trace elements (arsenic, copper, cadmium, chromium, lead, mercury, and zinc) frequently exceeded guidelines for the protection of aquatic life established by the Canadian Council of Ministers

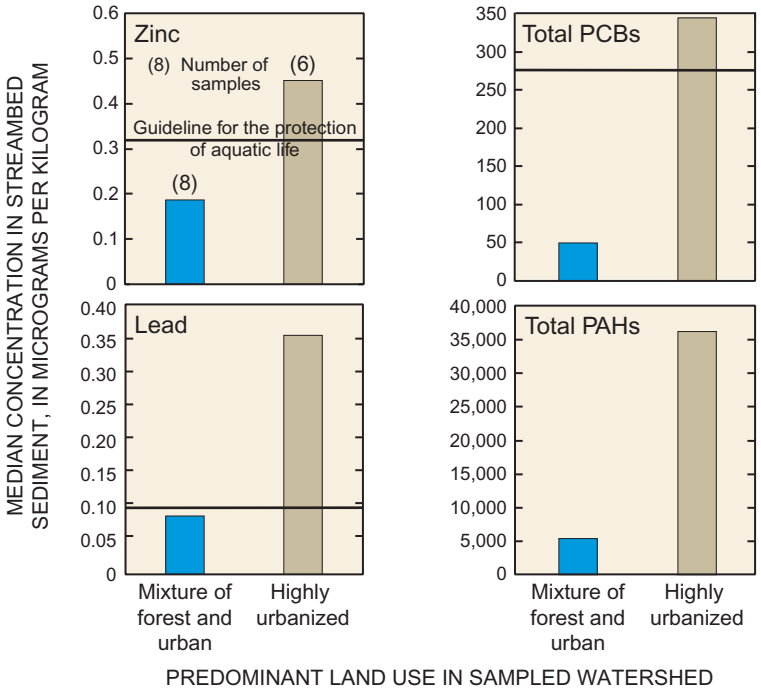


Figure 6. Zinc, lead, total PCBs, and total PAHs in streambed sediments were detected at highest concentrations and at levels exceeding guidelines for the protection of aquatic life in rivers draining highly urbanized watersheds in and near Boston and Providence. Concentrations were lower in mixed-land-use watersheds away from these major cities.

of the Environment (Canadian Council of Ministers of the Environment, 1999). For example, mercury was detected at concentrations above the aquatic-life protection guideline at 10 of 14 rivers, lead and chromium at 9 rivers, arsenic at 7 rivers, cadmium at 5 rivers, and copper at 3 rivers. (Lead and zinc data are shown in fig. 6.) Sediments from the Aberjona, Blackstone, Charles, Neponset, and Moshassuck Rivers (all in eastern Massachusetts and Rhode Island) had the greatest concentrations of many of the trace elements. These five highly urbanized rivers had concentrations of trace elements that were often 3 to 4 times those in the sediments of rivers draining less urbanized watersheds. These high concentrations indicate that urbanization has had a major effect on trace-element levels in sediments of the basins. A more detailed description of mercury in rivers of the basins is on page 14.

Streambed sediment in the 14 rivers sampled also contained 14 or more PAH compounds (Chalmers, 2002). Overall, concentrations of total PAHs in sediments were higher in rivers draining highly urbanized watersheds (median of 37,000 µg/kg [micrograms per kilogram]) than in less urbanized, more forested watersheds (median of 5,300 µg/kg) (fig. 6). The Aberjona River near Boston had the highest concentration of total PAHs (nearly 70,000 µg/kg), followed by the Charles River near Boston and the Moshassuck River in Providence, R.I. (greater than 40,000 µg/kg). In comparison, the least urbanized

Additional Information

Trace elements in the environment—The natural weathering of rocks and soils is a source for many trace elements, such as lead, zinc, mercury, arsenic, copper, cadmium, chromium, selenium, and nickel in streambed sediments. Human activities, however, can accelerate their release into the environment through industrial processing, fossil-fuel burning, wastewater discharges, and mining and agricultural practices. Many trace elements, including copper, selenium, and zinc, are essential to aquatic life but can be toxic in excessive amounts. Some trace elements such as mercury, cadmium, selenium, zinc, and lead can accumulate in the bodies of aquatic organisms.

Organic compounds in the environment—Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds, many of which are suspected carcinogens, that result primarily from the burning of organic matter such as wood and fossil fuels. Manmade sources of PAHs include industrial, powerplant, and automobile emissions. Natural sources of PAHs include volcanic eruptions and forest fires, but these sources are minor in comparison to manmade sources. Polychlorinated biphenyls (PCBs) are organochlorine compounds used in industrial products, including electrical transformers, capacitors, hydraulic fluids, and plasticizers. Organochlorine insecticides such as chlordane and DDT were developed in the middle of the 20th century and used extensively for the control of agricultural pests and for termite, ant, and mosquito infestations in residential areas. All uses of PCBs, chlordane, and DDT were discontinued by the late 1980s, but concentrations of these organic compounds, as well as DDT **breakdown products** DDD and DDE, still persist in the environment. Concentrations of PCBs, DDT, and chlordane magnify through the food chain by accumulating in the fatty tissue in aquatic organisms, possibly resulting in health risks to aquatic life, wildlife, and humans.

Kennebec and Androscoggin Rivers in Maine had concentrations of total PAHs of about 1,200 and 5,000 µg/kg, respectively.

The Canadian Council of Ministers of the Environment has not issued a guideline for total PAHs for the protection of aquatic life. Individual guidelines are available, however, for 12 of the 27 PAH compounds analyzed. The compounds benz[*a*]anthracene, chrysene, fluoranthene, phenanthrene, and pyrene were detected in nearly 60 percent of streambed-sediment samples at concentrations exceeding their respective aquatic-life-protection guidelines. Concentrations of the compound benzo[*a*]pyrene also exceeded aquatic-life-protection guidelines in 50 percent of the rivers sampled. Streambed sediments in the Charles River near Boston exceeded aquatic-life-protection guidelines for more PAH compounds (eight) than any other river sampled.

Similar to trace elements and total PAHs, concentrations of total PCBs in streambed sediments were greater in rivers draining highly urbanized watersheds (median of 350 µg/kg) than in less urbanized, more forested watersheds (median of 50 µg/kg)—indicating that urbanization increases the likelihood of finding PCBs in streambed sediments (fig. 6). Concentrations of total PCBs in the streambed sediments of the Aberjona, Neponset, Woonasquatucket, Moshassuck, and the Charles Rivers exceeded the aquatic-life-protection guideline of 277 µg/kg. In addition to PCBs, other organochlorine compounds commonly detected in the streambed sediments of the 14 New England Coastal Basins rivers included DDT (in 80 percent of the rivers), chlordane (64 percent), and dieldrin (50 percent). Concentrations of these compounds often exceeded aquatic-life-protection guidelines in the highly urbanized watersheds; yet in the mostly forested and undeveloped watersheds, these compounds often were undetected or below aquatic-life-protection guidelines.

Scientists collecting a sediment core in a Boston-area lake. (Photograph by C. Braun, U.S. Geological Survey.)

Additional Information

How is streambed-sediment and fish-tissue quality evaluated?—Statements in this report regarding possible adverse effects of contaminants on the health of aquatic life are based on Probable Effect Levels (PELs), as defined by the Canadian Council of Ministers of the Environment (1999). The PEL is an estimate of the concentration of a contaminant in streambed sediment above which adverse biological effects are expected to occur. The PELs are based on whole-sediment analysis, but the NAWQA Program collects and analyzes only the fine-grained sediment (less than 63 micrometers in diameter for trace elements and less than 2 millimeters in diameter for organic compounds). Concentrations of contaminants greater than the PEL guidelines may, therefore, be overestimated with the NAWQA data. Concentrations of organochlorine contaminants in fish tissue are evaluated using criteria developed by the State of New York to protect the health of fish-eating wildlife (Newell and others, 1987). Determination of the amount of organochlorine contaminants in fish by the NAWQA Program is based on analysis of whole-body tissue of fish. As a consequence, human food-consumption criteria are not directly relevant for the organochlorine compound data reported here because the criteria are based on concentrations in fish fillets.

Cores Reveal 50 Years of Elevated PAHs in Streambed Sediments of the Charles River

Streambed-sediment cores from the Charles River near Boston were collected and analyzed to determine long-term trends in concentrations of total PAHs (fig. 7). Results indicate that concentrations of total PAHs declined from 1965 to 2000 but have consistently been greater than the guideline for protecting the health of aquatic organisms that live in or near streambed sediments (22,800 µg/kg) (MacDonald and others, 2000). Concentrations of total PAHs (in the cores) peaked in the mid-1960s at a concentration of 300,000 µg/kg and decreased to 150,000 µg/kg in 2000. Despite these declines, concentrations

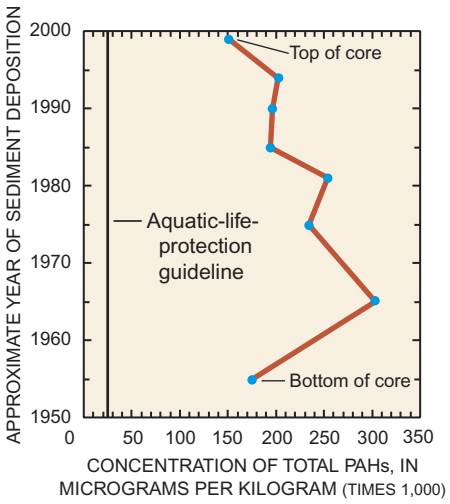


Figure 7. Concentrations of total polycyclic aromatic hydrocarbons (PAHs) in streambed sediments of the Charles River during the 1960s to 2000 appear to have declined, but they remain generally 5 to 10 times above the guideline for protecting the health of aquatic organisms that live in or near sediments.

of total PAHs remain nearly 5 times the concentration likely to have health effects on aquatic life. Breault and others (2000) also found that concentrations of inorganic elements and organic compounds in Charles River sediments were sufficiently high to cause potentially severe health effects to benthic organisms. These contaminated sediments may slow progress in meeting the goal of restoring the Charles River to swimmable and fishable quality by Earth Day 2005 (U.S. Environmental Protection Agency, 1995).

Combustion of fossil fuels from automobiles and power generators are likely a major source of the PAH compounds in the streambed sediments of the Charles River. VanMetre and others (2000) found that PAH concentrations in streambed and lakebed sediments were related to vehicular traffic in 10 other urban watersheds in the United States.

Organochlorine Compounds in Fish May Pose a Threat to Fish-Eating Wildlife

Total PCBs were found in whole-body tissue of fish (mostly white suckers) collected from 8 of the 12 rivers sampled at concentrations exceeding the New York State guideline for protecting fish-eating wildlife. The 110 µg/kg guideline for total PCBs (Newell and others, 1987) was exceeded in fish collected from less urbanized rivers as often as it was exceeded in fish from the highly urbanized rivers (fig. 8) (Chalmers, 2002). Fish collected from the Stillwater River in Massachusetts and Beaver Brook in New Hampshire had no detectable PCBs in their whole-body tissue; these rivers are among the smallest and least urbanized of the sampled rivers. The greatest concentrations were 2,200 µg/kg in the Charles River near Boston and 1,200 µg/kg in the Blackstone River near Providence. These results indicate that concentrations of the environmentally persistent PCBs are higher in fish from large rivers.

The median concentration of total PCBs in the whole body of fish taken from 12 rivers in the New England Coastal Basins was 325 µg/kg. This value is the highest median concentration of total PCBs in fish in comparison to 38 other NAWQA Study Units across the Nation (median of less than 50 µg/kg) (Chalmers, 2002).

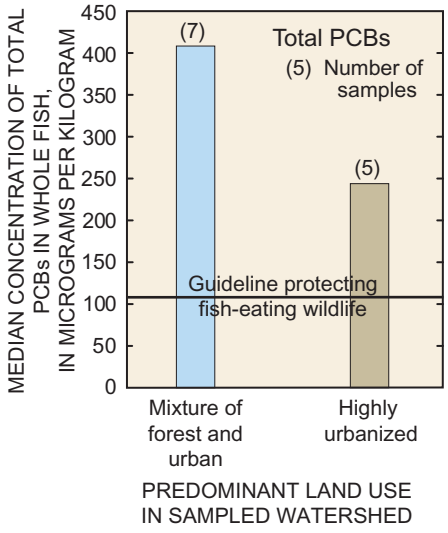
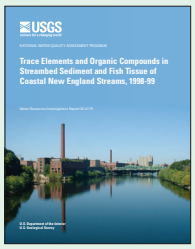


Figure 8. The median total PCB concentration was greater in the body of whole fish taken from slightly to moderately urbanized watersheds than in fish from highly urbanized watersheds. One possible reason for this finding is that larger fish were analyzed from the less urbanized rivers—larger fish had higher concentrations of PCBs in their bodies than smaller fish.

Electroshocking fish in the Merrimack River near Lawrence, Mass., resulted in the collection of these carp. (Photograph by J.F. Coles, U.S. Geological Survey.)

Banned pesticides were detected in whole-body tissue of fish collected from 11 of 12 (DDT), 5 of 12 (chlordane), and 2 of 12 (dieldren) sampled rivers. The greatest concentrations of all three pesticides were found in the Charles River near Boston. Total DDT concentrations in white suckers from the Charles River were 420 µg/kg, which exceeds the New York State Department of Environmental Conservation guideline for fish-eating wildlife of 200 µg/kg (Newell and others, 1987). None of the tissue samples from the other 11 rivers exceeded this guideline.

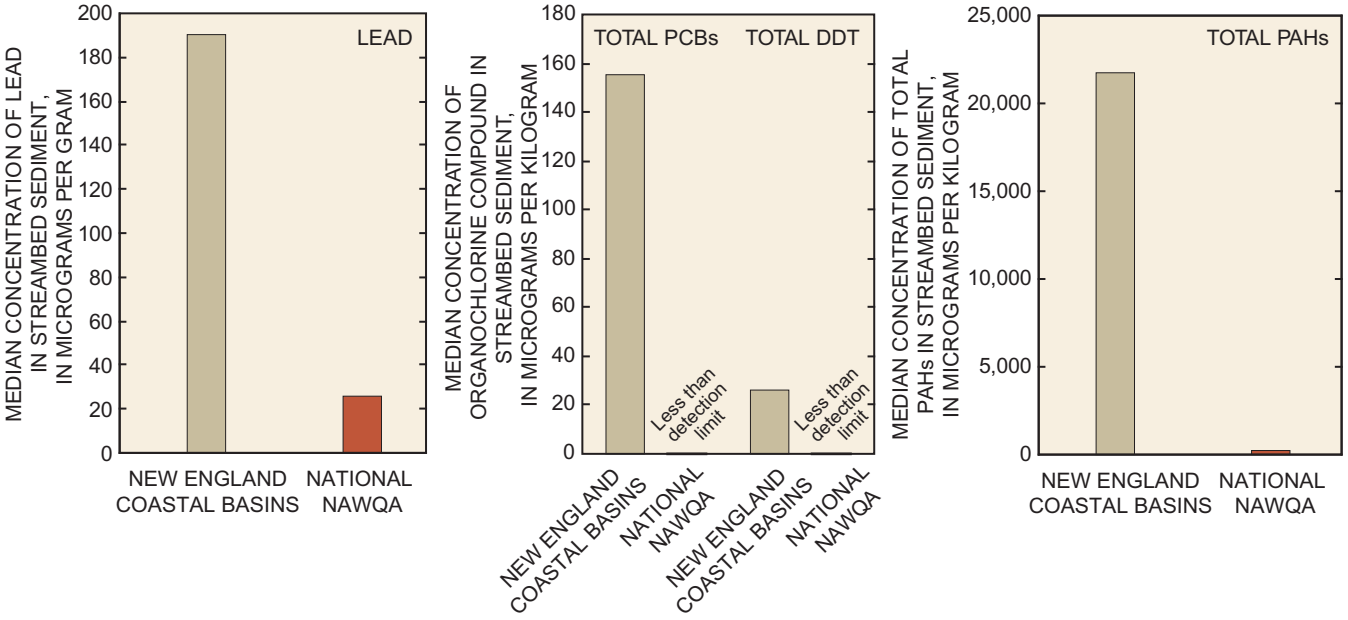


Detailed information on contaminants in streambed sediments and fish tissue of the New England Coastal Basins is in the following report:

Trace elements and organic compounds in streambed sediment and fish tissue of coastal New England streams, 1998–99, by Ann Chalmers; U.S. Geological Survey Water-Resources Investigations Report 02–4179 at **http://pubs.water.usgs.gov/wri024179**

NATIONAL PERSPECTIVE—Concentrations of Lead, PCBs, DDT, and PAHs in Streambed Sediments were the Highest in the Nation

The median concentrations of lead, total PCBs, total DDT, and total PAHs in streambed sediments from the 14 rivers sampled in the New England Coastal Basins were greater than those in 45 other NAWQA Study Units across the Nation (Chalmers, 2002). The relatively high concentrations of these contaminants in the New England Coastal Basins most likely reflect the targeted sampling of urbanized watersheds in and around Boston and Providence and the long history of industrial activity in eastern New England.



Mercury Contamination is Widespread in Streambed Sediments and Fish Tissue

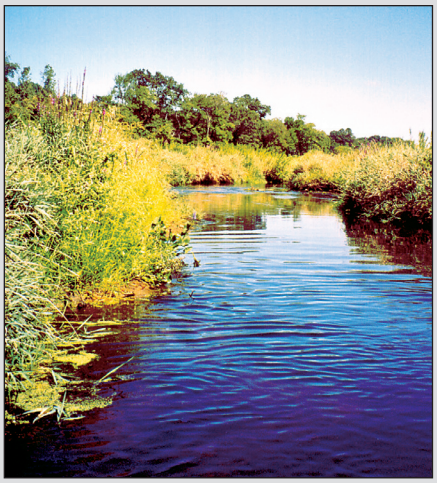
Concentrations of total mercury (which includes all forms of inorganic and organic mercury) were greatest in streambed sediments from streams in and near the urban center of Boston (fig. 9). These higher concentrations are likely related to greater amounts (or inputs) of mercury put on the landscape from the atmosphere and past and present wastewater discharges in urban areas around Boston as compared to more rural areas in southern New Hampshire and Maine (Pilgrim, 1998). The highest concentration for total mercury in streambed sediments was 3.1 µg/g in the Neponset River, which drains an urbanized watershed near Boston that has a long industrial history dating back to the early 1800s. Overall, mercury was detected in sediments in all 55 streams sampled, but only 7 percent of these sediment samples had concentrations that exceeded the guideline of 0.49 µg/g (microgram per gram) for protecting the health of aquatic life (Canadian Council of Ministers of the Environment, 1999) (fig. 9).

Elevated concentrations of total mercury in streambed sediments were not necessarily coincident with elevated concentrations of total mercury in fish. Concentrations of total mercury in fish fillets (typically from 2- to 3-year-old sunfish) were highest in less urbanized watersheds containing a mixture of forests and wetlands that are near urban areas (fig. 9). These less urbanized watersheds have lower concentrations of total mercury in streambed sediments than the more urbanized watersheds but have more favorable chemical and landscape characteristics (such as greater amounts of organic carbon in the water and wetlands in the watershed) for converting mercury to organic mercury (termed methylmercury), which is the most readily bioaccumulated form of mercury.

Overall, mercury was detected in fish fillets from all 27 sampled rivers in the basins. Mercury concentrations in fish fillets were greater than the USEPA's **human health advisory** of 0.3 µg/g for eating fish (U.S. Environmental Protection Agency, 2001a) in Black Brook, Beaver Brook, and the Nissitissit River in southern New Hampshire and the Ipswich River in northeastern Massachusetts (fig. 9). The highest concentra-

tion of total mercury in fish-fillet tissue among all sites was 0.40 µg/g (the average value of three samples) in the Ipswich River. The lowest concentration of total mercury in fish-fillet tissue was 0.04 µg/g in the highly urban Aberjona and Blackstone Rivers. None of the fish-fillet samples exceeded the **U.S. Food and Drug Administration human consumption action level** of 1 µg/g (wet-weight tissue) (U.S. Food and Drug Administration, 1984). Concentrations of mercury, however, are likely greater in older and larger game fish such as largemouth and smallmouth bass because these predatory fish are near the top of the food chain in rivers of the basins (but were not collected in this study).

Elevated concentrations of mercury in fish were related to the amount of wetlands in a watershed, which are affected by chemical and environmental variables such as the presence of organic matter and certain nutrients (nitrogen, phosphorus, and sulfate). (Photograph by M.L. Riskin, U.S. Geological Survey.)



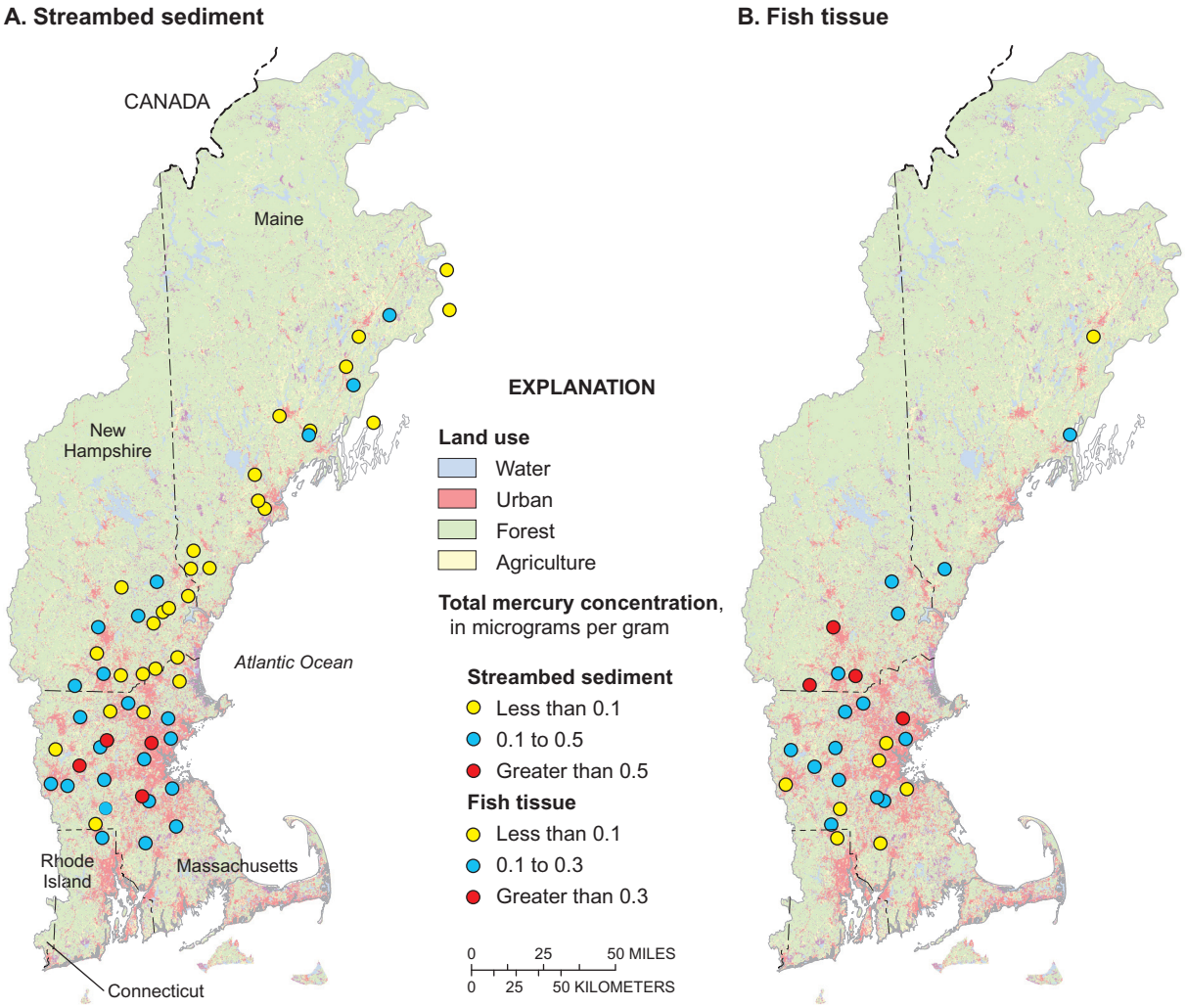
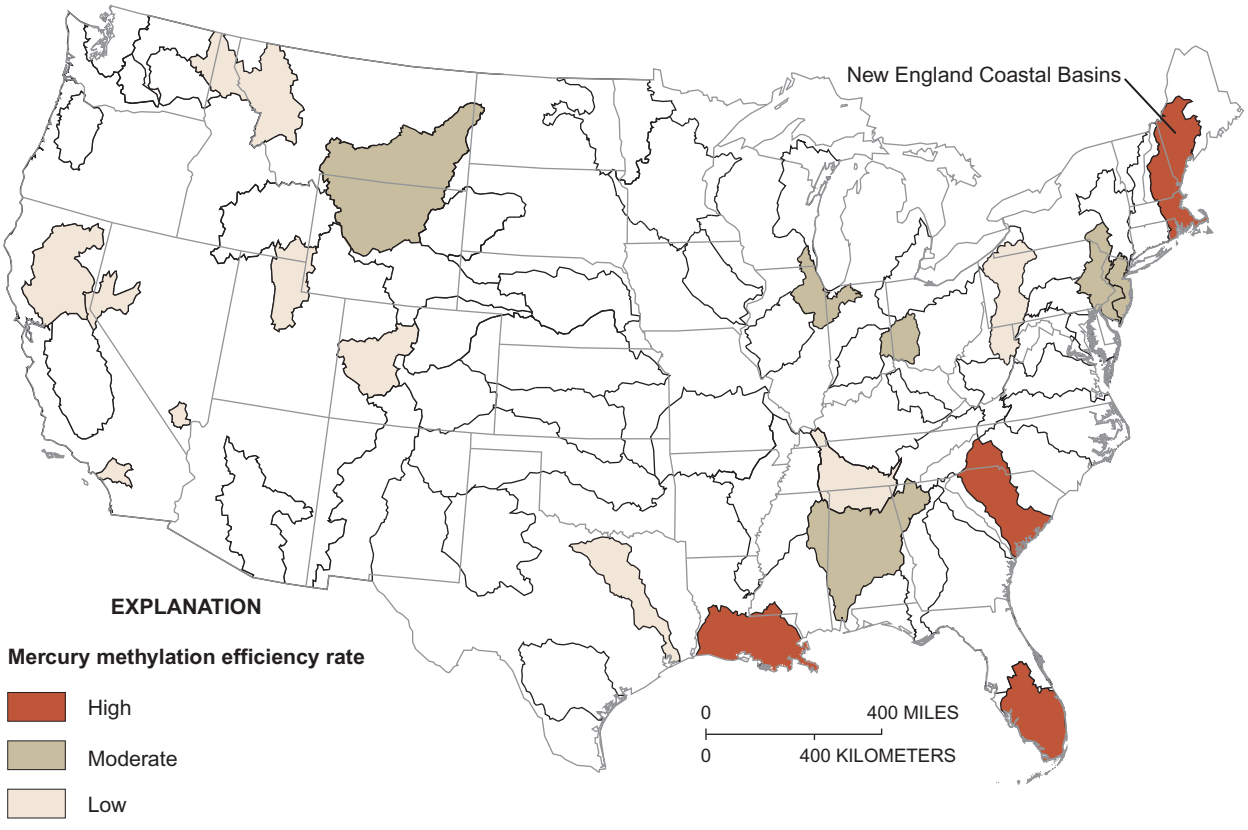


Figure 9. Concentrations of total mercury in streambed sediment (A) increased with increasing urbanization in the sampled watersheds, but total mercury in fish tissue (B) was greatest in less urbanized watersheds that are near urban centers.

NATIONAL PERSPECTIVE—Coastal Ecosystems in the Eastern United States are Highly Susceptible to Mercury Contamination

Environmental factors controlling the levels and production of methylmercury in water and streambed sediments were examined in 21 NAWQA basins across the Nation during the summer and fall of 1998 (Krabbenhoft and others, 1999). Wetland density was the single most important basin-scale factor controlling methylmercury levels and production. Enhanced production of methylmercury was found in four areas with wetland-rich stream ecosystems along the Gulf and Atlantic Coasts, including the New England Coastal Basins. The atmosphere is the dominant source of mercury to streams in the Eastern United States as atmospheric-deposition rates of inorganic mercury are elevated in this region of the Nation (Krabbenhoft and others, 1999). The high deposition rates of inorganic mercury, in combination with wetland-rich ecosystems, results in fish being highly susceptible to methylmercury contamination. Although the actual concentrations of mercury in fish fillets collected from the New England Coastal Basins were not the highest in the national study, they were among the highest when the results were adjusted for fish weight and size (Brumbaugh and others, 2001).



The percentage of total mercury that is in the methyl form (methylmercury) in water is known as the methylation efficiency rate and is an indication of how much mercury is readily available for accumulation in fish (Krabbenhoft and others, 1999). Methylation efficiency rates are greatest in wetland-rich areas along the Gulf and Atlantic coasts of the United States.

Mercury in the environment

Mercury contamination—Mercury is widespread globally, originating from natural and manmade sources such as mineral deposits, coal combustion, waste incineration, landfills, mining, and products such as paint, fluorescent lights, and thermometers. Mercury is usually released from these sources as a vapor and is transported throughout the atmosphere. Mercury can cause health problems in humans through consumption of contaminated fish; particularly sensitive are children and women of childbearing age. Elevated concentrations of mercury in fish were the leading cause of fish-consumption advisories reported by State agencies nationwide in 2001 (U.S. Environmental Protection Agency, 2002). All New England States except for Rhode Island have statewide advisories for children and women of childbearing age to limit consumption of certain predatory fish and seafood.

Types of mercury—Inorganic mercury, the predominant form emitted to the environment, is generally not a health risk; it is the organic form, methylmercury, that is highly toxic to the nervous system and is a contaminant that can affect the health of humans and wildlife. Methylmercury is produced in the environment from the methylation of inorganic mercury, a process that is controlled by certain bacteria and enhanced by chemical and environmental variables, such as the presence of organic matter. Of primary importance is the presence of abundant wetlands and forested stream corridors, which contain organic-rich, anaerobic (nonoxygenated) sediments with active sulfate-reducing bacteria (Gilmour and others, 1992; Ulrich and others, 2001; Wiener and others, 2002). More than 95 percent of all mercury in fish is methylmercury, and this form of mercury may accumulate and magnify to high concentrations at the top of food chains.

VOCs were Detected Frequently in Rivers and Ground Water

Thirty-four volatile organic compounds (VOCs) were detected at low concentrations (equal to or greater than 0.05 µg/L) in stream- or ground-water samples collected in the New England Coastal Basins. In the two rivers sampled for VOCs, the five most commonly detected compounds included the gasoline additive methyl *tert*-butyl ether (MTBE), the solvents trichloroethene (TCE), tetrachloroethene (PCE), and *cis*-1,2-dichloroethene (*cis*-1,2-DCE); and the disinfection byproduct and solvent chloroform (fig. 10). Nearly every stream sample from the highly urbanized Aberjona and Charles Rivers contained mixtures—at least four or more VOCs at concentrations greater than 0.05 µg/L—yet no concentrations exceeded established guidelines for the protection of aquatic life.

The most commonly detected compounds in ground water were MTBE, chloroform, 1,1,1-trichloroethane, *tert*-amyl methyl ether (TAME), and PCE (fig. 11). MTBE was the only VOC detected at a concentration above a **drinking-water standard** or **guideline**. VOC occurrence was greater in the sand and gravel aquifers of the basins than in the bedrock aquifers. Nearly 90 percent of the water samples from 30 public water-supply wells (with a median well depth of 54 ft) that pump water from sand and gravel aquifers contained at least one VOC (detected at a concentration equal to or greater than 0.05 µg/L). This result compares to detections of at least one VOC in 60 percent of 29 monitoring wells (median well depth of 22 ft) in sand and gravel aquifers and in 30 percent of 58 domestic (household) water-supply wells (median well depth of 282 ft) in bedrock aquifers.

MTBE was detected in all 23 water samples from the Aberjona River and in 28 of 29 samples from the Charles River, all at concentrations less than 5 µg/L. MTBE also was detected in about two-thirds of the public-supply wells, one-half of the monitoring wells, and nearly one-fifth of the domestic

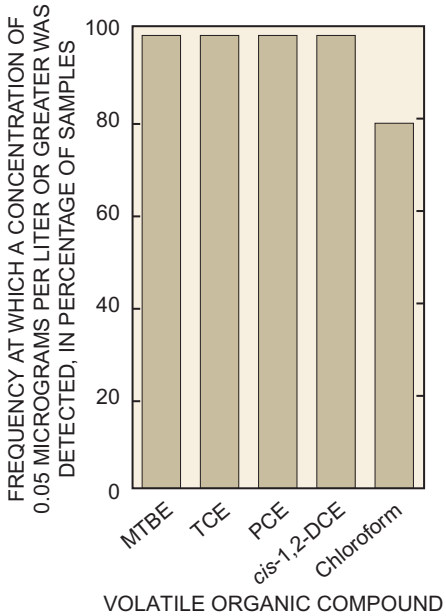


Figure 10. Five volatile organic compounds (VOCs) were commonly detected in water samples collected from the Aberjona and Charles Rivers near Boston, indicating that VOCs may be common in urban rivers of the basins.

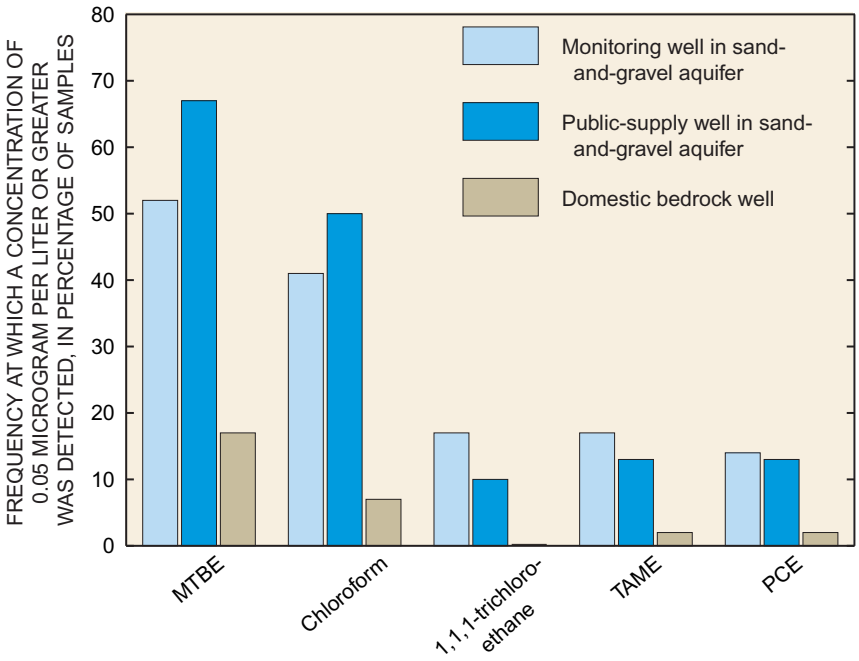


Figure 11. MTBE and chloroform were the most commonly detected volatile organic compounds in ground water of the New England Coastal Basins.

wells. The highest MTBE concentration detected in ground water was 267 µg/L from a monitoring well not used for drinking water, which is appreciably above the USEPA drinking-water guidelines for taste and odor of 20–40 µg/L (U.S. Environmental Protection Agency, 1997). All other ground-water samples had MTBE concentrations less than 10 µg/L. MTBE has been used as a gasoline oxygenate to improve air quality since 1979, but because of its widespread detection in ground and surface waters throughout the Nation some States have adopted or are considering legislation to ban or limit its use.

Chloroform, a solvent and trihalomethane (THM) compound formed in the chlorination of drinking water and wastewater, was detected in nearly 80 percent of water samples from the Aberjona and Charles Rivers and in samples from 50 percent of public-supply wells, 40 percent of monitoring wells, and 7 percent of domestic wells. The highest concentration in surface water was 1.9 µg/L in a sample from the Aberjona River, which is slightly below the Canadian guideline of 2 µg/L for protecting the health of aquatic life (Rowe and others, 1997). All concentrations of chloroform in ground water were less than 1.9 µg/L, which is substantially less than the USEPA drinking-water standard of 80 µg/L for total THMs. TCE and PCE were detected in nearly all streamwater samples but in less than 15 percent of the ground-water samples. These compounds are used in industrial and commercial degreasers and in household and dry-cleaning solvents. The highest concentration of any VOC measured in surface water was 17 µg/L for TCE in the Charles River, which is slightly less than the Canadian guideline of 21 µg/L for protecting the health of aquatic life.

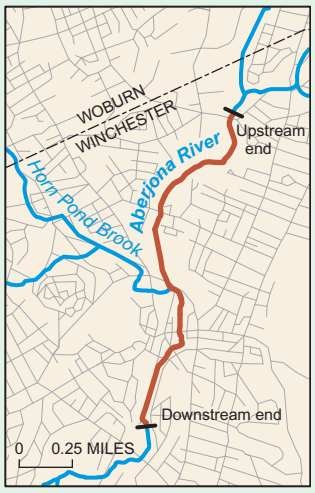
Additional Information

Sources of volatile organic compounds in water—Solvents and gasoline compounds enter surface water and ground water by way of accidental spills and releases from leaking underground fuel tanks and pipelines, surface spills and leaks, permitted releases to the environment, automobile emissions, and precipitation. Chloroform enters surface water and ground water from the watering of lawns with chlorinated drinking water and from leaky water mains, permitted releases in wastewater, or the use of solvents and cleaning agents (Lopes, 1999). (Photograph reprinted from Maine Department of Environmental Protection, and published with permission.)

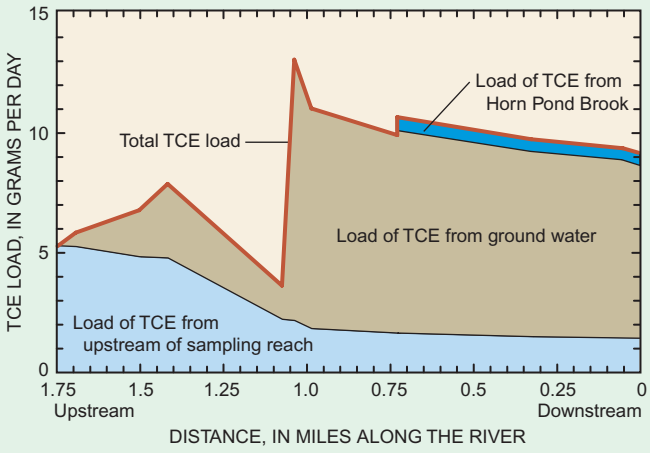
Contaminated ground water and leaking underground storage tank are primary sources of VOCs in the Aberjona River

The Aberjona River watershed, located north of Boston in Woburn and Winchester, Mass., is highly urbanized (68 percent urban land) and has had a long history of industrial activity that dates back to the early 1800s. The occurrence of VOC contamination in public drinking-water wells near the Aberjona River and its possible health effects on Woburn residents are chronicled in the book "A Civil Action" (Harr, 1995).

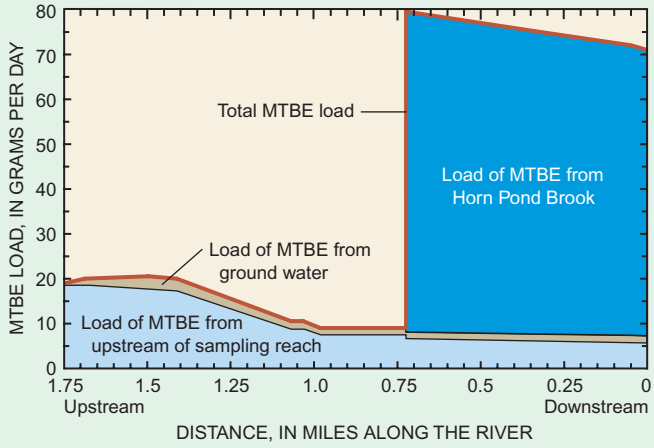
Water samples from the river and ground water just beneath the streambed were collected and analyzed for VOCs at 14 sites along a 1.75-mile river reach and a tributary, Horn Pond Brook, to assess sources and transport of VOCs in the watershed. Study results indicate that the solvents TCE and PCE likely entered the Aberjona River as contaminated ground-water inflow in Winchester as a result of historical releases of these chemicals to ground water. The amount (load) of MTBE in the Aberjona River increased abruptly at the confluence with Horn Pond Brook, which became contaminated with MTBE as a result of a leaking underground gasoline storage tank that has since been removed. The brook, however, continues to receive ground water containing MTBE and transports it to the Aberjona River. These findings suggest that rivers in urbanized watersheds, like the Aberjona, can potentially be receiving contaminated waters after the source of the contamination has been eliminated.



Sampling reach along the Aberjona River, in Winchester, Mass.



Contaminated ground water is the primary source of TCE and PCE (not shown), in the sampling reach, to the Aberjona River in Winchester, Mass.



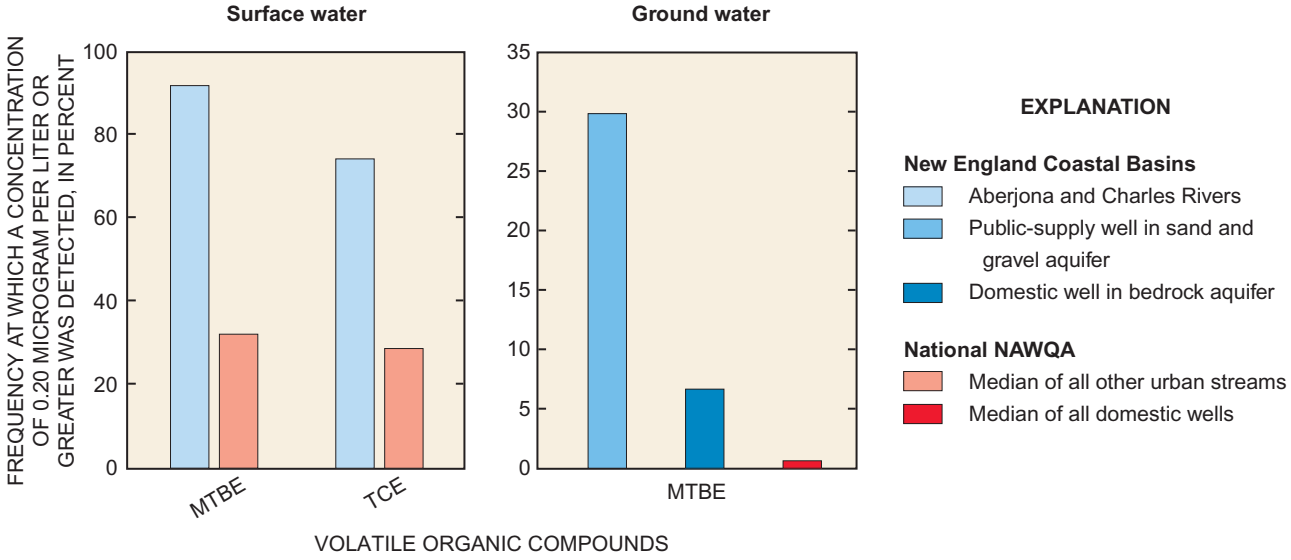
Ground water contaminated by an underground gasoline storage tank in the Horn Pond Brook watershed is the primary source of MTBE, in the sampling reach, to the Aberjona River in Winchester, Mass.

Collecting a ground-water sample beneath the streambed of the Aberjona River. (Photograph by K.W. Robinson, U.S. Geological Survey.)

NATIONAL PERSPECTIVE—VOCs are Detected More Frequently in the New England Coastal Basins than in the Rest of the Nation

The widespread use of MTBE in gasoline, together with a long history of industrial activity in New England, may explain why the occurrence of VOCs is more common in waters in the New England Coastal Basins than in waters in other urban areas of the Nation. The frequency of MTBE and trichloroethene (TCE) detection in the Aberjona and Charles Rivers was greater than the median detection frequency of these VOCs in 20 other urban rivers sampled across the Nation by the NAWQA Program.

Similarly, MTBE was detected more frequently in public and domestic drinking-water wells in the New England Coastal Basins than in the median of domestic drinking-water wells elsewhere in the Nation. MTBE was detected in ground water from nearly 40 percent of the 29 shallow monitoring wells in the Boston metropolitan area compared to a detection of MTBE in 13 percent of 840 similar monitoring wells in other metropolitan areas throughout the Nation (not shown in figure).



MTBE and TCE were detected twice as often in the Aberjona and Charles Rivers near Boston, Mass., than they were in 20 other urban streams in the Nation. MTBE was detected more frequently in ground water from the two major aquifers in the New England Coastal Basins than in other major aquifers of the Nation. Number of detections in the New England Coastal Basins compared to other basins in the Nation were assessed at the national reporting level of 0.2 microgram per liter.

Detailed information on VOCs and other contaminants in monitoring wells in the Boston area is in the following report:

Shallow ground-water quality in the Boston, Massachusetts, metropolitan area, by S.M. Flanagan and others; U.S. Geological Survey Water-Resources Investigations Report 01–4042 at **http://pubs.water.usgs.gov/wri014042**

Pesticides were Detected Frequently in Streams but Rarely in Ground Water

Low concentrations of pesticides, between 0.005 and 0.5 µg/L, were found in 19 of 31 streams sampled in the New England Coastal Basins. Overall, the frequency and concentrations of pesticides increased with increasing urbanization; watersheds with less than 5 percent urban land usually had no pesticide detections above 0.005 µg/L. The most commonly detected pesticides were the insecticides diazinon and carbaryl and the herbicides prometon, atrazine, and simazine (fig. 12); all five of these pesticides are commonly used in urban areas.

Pesticide sampling during 1999 and 2000 in the highly urbanized Aberjona and Charles Rivers watersheds found that pesticides were detected in most samples. At least one pesticide compound was detected in 98 percent of 50 water samples collected from the Aberjona River and in 70 percent of 20 water samples from the Charles River near Boston. Out of a total of 44 pesticides and 4 pesticide degradation products analyzed for in the water samples, 11 herbicides, 3 insecticides, and 1 herbicide degradation product were detected at or above 0.005 µg/L in these two rivers. In the Aberjona River, nearly 15 percent of the water samples exceeded the diazinon guideline of 0.08 µg/L for protecting the health of aquatic life (International Joint Commission, 1977) and 6 percent exceeded the 0.20 µg/L aquatic-life protection guideline for carbaryl (Canadian Council of Ministers of the Environment, 1999). Elevated concentrations typically were seasonal, in that exceedances occurred in spring and summer, when use of these insecticides for household and yard insect control is greatest. Diazinon has been used outdoors on lawns and gardens to control insects, grubs, and (turf) nematodes and indoors for fly control and for veterinary use to control fleas and ticks through pet collars. In 2001, the USEPA began phasing out the use of diazinon. None of the other 29 rivers sampled had insecticide concentrations exceeding aquatic-life-protection guidelines.

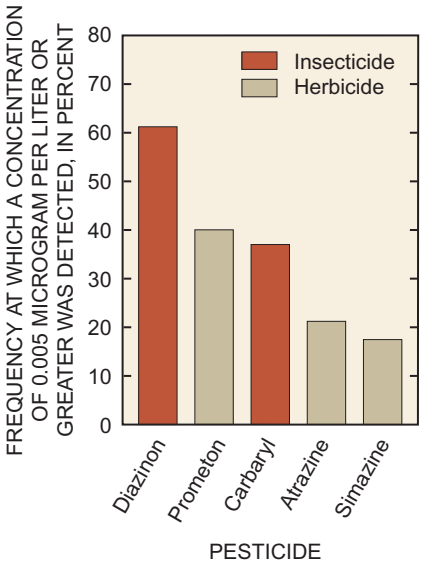


Figure 12. Diazinon, prometon, carbaryl, atrazine, and simazine were the most commonly detected pesticides in 31 rivers in the New England Coastal Basins.

Concentrations of the herbicides atrazine and simazine used to control vegetation around homes, commercial centers, and on agricultural lands were below guidelines for protecting the health of aquatic life. No guidelines have been established for prometon, the most commonly detected herbicide, which is used to control weeds along roadways and utility rights-of-way.

Only 5 of 44 pesticides, the herbicides simazine, tebuthiuron, atrazine, and prometon and the pesticide degradation compound deethyl atrazine, were detected at concentrations equal to or greater than 0.005 µg/L in ground-water samples from drinking-water wells in the basins (fig. 13). All pesticide concentrations were less than 0.20 µg/L, and none exceeded USEPA drinking-water standards.

Herbicides were detected more frequently in water from the public-supply wells completed in sand and gravel aquifers (30 percent of 29 wells) than in water from domestic wells completed in bedrock aquifers (10 percent of 56 wells). This result is because the relatively shallow and permeable sand and gravel aquifers are more susceptible to downward movement of pesticides from the land surface than are the deeper bedrock aquifers. The highest pesticide concentration in ground water was 0.18 µg/L for tebuthiuron from a public-supply well in Massachusetts. In New England, tebuthiuron is commonly used to control plant growth in powerline and pipeline rights-of-way.

The absence of diazinon and carbaryl in ground waters of the basins, despite their high rate of detection in the urban rivers, demonstrates that these insecticides are less soluble in water and, therefore, less likely to migrate to and be detected in ground-water systems than herbicides. Highly water-soluble herbicide compounds, such as atrazine, move more readily to the water table and deeper ground water.

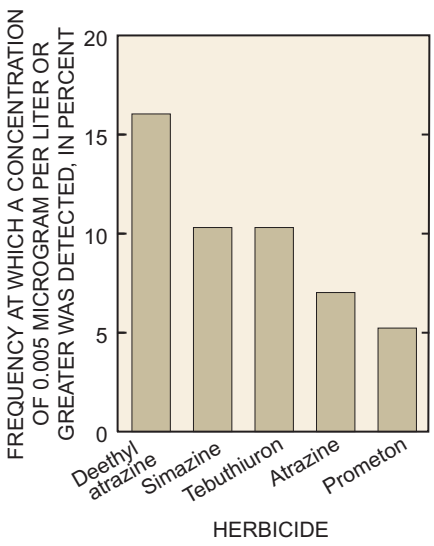


Figure 13. Only four herbicides and one herbicide degradation product were detected in ground water at concentrations at or above 0.005 microgram per liter in public-supply and domestic drinking-water wells in the New England Coastal Basins. All concentrations were well within drinking-water standards.

Nitrogen and Phosphorus Concentrations in Streams are Related to Urbanization

The water quality of about 40 percent of the Nation's waterways is degraded as a result of elevated concentrations of nutrients (nitrogen and phosphorus) (U.S. Environmental Protection Agency, 2000a). Elevated nutrient concentrations in streams can result in excessive algal growth, low concentrations of dissolved oxygen, fish-kills, turbid water, and loss of desirable flora and fauna—all symptoms of **eutrophication** in water bodies.

Nationally, nutrient concentrations are greater in urban and agricultural streams than in forested (referred to as "reference") streams (U.S. Geological Survey, 1999). Sampling of nine rivers in the New England Coastal Basins found results similar to those reported nationally. Mean concentrations of total nitrogen (after being adjusted for variations in streamflow, termed "flow-weighted") ranged from 0.4 mg/L in the forested Kennebec River watershed in Maine to 2.6 mg/L in the highly urbanized Aberjona River watershed in Massachusetts (fig. 14). Nitrogen in the nine rivers is predominantly in the form of dissolved nitrate and organic nitrogen, indicating that most of the nitrogen is from nonpoint sources such as atmospheric deposition, fertilizers, and ground-water inflow. The one exception is the Aberjona River, where nearly 30 percent of the nitrogen is dissolved ammonia, most likely originating from combined sewer overflows and(or) illegal connections to storm drains (Campo and others, 2003). None of the streamwater samples exceeded the drinking-water standard of 10 mg/L for nitrate, which is the only form of nitrogen with an established standard (U.S. Environmental Protection Agency, 2000b). Findings from NAWQA monitoring of rivers throughout the Nation show that nonpoint nitrogen contamination is a major issue in urban areas (U.S. Geological Survey, 1999). Reducing the amount of nitrogen in rivers will depend not only on improved infrastructure (such as expanding and upgrading sewer lines) but also on management of urban nonpoint sources such as pet waste, residential use of fertilizers, and runoff to storm drains.

Collecting a depth- and width-integrated water sample in a river in Massachusetts. (Photograph by J.R. Deacon, U.S. Geological Survey.)

Among the nine rivers sampled, flow-weighted mean concentrations of total phosphorus ranged from less than 0.008 mg/L in four rivers (the Kennebec River in Maine and the Stillwater, Wading, and Ipswich Rivers in Massachusetts) to 0.071 mg/L in the Merrimack River in Massachusetts. Higher phosphorus concentrations in the Merrimack River (as compared to other rivers sampled) are due to nearly 50 permitted municipal wastewater discharges upstream from the sampling site in Lowell, Mass. Nearly 25 percent of the phosphorus concentrations in water samples from the Merrimack River and 16 percent from the Charles River exceeded the U.S. Environmental Protection Agency goal of 0.10 mg/L, which is designed to prevent excessive plant growth in streams (U.S. Environmental Protection Agency, 2001b). Most of the phosphorus in streams in the basins is in the suspended form and likely originates from soil erosion (Campo and others, 2003). Measures implemented to control erosion may, therefore, help to reduce nonpoint sources of phosphorus.

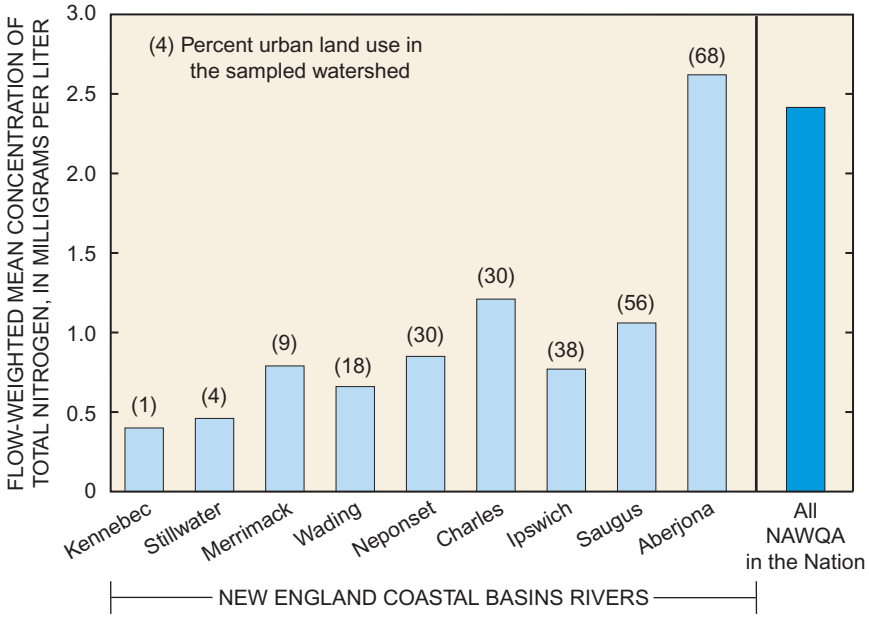
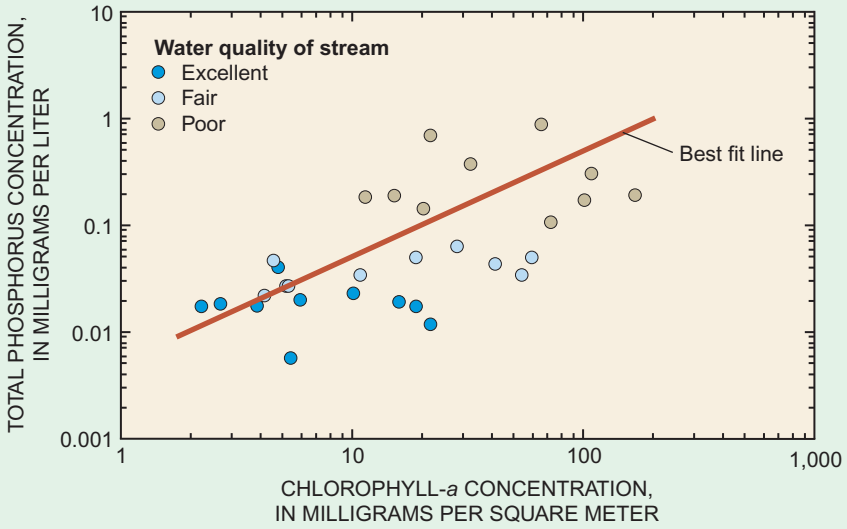


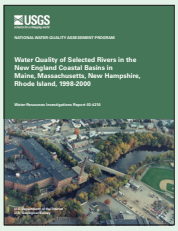
Figure 14. Mean flow-weighted concentrations of nitrogen in nine New England Coastal Basins rivers increased with increasing amounts of urban land in the watershed, but most concentrations are still less than the mean of 477 rivers monitored across the Nation by the NAWQA Program from 1992 to 2001.

Water-quality data can assist in developing regional nutrient criteria

Because high concentrations of nutrients are a frequent cause of degraded stream quality in the Nation, the USEPA, in partnership with other Federal agencies, States, and Tribes, is in the process of developing nutrient criteria to help define acceptable concentrations of nutrients in rivers and streams (U.S. Environmental Protection Agency, 2000a). The USEPA has proposed a regional approach whereby nutrient criteria are designated by ecoregions because of the geographic and environmental variability of nutrients in surface waters across the Nation. In support of nutrient-criteria development, 13 wadeable streams within the Northeastern Coastal Zone ecoregion were sampled for phosphorus and periphyton chlorophyll-*a*, which are indicators of algal growth on streambeds (Riskin and others, 2003). Nutrient and algal sampling at 6 of the 13 streams, all unshaded stream sites, found that chlorophyll-*a* concentrations around 16 mg/m^2 (milligrams per square meter) were associated more often with a phosphorus concentration of about 0.08 mg/L or higher. A chlorophyll-*a* concentration of more than 16 mg/m^2 generally was found in streams considered by the USEPA to have poor water quality because of excessive plant growth. This general relation can be used in the process, along with other water-quality evaluations, to define acceptable phosphorus levels in streams of the Northeastern Coastal Zone ecoregion.

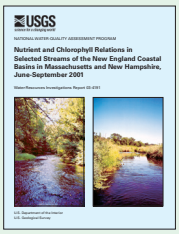


The concentrations of chlorophyll-*a* and phosphorus generally are related in New England Coastal Basins streams. This relation can be used in evaluating acceptable levels of phosphorus in streams. Characterizations of the water quality of streams are defined in Riskin and others (2003).



Detailed information on nutrients, VOCs, and pesticides in streams in the New England Coastal Basins is in the following report:

Water quality of selected rivers in the New England Coastal Basins (Maine, Massachusetts, New Hampshire and Rhode Island), 1998–2000, by K.W. Campo and others; U.S. Geological Survey Water-Resources Investigations Report 03–4210 at **http://pubs.water.usgs.gov/wri034210**



Detailed information on nutrients and chlorophyll in selected streams in the New England Coastal Basins is in the following report:

Nutrient and chlorophyll relations in selected streams of the New England Coastal Basins in Massachusetts and New Hampshire, June-September 2001, by M.L. Riskin and others; U.S. Geological Survey Water-Resources Investigations Report 03–4191 at **http://pubs.water.usgs.gov/wri034191**

Drinking-Water Standard for Nitrate Rarely Exceeded in Ground Water

Concentrations of nitrate in ground water underlying the New England Coastal Basins generally were low and less than concentrations detected in similar ground-water studies done by the NAWQA Program across the Nation (fig. 15). Concentrations of nitrate in only 1 of the 117 wells sampled exceeded the USEPA drinking-water standard of 10 mg/L (U.S. Environmental Protection Agency, 2000b). This one sample was collected from a shallow monitoring well (less than 25 feet deep) in a sand and gravel aquifer underlying urban land in the Boston metropolitan area (Flanagan and others, 2001). Although shallow sand and gravel aquifers underlying urban lands generally are not used as sources of drinking water, the potential for nitrate-enriched water in these aquifers to reach supply sources (including public-supply wells) may be cause for concern.

Concentrations of nitrate were low (a median of 0.7 mg/L) in ground water collected from 30 public-supply wells completed in the sand and gravel aquifers throughout the basins (fig. 15). None of the samples from the 30 wells exceeded a concentration of 3 mg/L. Concentrations above 3 mg/L likely reflect contamination from human influences, such as fertilizer applications and septic-tank effluent. The relatively good quality of the public well water may be due to many factors, such as nutrient-poor soils and the small amount of agricultural lands in the basins. In addition, water pumped for public-supply wells generally represents a mix of shallow and deep water in the sand and gravel aquifers; deep water is typically less vulnerable to surface contamination.

Nitrate was low in domestic wells in bedrock aquifers—less than 0.05 mg/L in nearly 60 percent of 58 well samples (fig. 15). In four domestic wells (7 percent), however, nitrate concentrations exceeded 3 mg/L, which indicates that bedrock aquifers are also susceptible to contamination. The maximum detected concentration (8.9 mg/L) was in a domestic well completed in bedrock in a rural and agricultural setting in Maine. Homeowners may not be aware of elevated nitrate in their well water because these wells are typically not monitored on a routine basis. In addition, many homeowners in newly established residential areas that rely on domestic wells for drinking water are not aware that nitrate and other chemicals from previously farmed land can remain in the ground water for decades as a result of its slow movement.

Collecting a water sample from a domestic well in Maine. (Photograph by K.W. Robinson, U.S. Geological Survey.)

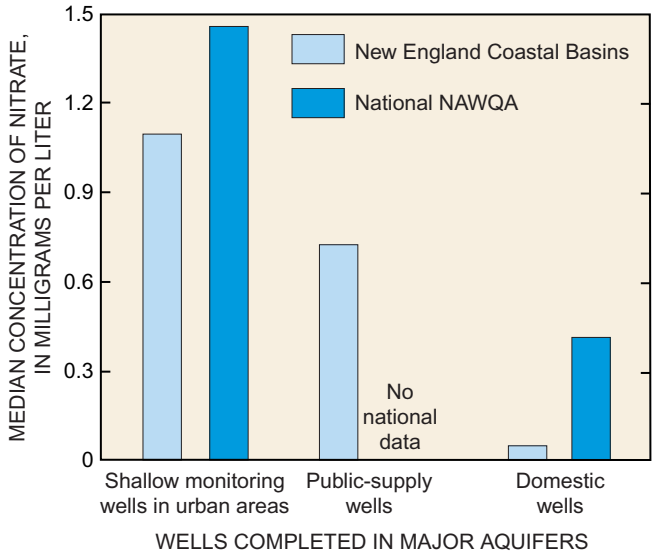


Figure 15. Concentrations of nitrate in ground water of the New England Coastal Basins were generally less than concentrations found in similar ground-water studies done by the NAWQA Program throughout the Nation.

Arsenic is Common in New England Ground Water

The presence of arsenic in drinking water has been associated with adverse health effects such as human cancers. Because of these human health concerns, the USEPA lowered the drinking-water standard for arsenic in water from 50 to 10 µg/L in 2001; this standard will become effective by January 2006 (U.S. Environmental Protection Agency, 2001c).

Concentrations of arsenic are common in New England ground water, as shown by water-quality data collected from more than 1,800 wells used for public supply. Specifically, concentrations in potable, untreated water samples (as opposed to actual treated drinking water) equaled or exceeded the USEPA drinking-water standard of 10 µg/L in 11 percent of wells completed in bedrock aquifers and in 3 percent of wells completed in sand and gravel aquifers (fig. 16) (Ayotte and others, 2003). The data also indicated that arsenic concentrations in ground water greater than 10 µg/L are found primarily in the east-

ern parts of New England—coincident with the location of the New England Coastal Basins and where **calcareous metamorphic bedrock** is present. Concentrations of arsenic in 20 percent of water samples from this type of bedrock exceeded 10 mg/L, whereas less than 10 percent of samples from other types of bedrock exceeded the standard (Ayotte and others, 1999).

Similarly, NAWQA analysis of samples from domestic wells in bedrock found that water from nearly 30 percent of 28 wells completed in the calcareous metamorphic bedrock exceeded the standard of 10 µg/L, compared to 7 percent of 30 wells completed in **igneous and other metamorphic bedrock** (fig. 17) (Ayotte and others, 2003). The maximum arsenic concentration was 51 µg/L, in a sample from a domestic well in Maine. Only 1 sample from 30 public-supply wells completed in sand and gravel aquifers exceeded 10 µg/L (fig. 17). None of the 29 shallow monitoring wells in sand and gravel aquifers in the Boston metropolitan area had water with arsenic exceeding 10 µg/L (Flanagan and others, 2001). The review of existing ground-water quality data for public-supply systems and the data collected by NAWQA indicate a possible geologic source of arsenic in New England ground water (Ayotte and others, 2003).

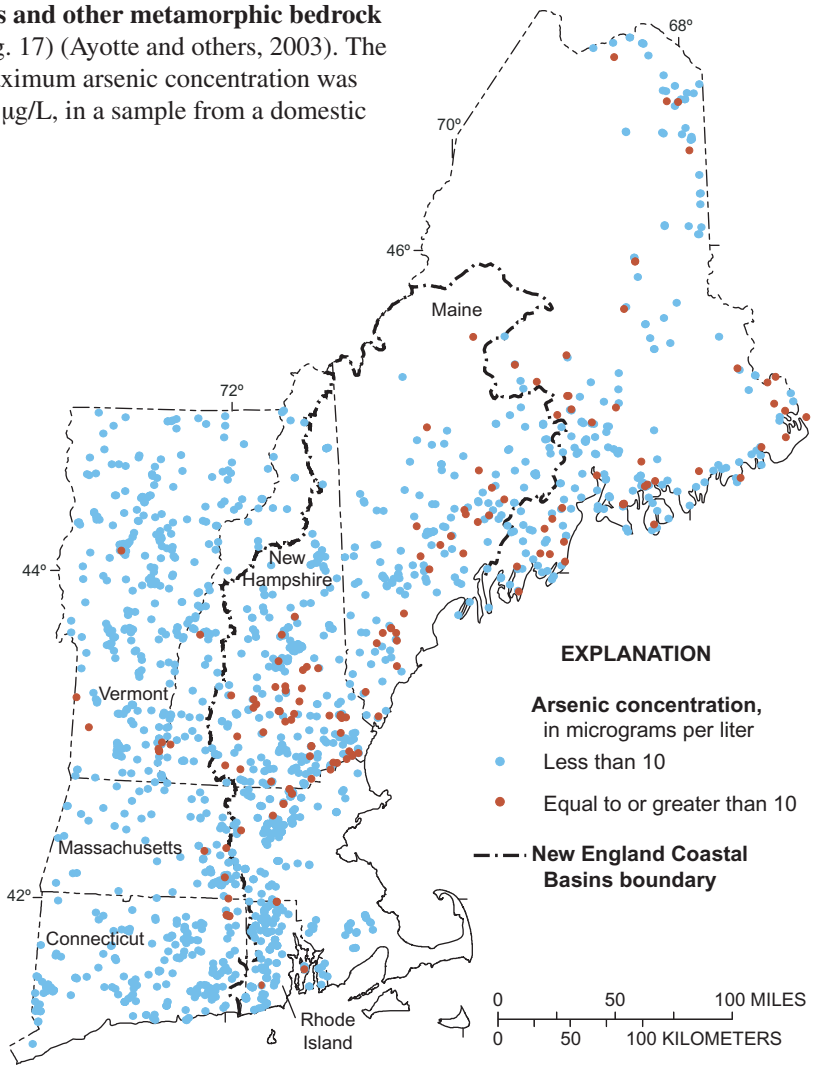


Figure 16. The concentration of arsenic in about one out of nine wells in bedrock aquifers used as a source of public drinking water in New England exceeded the U.S. Environmental Protection Agency's 10-µg/L drinking-water standard. Most of these wells (shown as red circles) are in eastern New England.

Domestic wells are at risk of tapping water with elevated arsenic concentrations

As many as 103,000 people using household bedrock wells in the basins may be drinking water with concentrations of arsenic exceeding 10 µg/L (Ayotte and others, 2003). Most of these people live in eastern New Hampshire and Maine, one of the fastest growing regions of New England. This growing population is increasingly reliant on water from bedrock aquifers to serve drinking-water and other domestic needs. These estimates emphasize the need for homeowners to routinely test their well water for arsenic.

Geochemical conditions control arsenic variability in ground water

Sulfide minerals associated with calcite, such as pyrite and pyrrhotite, most likely are important naturally occurring sources of arsenic in ground water (Welch and others, 2000; Ayuso and others, 2002). Variability in concentrations of arsenic in New England ground water results largely from differences in aquifer materials and the natural chemistry of water that combine to control the release of arsenic into ground water. For example, water in the calcareous metamorphic bedrock aquifers commonly is alkaline (pH greater than 7) with less than 1 mg/L of dissolved oxygen; these conditions favor the release of arsenic from the aquifer materials, such as iron oxides. Water in the sand and gravel aquifers generally is acidic (pH less than 7) with detectable dissolved oxygen—greater than 1.0 mg/L; these are conditions that generally inhibit the release of arsenic (fig. 18).

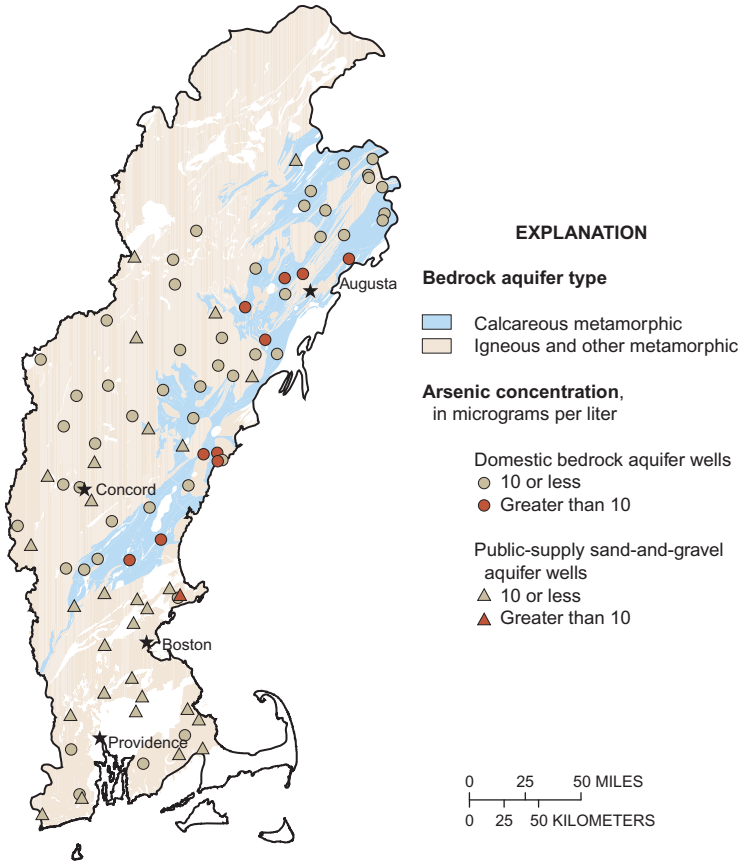


Figure 17. NAWQA sampling of wells found arsenic concentrations exceeded the U.S. Environmental Protection Agency drinking-water standard of 10 micrograms per liter more frequently in the calcareous metamorphic bedrock aquifers than in other types of aquifers. (The areal extent of the sand and gravel aquifers is shown on page 28).

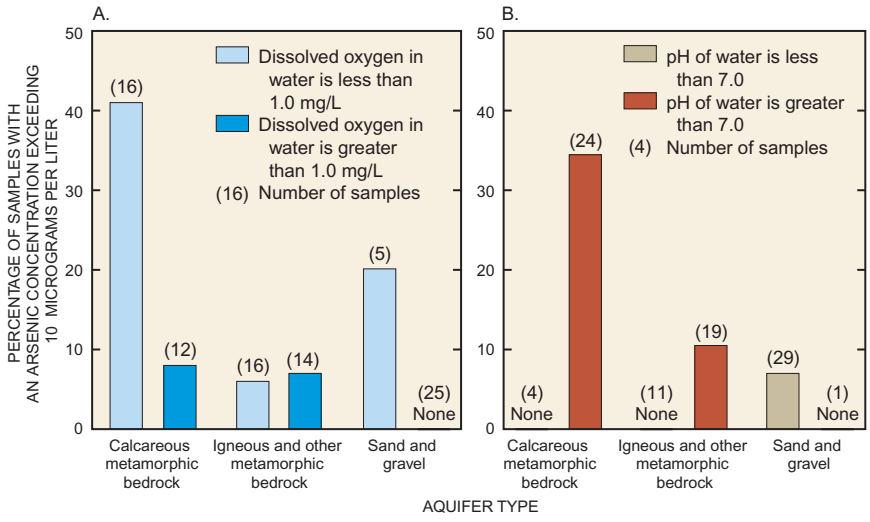


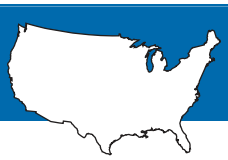
Figure 18. Arsenic concentrations exceeding 10 micrograms per liter are found most frequently in ground water (A) that has minimal dissolved oxygen and (B) is alkaline (pH greater than 7).

Radon Exceeded Proposed Standards in Most Ground Water

Water samples from 97 percent of the 115 monitoring, public-supply, and domestic wells sampled in the New England Coastal Basins contained radon that exceeded the U.S. Environmental Protection Agency (1999b) proposed drinking-water standard of 300 pCi/L (**picocuries** per liter). The median concentrations of radon from NAWQA sampling of bedrock wells in the basins was nearly 2,200 pCi/L; this highlights the fact that much of the bedrock in New England contains ground water with levels of radon far above 300 pCi/L. These results confirm previous studies noting that bedrock aquifers in New England contain waters with elevated radon. Radon is a colorless and odorless gas that forms naturally in rocks and soils through the radioactive decay of uranium. Radon from ground water is released into household air when water is used for showering, washing, or 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 (National Academy of Sciences, 1999).

The USEPA also has proposed an Alternative Maximum Contaminant Level (AMCL) of 4,000 pCi/L. To comply with the AMCL, plans must be developed for an indoor air radon-reduction program to reduce radon concentrations in drinking water to 4,000 pCi/L or less. None of the water samples from 30 public-supply wells in sand and gravel aquifers exceeded the AMCL for radon.

Testing for radon in water from domestic bedrock wells is generally not required, yet sampling found that water from many of these wells is likely to contain high concentrations of radon. Nearly 45 percent of 29 water samples from domestic wells completed in igneous and metamorphic bedrock and 15 percent of 27 water samples in domestic wells completed in calcareous metamorphic bedrock exceeded the AMCL for radon. The highest radon concentration was 220,000 pCi/L, in a domestic well completed in igneous rock in New Hampshire. This also was the highest radon value measured in the Nation as part of the NAWQA Program.



NATIONAL PERSPECTIVE—Arsenic is Common in Ground Water Throughout the Nation

Analysis of samples from more than 30,000 wells across the Nation by the USGS indicated that ground waters of the Nation typically contain arsenic concentrations less than 10 µg/L (Welch and others, 2000). Moderate to high concentrations of arsenic (10 to 50 µg/L), however, occur in some areas—including the West and parts of the Midwest and Northeast—in geographic patterns related to geology and ground-water chemistry (Focazio and others, 1999; Welch and others, 2000).

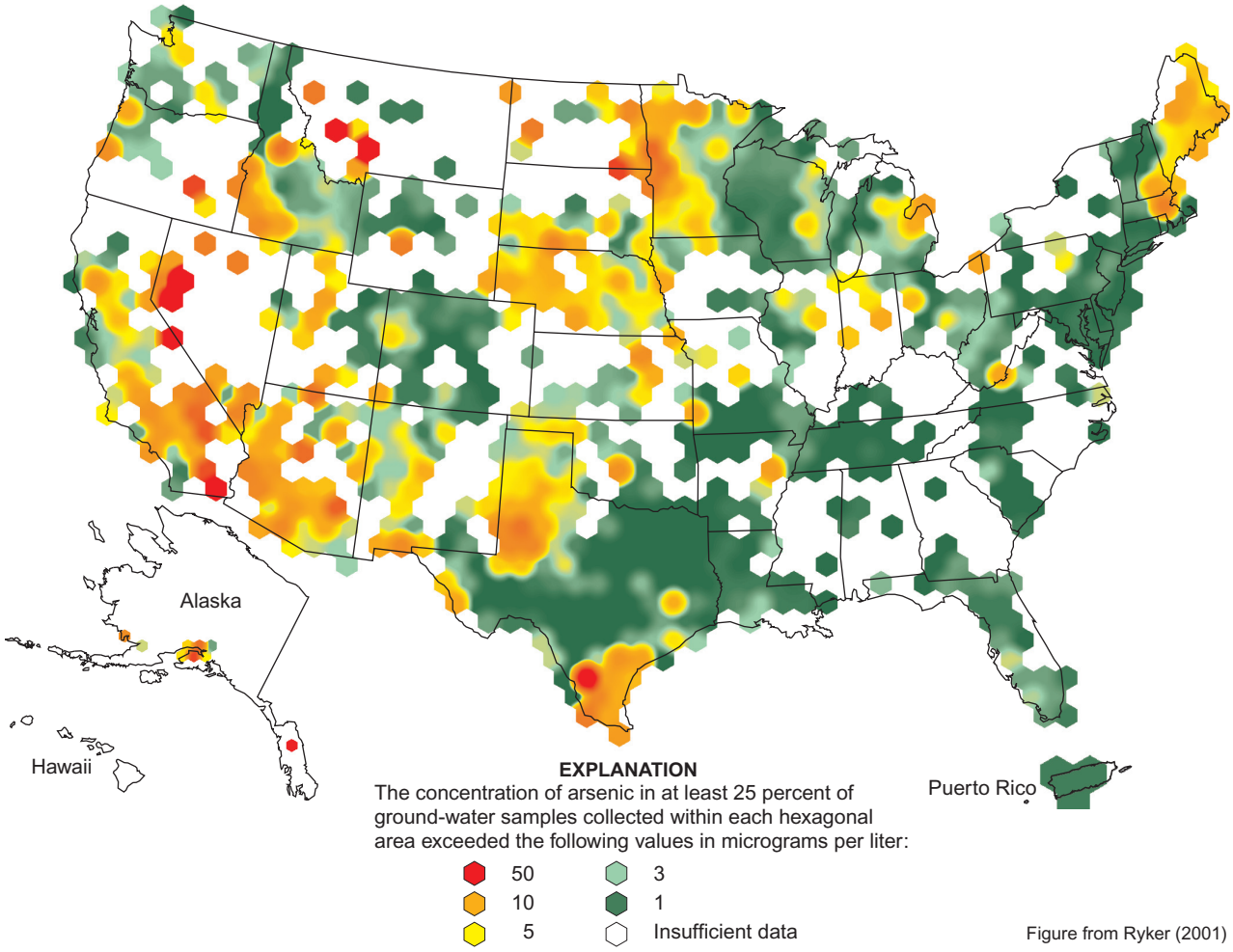
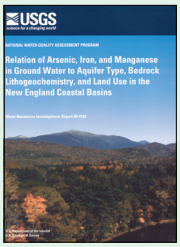


Figure from Ryker (2001)



Detailed information on arsenic in ground water of the New England Coastal Basins is in the following reports:

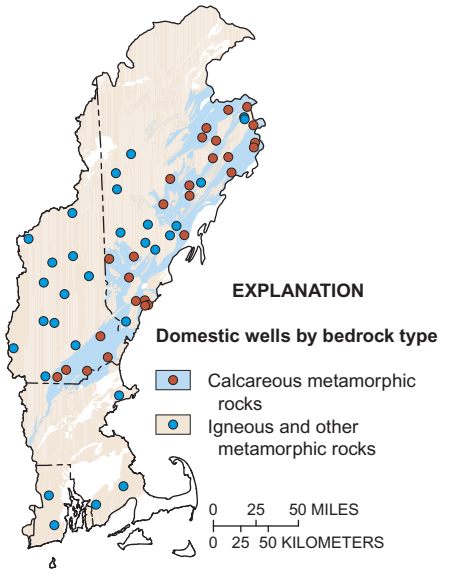
Relation of arsenic, iron, and manganese in ground water to aquifer type, bedrock lithogeochemistry, and land use in the New England Coastal Basins, by J.D. Ayotte and others; U.S. Geological Survey Water-Resources Investigations Report 99–4162 at **http://pubs.water.usgs.gov/wri994162**

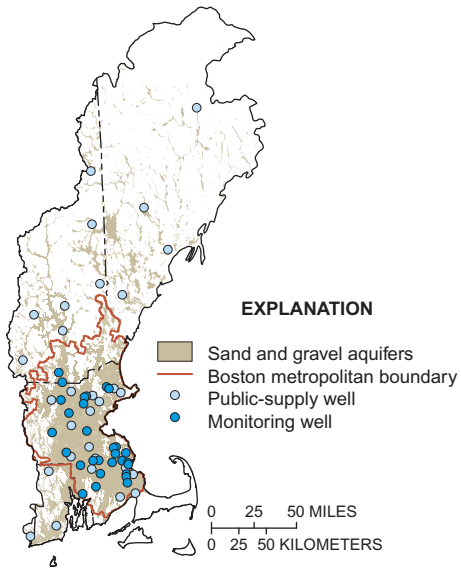
Arsenic in groundwater in eastern New England: Occurrence, controls, and human health implications, by J.D. Ayotte and others: *in Environmental Science & Technology, 2003,* v. 37, no. 10, p. 2075–2083 at **http://nh.water.usgs.gov/Publications/es026211g.pdf**

Study-Unit Design

Ground-Water Chemistry

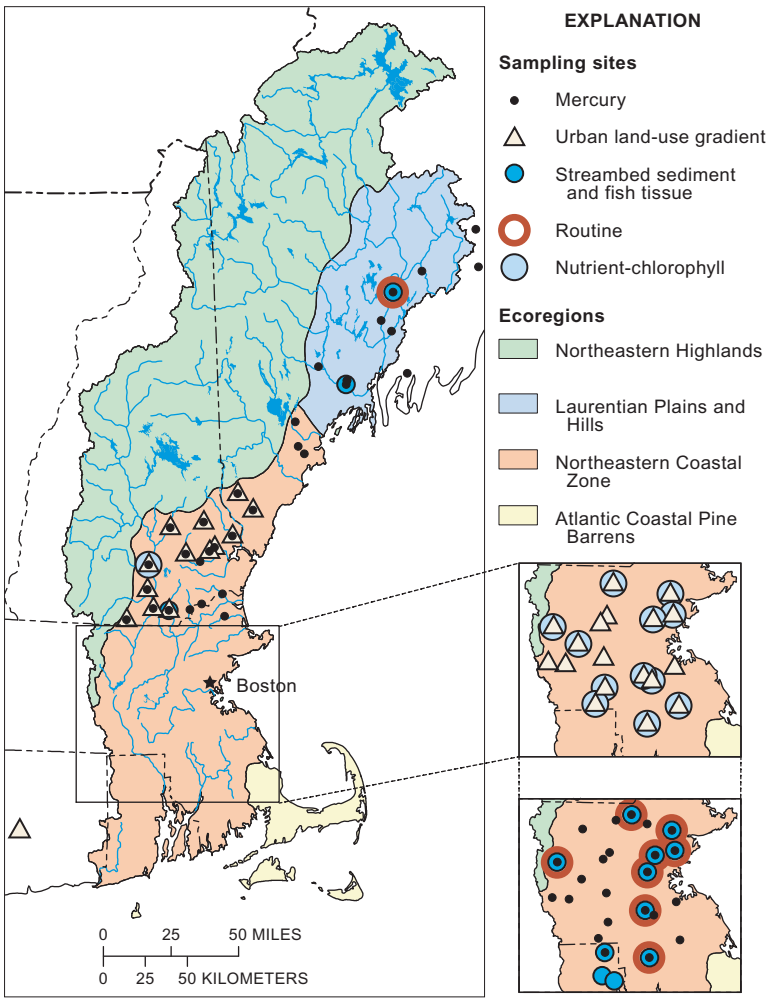
Ground-water studies were done in three drinking-water-supply aquifers to evaluate how the quality differed among the major aquifers of the basins. Specifically, public-supply wells completed in sand and gravel aquifers and domestic wells completed in two groups of bedrock aquifers were sampled. Special emphasis was placed on determining how arsenic and radon concentrations differed between the aquifers. The quality of shallow ground water underlying newly urbanized lands throughout the Boston metropolitan area was investigated by the installation and sampling of monitoring wells in the sand and gravel aquifer.





Stream Chemistry and Aquatic Ecology

Streams were sampled primarily in the Northeastern Coastal Zone ecoregion to evaluate how different amounts of urbanization affected stream chemistry and aquatic ecosystems in small, wadeable streams and in large rivers. Most of this sampling was done in and around the Boston metropolitan area. Stream-sampling frequency ranged from one time only to weekly, depending on the study and type of sampling site.



Summary of major data collection activities for the New England Coastal Basins Study Unit, 1999–2001

Study component	What data were collected and why	Types of sites sampled	Number of sites sampled	Sampling frequency and period
Stream Chemistry and Aquatic Ecology				
Routine stream-monitoring sites	Streamflow measured continuously and samples collected for major ions, nutrients, organic carbon, and suspended sediment to describe concentrations, seasonal variability, and loads.	Streams draining watersheds ranging in size from 23.3 to 5,411 square miles and representing a range of urban, forested, and mixed land uses in the Northeast Coastal Zone ecoregion.	9	Monthly, plus 2–6 extreme high and low flows (October 1998–September 2000)
Intensive stream-monitoring sites	In addition to the above constituents, samples were analyzed for volatile organic compounds and dissolved pesticides to determine concentrations and seasonal variability.	Two of the routine sites, Aberjona and Charles Rivers, draining primarily urban land uses.	2	Weekly to biweekly depending on season (October 1998–September 2000)
Streambed sediments and fish tissue study	Streambed sediments and fish tissue were analyzed for trace elements, hydrophobic pesticides, and other organic compounds to determine occurrence.	Sediment deposition zones and either fillets or whole body of white sucker or bass from all rivers representing urban and mixed land uses in the Northeast Coastal Zone ecoregion.	14 (sediments), 12 (fish tissue)	Once, summer 1998 or 1999
Mercury study	Total and methylmercury, organic carbon, and sulfate were collected from water and streambed sediments; and total mercury in fillets of 2- to 3-year-old sunfish to determine occurrence in relation to urbanization and patterns of atmospheric deposition of mercury.	Routine monitoring sites and other sites representing urban, forested, and mixed land uses in the Northeastern Coastal Zone and Laurentian Plains and Hills ecoregions.	55 (water and sediment), 27 fish tissue	Once, summer or fall 1998–2000
Ecological routine-site reach assessment	Fish, benthic invertebrates, algae, and aquatic and riparian habitats were sampled and described to assess aquatic biological community structure.	Stream reaches at or near routine monitoring sites having watersheds of less than 50 square miles.	6	Summers, 1999 and 2000
Urban land-use gradient study	Fish, benthic invertebrates, algae, water chemistry, continuous water temperature and stream stage, and aquatic and riparian habitats were sampled and described to assess aquatic community structure along a gradient of urban intensity.	Stream reaches at or near routine monitoring and other sites having watersheds of less than 50 square miles and within the Northeastern Coastal Zone ecoregion.	30	Once (summer) for ecological assessment and twice (spring and summer) for water chemistry, 2000
Nutrient-chlorophyll synoptic study	Instantaneous streamflow, major ions, nutrients, organic carbon, habitat, and chlorophyll-*a* in periphyton and in phytoplankton to establish relations between nutrients and chlorophyll in streams.	Subset of urban land-use gradient study sites that represent excellent to poor stream quality.	13	Five times during summer 2001
Ground-Water Chemistry				
Land-use monitoring-well study	Nutrients, major ions, trace metals, organic carbon, field parameters, radon, CFCs, VOCs, and pesticides to measure the effects of urban land uses on shallow ground water.	Monitoring wells 10 feet below the water table underlying new residential and commercial lands (less than 30 years old) in sand and gravel aquifers in the 4,800-square mile Boston metropolitan area.	29	Once in summer 1999
Domestic (household) well bedrock studies	Same as land-use survey, except radium samples also collected; to measure water-quality conditions in the bedrock-aquifers used for domestic water supply.	Existing domestic wells underlying calcareous metamorphic, other metamorphic, and igneous bedrock.	58	Once in fall 1999 and spring and summer 2000
Public-supply well study	Same as domestic well studies, with additional age dating; to measure water-quality conditions in the sand and gravel aquifers used for public drinking-water supply.	Existing public-supply gravel-packed wells completed in sand and gravel aquifers.	30	Once in summer 2001

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Glossary

Breakdown product—A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.

Calcareous metamorphic bedrock—Generalized term to characterize bedrock derived from metamorphosed marine sediments described as variable calcareous (5–50 percent calcite) or from calcareous protoliths. This term includes lithology units classified as Calcpelite and Calcgranofels in Major Group 1 of Robinson and others (2002).

Drinking-water standards/guidelines—A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Ecoregion—An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant characteristics.

Environmental setting—Land area characterized by a unique combination of natural and human-related factors, such as row-crop cultivation or glacial-till soils.

EPT taxa—The sum of the number of taxa in three insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), that are composed primarily of species considered to be relatively intolerant to environmental alterations.

Eutrophication—The process by which water becomes enriched with plant nutrients, most commonly phosphorus and nitrogen.

Guidelines for the protection of aquatic life—Specific concentrations of substances in water which, if reached, may adversely affect aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Human Health Advisory—Guidance provided by U.S. Environmental Protection Agency, State agencies, or scientific organizations, in the absence of regulatory limits, to describe acceptable contaminant levels in drinking water or edible fish.

Igneous and other metamorphic bedrock—Generalized term to characterize bedrock derived from felsic igneous rocks, such as granites, and undifferentiated metamorphosed sedimentary rocks included in the calcareous metamorphic bedrock group by Robinson and others (2002).

Milligrams per liter (mg/L)—A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most stream water and ground water. One thousand micrograms per liter equals 1 mg/L.

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

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 1010 radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm) or 0.037 dps.

Sand and gravel aquifer—A water-bearing deposit consisting primarily of unconsolidated layers of clay, silt, sand, and gravel deposits, but may also contain cobbles and boulders. Also known as startified-drift, unconsolidated, or surficial aquifer.

Stream depth—The mean distance as measured from the water surface to the stream bottom at three locations across a stream's width. One of the three measuring points is at the deepest point in the stream.

U.S. Food and Drug Administration (FDA) human consumption 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 concentrations 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.

Water-quality criteria—Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria established by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific concentrations of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Appendix—Water-Quality Data from the New England Coastal Basins in a National Context

Concentrations and detection frequencies of some of the most commonly detected constituents, constituents that exceed a drinking-water standard or aquatic-life guideline, or constituents that are of regulatory or scientific importance, are presented below. Plots of other pesticides, nutrients, VOCs, and trace elements assessed in the New England Coastal Basins are available at our Web site at:

http://water.usgs.gov/nawqa/graphs

These summaries of chemical concentrations and detection frequencies from the New England Coastal Basins are compared to findings from 51 NAWQA Study Units investigated from 1991 to 2001 and to water-quality benchmarks for human health, aquatic life, fish-eating wildlife, or prevention of nuisance plant growth. These graphical summaries provide a comparison of chemical concentrations and detection frequencies between (1) surface- and ground-water resources, (2) agricultural, urban, and mixed land uses, and (3) shallow ground water and aquifers commonly used as a source of drinking water.

CHEMICALS IN WATER

Concentrations and detection frequencies, New England Coastal Basins, 1999–2001

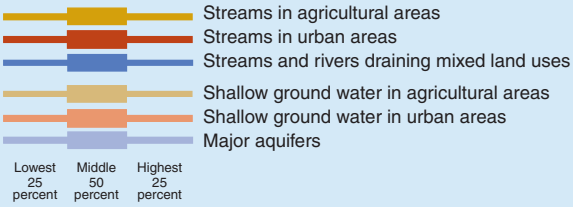
◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 51 NAWQA Study Units, 1991–2001—Ranges include only samples in which a chemical was detected



National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and the desired goal for preventing nuisance plant growth due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)

| Protection of aquatic life (applies to surface water only)

| Prevention of nuisance plant growth in streams

* No benchmark for drinking-water quality

** No benchmark for protection of aquatic life

NOTE to users:

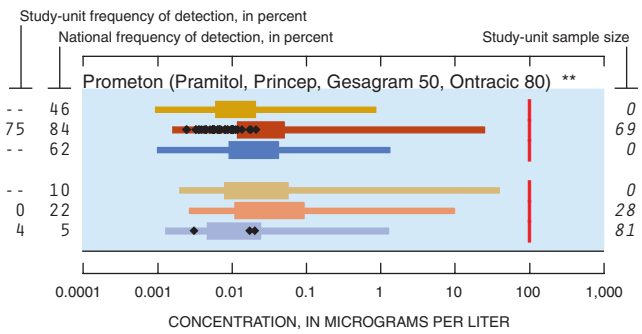
- The analytical detection limit varies among the monitored chemicals, thus frequencies of detections are not comparable among chemicals.
- It is important to consider the frequency of detection along with concentration. For example, ammonia was detected less frequently in urban ground-water areas in the New England Coastal Basins than in urban groundwater areas nationwide (17 percent compared to 61 percent) but generally was detected at higher concentrations.
- In this Appendix, 10 New England Coastal Basins stream sampling sites were characterized as having fish tissue from streams in urban areas, whereas in the report, 5 sites were characterized. In addition, VOC samples collected from the Charles River were excluded in this Appendix, but are described in the body of the report. Fish-tissue samples (fish fillets) collected in the New England Coastal Basins for trace-element concentrations ere not compiled in this appendix because they were not compatible to the fish-liver samples collected by other NAWQA Study Units.
- Data in this Appendix were compiled in a nationally consistent manner to facilitate comparisons among NAWQA Study Units. Some data presented in the body of this report may be compiled in a different manner to better describe variability in the New England Coastal Basins Study Unit.
- Quality-control data for these analytes indicate relatively frequent low-level contamination of samples during sample processing for analysis. Results for these analytes cannot, therefore, be presented using the generalized methods that were applied to other analytes in this Appendix. Analysis of results for analytes potentially affected by contamination requires special statistical treatment beyond the scope of this report. For more information about these analytes and how to interpret data on their occurrence and concentrations, please contact the appropriate NAWQA Study Unit.

  Trace elements in ground water: aluminum, barium, boron, cadmium, chromium, cobalt, copper, lithium, nickel, strontium, zinc

  SVOCs in bed sediment: phenol, bis(2-ethylhexyl)phthalate, butylbenzylphthalate, di-*n*-butylphthalate, diethylphthalate

  Insecticides in water: *p,p'*-DDE

Pesticides in water—Herbicides



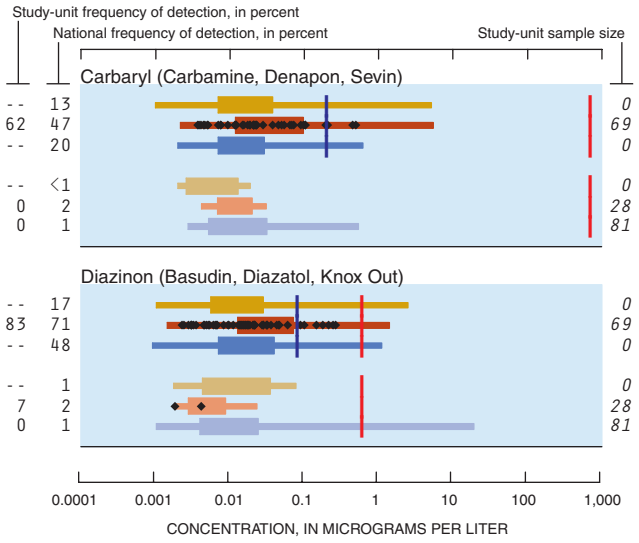
Other herbicides detected

Atrazine (AAtrex, Atrex, Atred)
Benfluralin (Balan, Benefin, Bonalan, Benefex) * **
Cyanazine (Bladex, Fortrol)
DCPA (Dacthal, chlorthal-dimethyl) **
Deethylatrazine (Atrazine metabolite, desethylatrazine) * **
EPTC (Eptam, Farmarox, Alirox) * **
Metolachlor (Dual, Pennant)
Napropamide (Devrinol) * **
Pendimethalin (Pre-M, Prowl, Weedgrass Control, Stomp, Herbadox) * **
Pronamide (Kerb, Propyzamid) **
Simazine (Princep, Caliber 90, Gesatop, Simazat)
Tebuthiuron (Spike, Tebusan)
Triallate (Far-Go, Avadex BW, Tri-allate) *
Trifluralin (Treflan, Gowan, Tri-4, Trific, Trilin)

Herbicides not detected

Chloramben, methyl ester (Amiben methyl ester) * **
Acetochlor (Harness Plus, Surpass) * **
Alachlor (Lasso, Bronco, Lariat, Bullet) **
Butylate (Sutan +, Genate Plus, Butilate) **
2,6-Diethylaniline (metabolite of Alachlor) * **
Ethalfluralin (Sonalan, Curbit) * **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
Metribuzin (Lexone, Sencor)
Molinate (Ordram) * **
Pebulate (Tillam, PEBC) * **
Propachlor (Ramrod, Satecid) **
Propanil (Stam, Stampede, Wham, Surcopur, Prop-Job) * **
Terbacil (Sinbar) **
Thiobencarb (Bolero, Saturn, Benthiocarb, Abolish) * **

Pesticides in water—Insecticides



Other insecticide detected

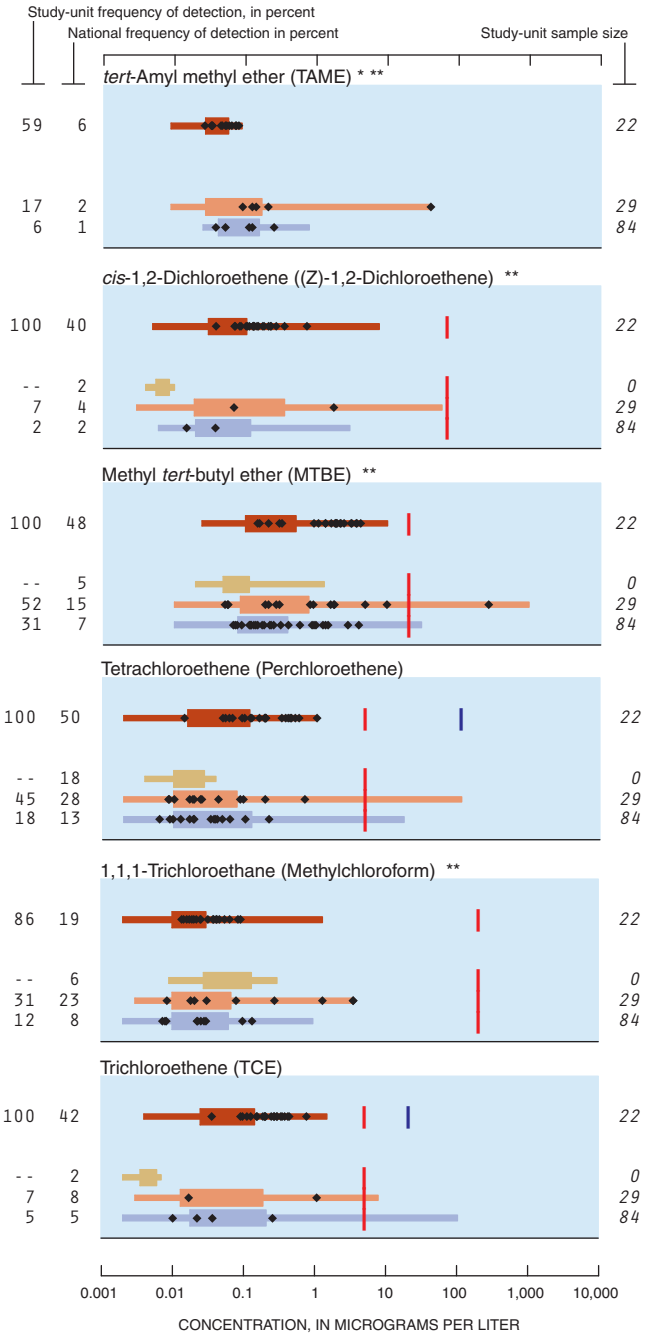
Chlorpyrifos (Brodan, Dursban, Lorsban)

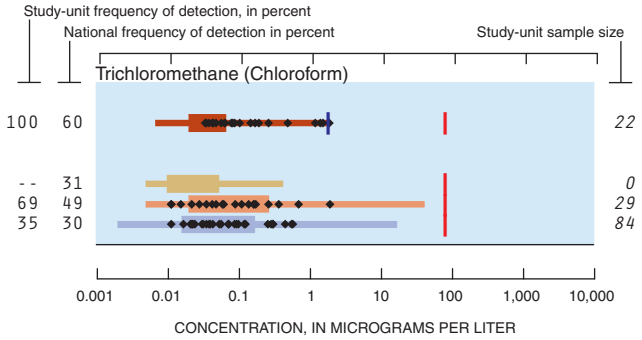
Insecticides not detected

Azinphos-methyl (Guthion, Gusathion M) *
Carbofuran (Furadan, Curaterr, Yaltox)
Dieldrin (Panoram D-31, Octalox)
Disulfoton (Disyston, Di-Syston, Frumin AL, Solvirex, Ethylthiodemeton) **
Ethoprop (Mocap, Ethoprophos) * **
Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
alpha-HCH (alpha-BHC, alpha-lindane) **
gamma-HCH (Lindane, gamma-BHC, Gammexane)
Malathion (Malathion)
Methyl parathion (Penncap-M, Folidol-M, Metacide, Bladan M) **
Parathion (Roethyl-P, Alkron, Panthion) *
cis-Permethrin (Ambush, Astro, Pounce) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **
Propargite (Comite, Omite, Ornamite) * **
Terbufos (Contraven, Counter, Pilarfox) **

Volatile organic compounds (VOCs) in water

These graphs represent data from 32 Study Units, sampled from 1994 to 2001





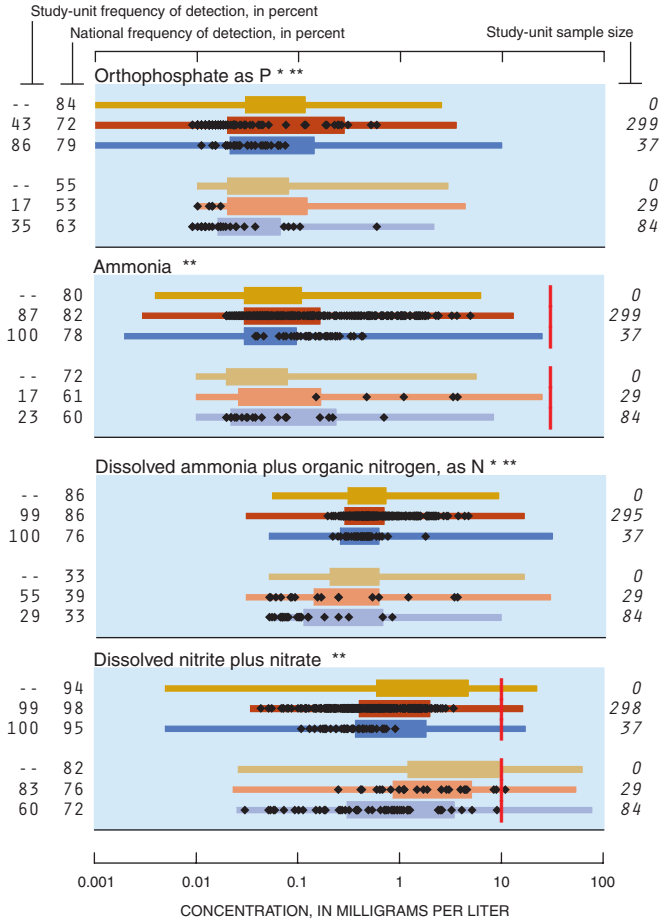
Other VOCs detected

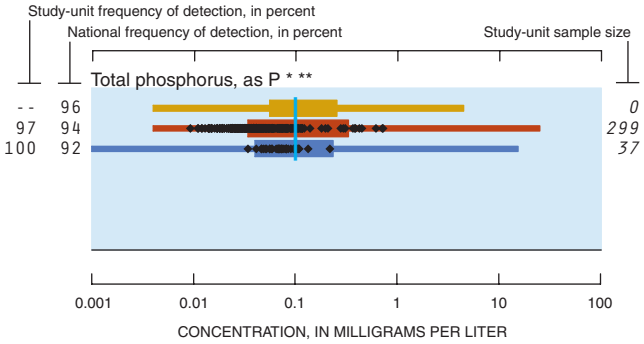
Acetone (Acetone) * **
Benzene
Bromodichloromethane (Dichlorobromomethane) **
2-Butanone (Methyl ethyl ketone (MEK)) **
sec-Butylbenzene ((1-Methylpropyl)benzene) * **
tert-Butylbenzene ((1,1-Dimethylethyl)benzene) * **
Carbon disulfide * **
1-Chloro-2-methylbenzene (*o*-Chlorotoluene) **
Chlorobenzene (Monochlorobenzene)
Chloroethene (Vinyl chloride) **
Chloromethane (Methyl chloride) **
Dibromochloromethane (Chlorodibromomethane) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)
Dichlorodifluoromethane (CFC 12, Freon 12) **
1,2-Dichloroethane (Ethylene dichloride)
1,1-Dichloroethane (Ethylidene dichloride) * **
1,1-Dichloroethene (Vinylidene chloride) **
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene) **
Dichloromethane (Methylene chloride)
1,2-Dichloropropane (Propylene dichloride) **
Diethyl ether (Ethyl ether) * **
Diisopropyl ether (Diisopropylether (DIPE)) * **
1,2-Dimethylbenzene (*o*-Xylene) **
1,3 & 1,4-Dimethylbenzene (*m*-&*p*-Xylene) **
Ethenylbenzene (Styrene) **
Ethyl *tert*-butyl ether (Ethyl-t-butyl ether (ETBE)) * **
Ethylbenzene (Phenylethane)
2-Ethyltoluene (*o*-Ethyltoluene) * **
Isopropylbenzene (Cumene) * **
p-Isopropyltoluene (*p*-Cymene, 1-Isopropyl-4-methylbenzene) * **
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) * **
Methylbenzene (Toluene)
n-Propylbenzene (Isocumene) * **
Tetrahydrofuran (Diethylene oxide) * **
1,2,3,5-Tetramethylbenzene (Isodurene) * **
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113) * **
Trichlorofluoromethane (CFC 11, Freon 11) **
1,2,3-Trimethylbenzene (Hemimellitene) * **
1,2,4-Trimethylbenzene (Pseudocumene) * **
1,3,5-Trimethylbenzene (Mesitylene) * **

VOCs not detected

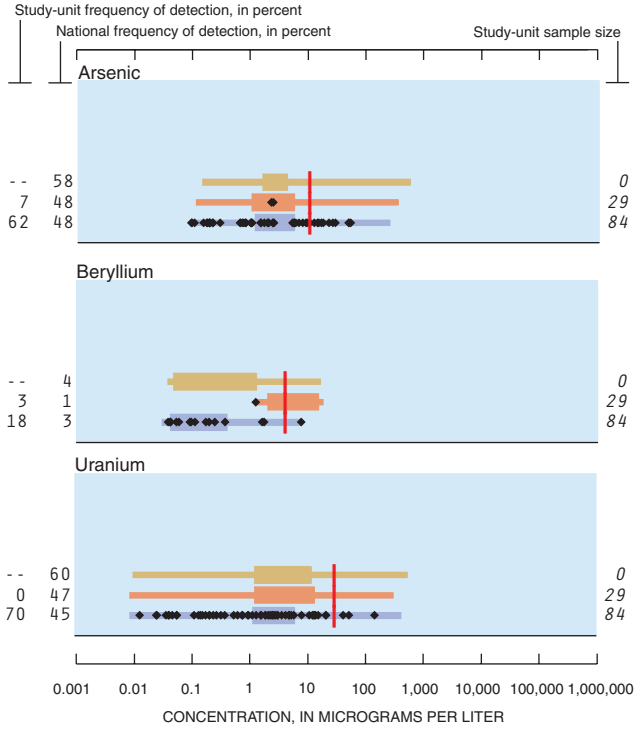
Bromobenzene (Phenyl bromide) * **
Bromochloromethane (Methylene chlorobromide) **
Bromoethene (Vinyl bromide) * **
Bromomethane (Methyl bromide) **
n-Butylbenzene (1-Phenylbutane) * **
3-Chloro-1-propene (3-Chloropropene) * **
1-Chloro-4-methylbenzene (*p*-Chlorotoluene) **
Chloroethane (Ethyl chloride) * **
1,2-Dibromo-3-chloropropane (DBCP, Nemagon) **
1,2-Dibromoethane (Ethylene dibromide, EDB) **
Dibromomethane (Methylene dibromide) * **
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) * **
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
2,2-Dichloropropane * **
1,3-Dichloropropane (Trimethylene dichloride) * **
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene) **
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene) **
1,1-Dichloropropene * **
Ethyl methacrylate (Ethyl methacrylate) * **
1,1,2,3,4,4-Hexachloro-1,3-butadiene (Hexachlorobutadiene)
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane) **
2-Hexanone (Methyl butyl ketone (MBK)) * **
Iodomethane (Methyl iodide) * **
Methyl acrylonitrile (Methacrylonitrile) * **
Methyl methacrylate (Methyl-2-methacrylate) * **
Methyl-2-propenoate (Methyl acrylate) * **
Naphthalene
2-Propenenitrile (Acrylonitrile) **
1,1,2,2-Tetrachloroethane **
1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA) **
Tetrachloromethane (Carbon tetrachloride)
1,2,3,4-Tetramethylbenzene (Prehnitene) * **
Tribromomethane (Bromoform) **
1,2,4-Trichlorobenzene
1,2,3-Trichlorobenzene (1,2,3-TCB) *
1,1,2-Trichloroethane (Vinyl trichloride) **
1,2,3-Trichloropropane (Allyl trichloride) **

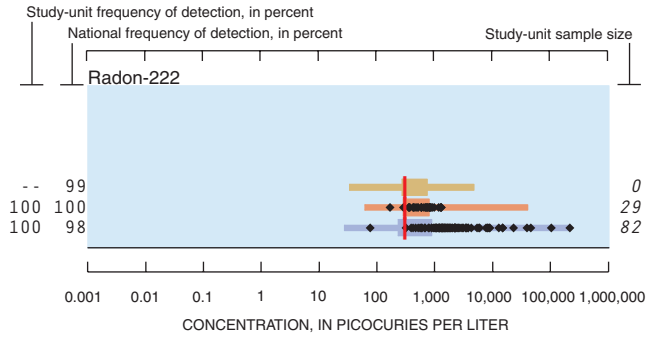
Nutrients in water





Trace elements in ground water





Other trace elements detected

Antimony
Lead
Manganese *
Molybdenum
Selenium
Thallium
Vanadium *

Trace element not detected

Silver

CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, New England Coastal Basins, 1999–2001—Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

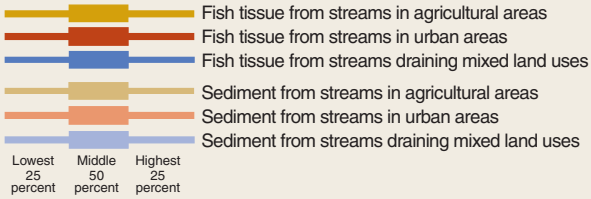
◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size

National ranges of concentrations detected, by land use, in 51 NAWQA Study Units, 1991–2001—Ranges include only samples in which a chemical was detected



National benchmarks for fish tissue and bed sediment

National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment.

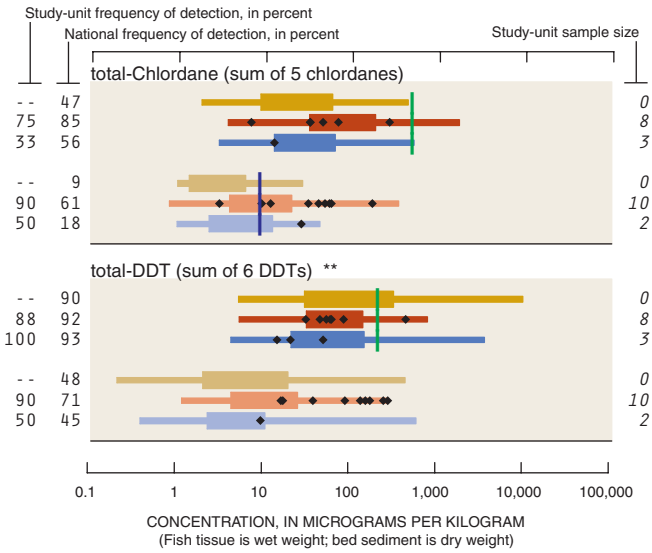
| Protection of fish-eating wildlife (applies to fish tissue)

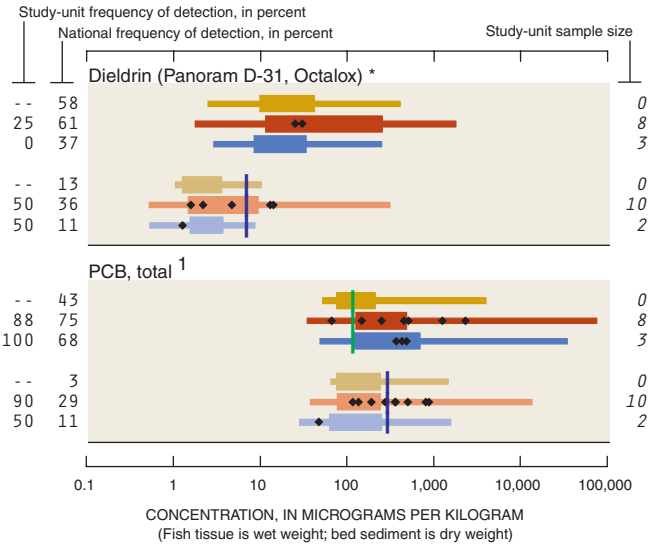
| Protection of aquatic life (applies to bed sediment)

* No benchmark for protection of fish-eating wildlife

** No benchmark for protection of aquatic life

Organochlorines in fish tissue (whole body) and bed sediment





[1] The national detection frequencies for total PCB in sediment are biased low because about 30 percent of the samples nationally had elevated detection limits compared to this Study Unit. See http://water.usgs.gov/nawqa/ for additional information.

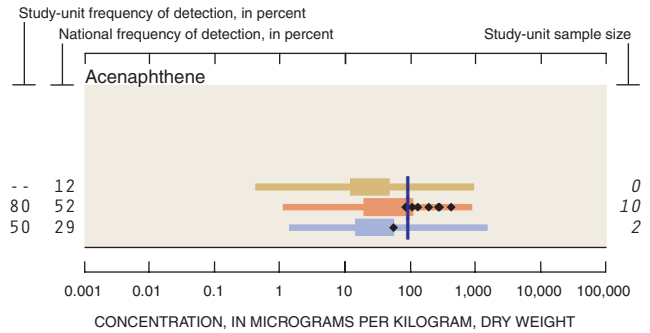
Other organochlorines detected

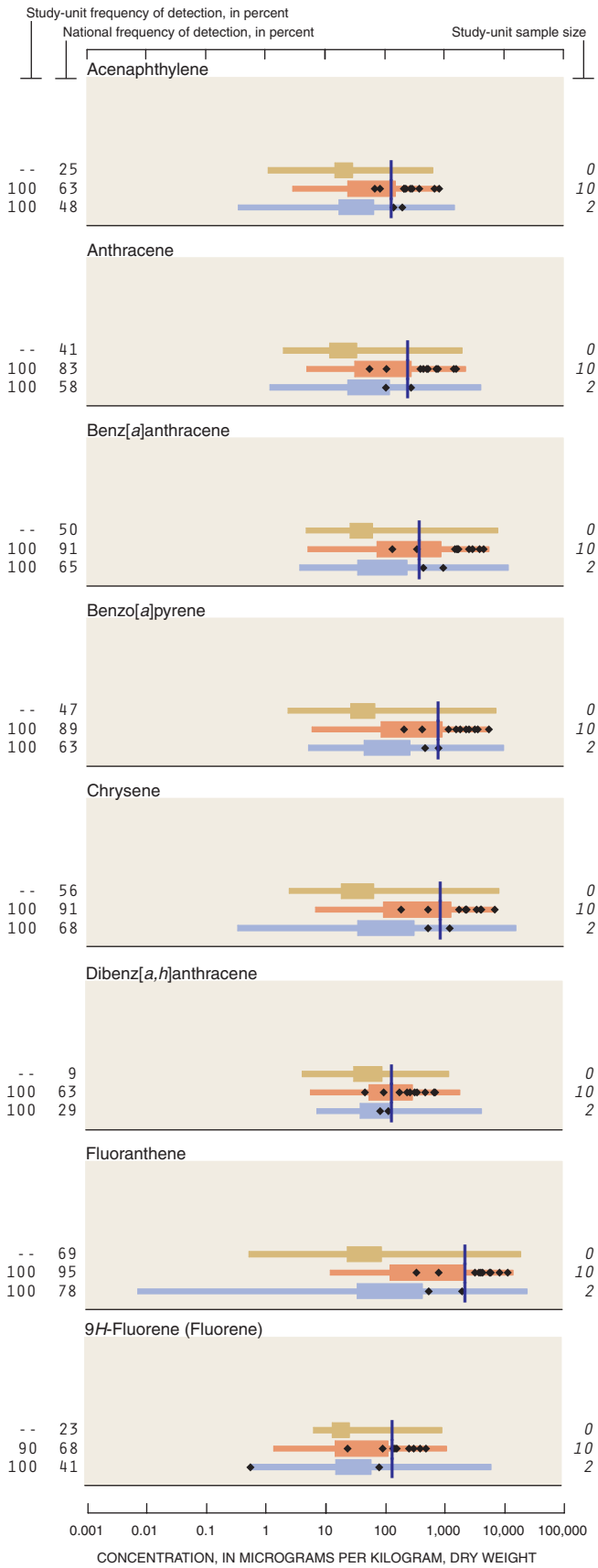
o,p'+*p,p'*-DDD (sum of *o,p'*-DDD and *p,p'*-DDD) *
p,p'-DDE * **
o,p'+*p,p'*-DDE (sum of *o,p'*-DDE and *p,p'*-DDE) *
o,p'+*p,p'*-DDT (sum of *o,p'*-DDT and *p,p'*-DDT) *
Dieldrin+aldrin (sum of dieldrin and aldrin) **
Heptachlor epoxide (Heptachlor metabolite) *
Heptachlor+heptachlor epoxide **
Hexachlorobenzene (HCB) **
Mirex (Dechlorane) **
trans-Permethrin (Ambush, Astro, Pounce) * **

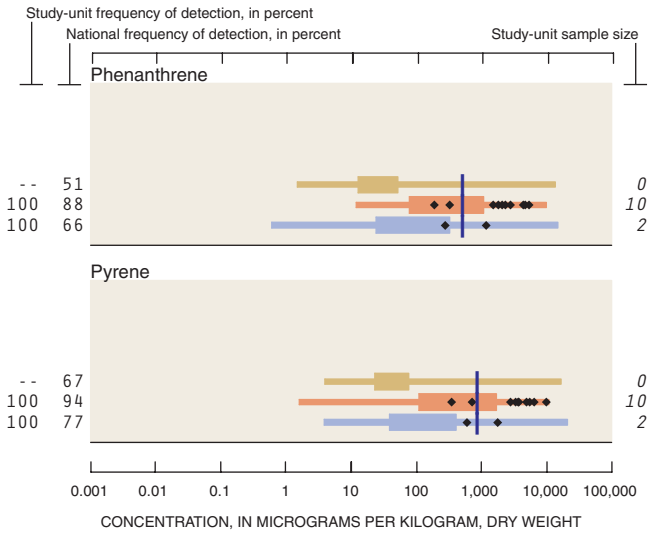
Organochlorines not detected

Chloroneb (chloronebe, Demosan) * **
DCPA (Dacthal, chlorthal-dimethyl) * **
Endosulfan I (alpha-Endosulfan, Thiodan) * **
Endrin (Endrine)
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Total HCH (sum of alpha, beta, gamma, and delta-HCH) **
Isodrin (Isodrine, Compound 711) * **
p,p'-Methoxychlor (Marlate, methoxychlore) * **
o,p'-Methoxychlor * **
Pentachloroanisole (PCA, pentachlorophenol metabolite) * **
cis-Permethrin (Ambush, Astro, Pounce) * **
Toxaphene (Camphechlor, Hercules 3956) * **

Semivolatile organic compounds (SVOCs) in bed sediment







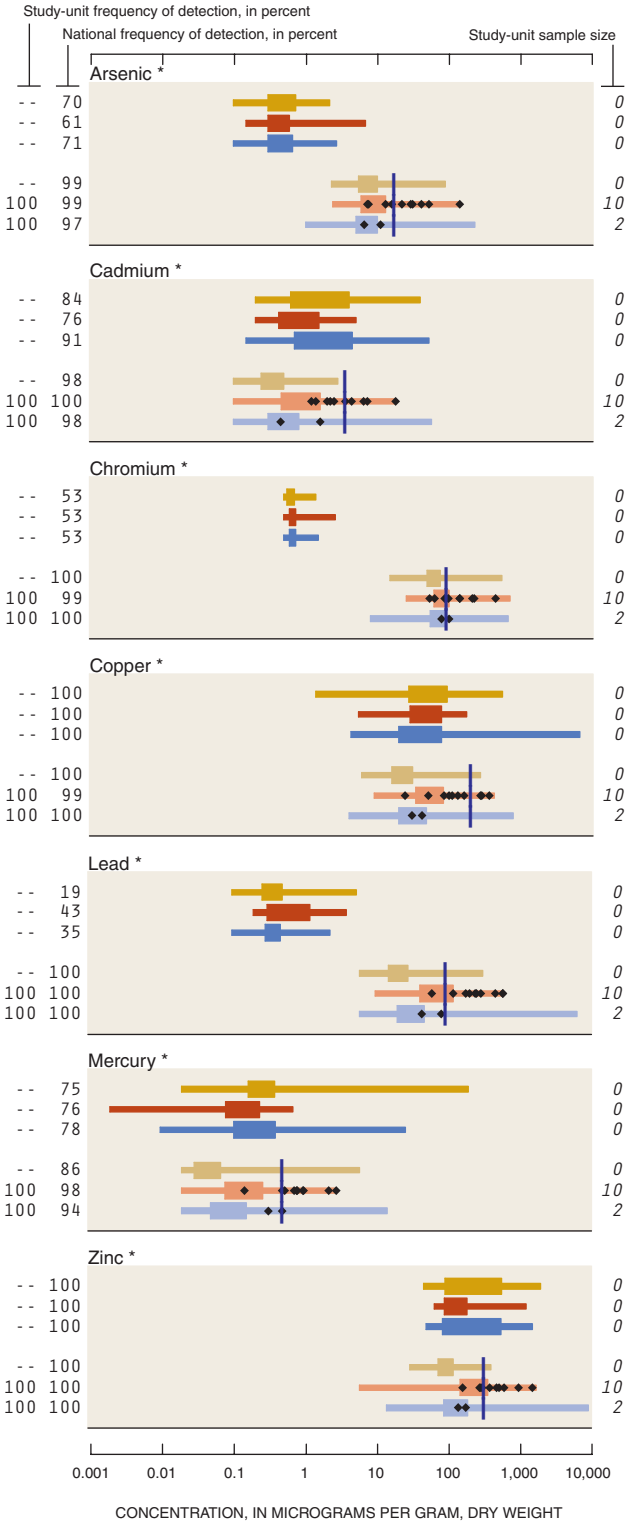
Other SVOCs detected

Acridine **
Anthraquinone **
Azobenzene **
Benzo[*b*]fluoranthene **
Benzo[*g,h,i*]perylene **
Benzo[*k*]fluoranthene **
2,2-Biquinoline **
9*H*-Carbazole **
p-Cresol **
Di-*n*-octylphthalate **
Dibenzothiophene **
1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB) **
1,2-Dimethylnaphthalene **
1,6-Dimethylnaphthalene **
2,6-Dimethylnaphthalene **
3,5-Dimethylphenol **
Dimethylphthalate **
Indeno[1,2,3-*c,d*]pyrene **
Isoquinoline **
1-Methyl-9*H*-fluorene **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Naphthalene
N-Nitrosodiphenylamine **
Phenanthridine **
Quinoline **
1,2,4-Trichlorobenzene **
2,3,6-Trimethylnaphthalene **

SVOCs not detected

C8-Alkylphenol **
Benzo[*c*]cinnoline **
4-Bromophenyl-phenylether **
4-Chloro-3-methylphenol **
bis (2-Chloroethoxy)methane **
bis (2-Chloroethyl)ether **
2-Chloronaphthalene **
2-Chlorophenol **
4-Chlorophenyl-phenylether **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
2,4-Dinitrotoluene **
Isophorone **
Nitrobenzene **
N-Nitrosodi-*n*-propylamine **
Pentachloronitrobenzene **

Trace elements in fish tissue (livers) and bed sediment



Other trace elements detected

Nickel * **
Selenium *

Coordination with agencies and organizations in the New England Coastal Basins was integral to the success of this water-quality assessment. We thank those who served as members of our liaison committee.

Federal agencies
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
National Park Service
U.S. Department of Agriculture

State agencies
New Hampshire Department of Environmental Services
New Hampshire Geological Survey
Maine Department of Environmental Protection
Maine Geological Survey
Massachusetts Dept. of Environmental Protection
Maine State Planning Office
New Hampshire Office of State Planning
Rhode Island Dept. of Environmental Management
Maine Department of Inland Fish and Wildlife

Local and regional agencies
New England Interstate Water Pollution Control Commission
New England Governors' Conference Inc.

Universities
University of Massachusetts
University of Rhode Island
Tufts University
Bates College
University of Southern Maine
University of New Hampshire

Other public and private organizations
Cape Cod Commission
Merrimack River Watershed Council
Manchester Water Works
Weston Sampson Engineers Inc.
Charles River Watershed Association
River Watch Network
New Hampshire Farm Bureau
Maine Farm Bureau
Ipswich Watershed Association

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