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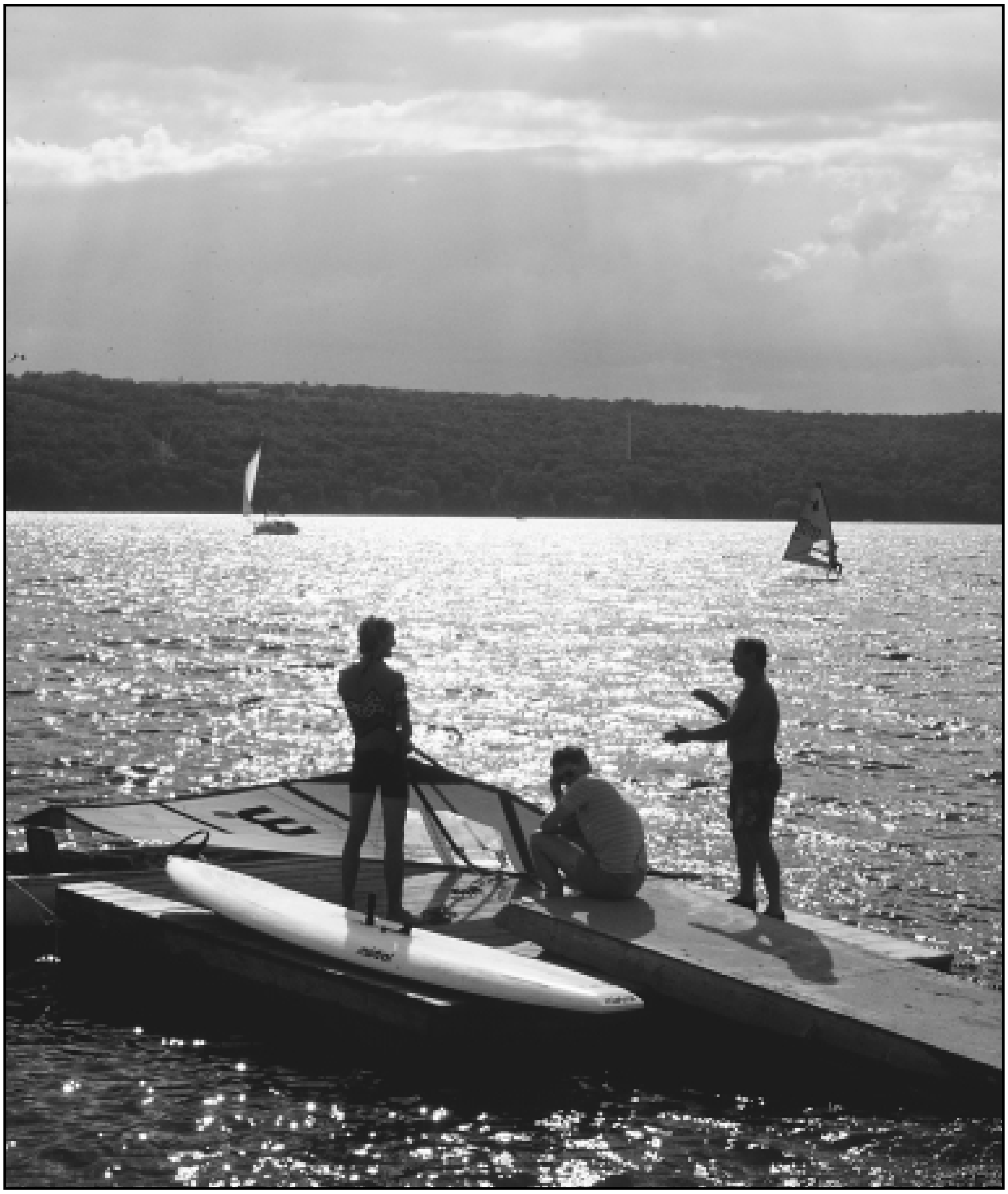

John McShane, Cayuga Lake, Ithaca, NY

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Public Health and Aquatic Life Concerns

Previous chapters described states' and tribes' efforts to assess the status of waters compared to state and tribal water quality standards. States and tribes adopted water quality standards specifically to protect public health and aquatic life. These standards include designated uses such as swimming, fish consumption, drinking water, and aquatic life. Water quality standards also include numeric criteria, which establish thresholds for the levels of individual pollutants that are safe for human exposure and aquatic life.

This chapter describes how impaired water quality may affect public health and aquatic life. It is made up of several sections, each describing efforts to protect different beneficial uses. These uses include fish and wildlife consumption, shellfish consumption, drinking water, recreation, and aquatic life.

Water pollution threatens both public health and aquatic life. Public health may be threatened directly through the consumption of contaminated food and/or drinking water or indirectly through skin exposure to contaminants present in recreational and/or bathing waters. Contaminants that threaten human health include toxic chemicals as well as viruses and bacteria.

Many contaminants present in our environment have the potential to affect human health. Toxic chemicals have been linked to human birth defects, cancer, neurological disorders, and kidney ailments. Waterborne viruses and bacteria can cause infectious hepatitis, gastroenteritis, dysentery, and cholera.

Although aquatic organisms can tolerate most viruses and bacteria harmful to humans, they may be more severely affected by the presence of toxic chemicals in their environment than humans. Toxic chemicals have the potential to kill all aquatic organisms within a community, kill select organisms within the community, increase susceptibility to disease, interfere with reproduction, or reduce the viability of their young. Toxic chemicals may also affect aquatic organisms indirectly by altering the delicate physical and chemical balance that supports life in an aquatic community. Whole aquatic communities can be lost either directly or indirectly as a result of chemical contamination in the water. Aquatic organisms are also particularly susceptible to changes in the physical quality of their environments, such as changes in pH, temperature, dissolved oxygen, and habitat.

Public Health Concerns

Toxic chemicals that remain in the environment for long periods of time can affect public health through a variety of different exposure pathways. Humans may

Many toxic chemicals concentrate in fish and shellfish.

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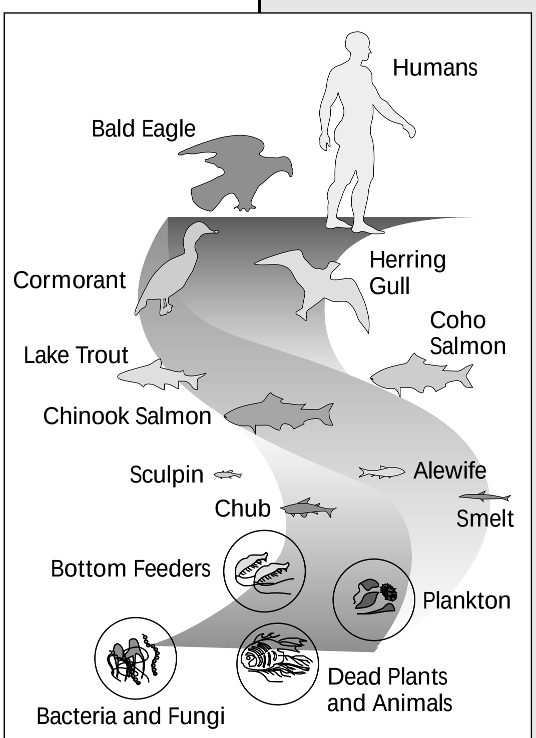
Bioaccumulation of Pollutants in the Food Chain

Certain organic pollutants (such as PCBs and DDT) have two properties that lead to high bioaccumulation rates. These pollutants are hydrophobic (i.e., do not have an affinity to water) and thus attach to particles such as clay and small aquatic plants called phytoplankton. These organic pollutants are also lipophilic (i.e., have an affinity to lipids or fatty tissues) and are readily stored in fatty tissues of plants and animals. As a result, these pollutants biologically accumulate (bioaccumulate) in phytoplankton, sediment, and fat tissue at concentrations that exceed the pollutant concentrations in surrounding waters. In fact, the concentration in surrounding waters may be so low that they cannot be measured even by very sensitive methods.

Small fish and zooplankton (microscopic grazers) consume vast quantities of phytoplankton. In doing so, any toxic chemicals accumulated by the phytoplankton are further concentrated in the fish, especially in their fatty tissues. These concentrations are increased at each level in the food chain. This process of increasing pollutant concentration through the food chain is called biomagnification.



The top predators in a food chain, such as lake trout, coho and chinook salmon, and fish-eating gulls, herons, and bald eagles, may accumulate concentrations of a toxic chemical high enough to cause serious deformities or death or to impair their ability to reproduce. The concentration of some chemicals in the fatty tissues of top predators can be millions of times higher than the concentration in the surrounding water.

Eggs of fish-eating birds often contain some of the highest concentrations of toxic chemicals. Thus, the first apparent effects of a toxic chemical in a waterbody may be unhatched eggs or dead or malformed chicks. Scientists monitor colonies of gulls and other aquatic birds because these effects can serve as early warning signs of a growing toxic chemical problem.

Biomagnification of pollutants in the food chain is also a significant concern for human health. To protect their residents from these risks, states issue fish consumption advisories or warnings about eating certain types of fish or shellfish.

Source: Adapted from U.S. EPA, 1994, *The EPA Great Waters Program: An Introduction to the Issues and the Ecosystems*, EPA-453/B-94/030, Office of Air Quality Standards, Durham, NC.

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be exposed to toxic chemicals if contaminated water is used as a source of drinking water without adequate treatment. Humans may also be exposed through the ingestion of aquatic life that lived in and ate organisms in contaminated water and sediments. Specifically, humans may be exposed to toxic chemicals by eating contaminated fish and shellfish. Because some toxic chemicals accumulate and concentrate in the tissue of fish and shellfish, consumption of contaminated tissue can sometimes pose a greater health risk than either drinking or swimming in contaminated water (see sidebar on bioaccumulation, page 192). The concentration of some toxic chemicals within fish and shellfish tissue may be up to 1 million times the concentration of toxicants in the surrounding water.

Waterborne viral and bacterial pollutants may also cause serious human illness and death. People can contract infectious hepatitis, gastroenteritis, dysentery, and cholera from waters receiving inadequately treated sewage. Bacteria and viruses may enter human systems through contact with contaminated swimming and bathing waters or through ingestion of contaminated drinking water or shellfish.

Fish and Wildlife Consumption Advisories

States and tribes issue fish and wildlife consumption advisories to protect the public from ingesting harmful quantities of toxic pollutants in contaminated noncommercial fish and wildlife. In general, advisories recommend that the public limit the quantity and frequency of consumption of fish and wildlife harvested from contaminated waterbodies. The states tailor individual advisories to minimize health risks based on contaminant data collected in their tissue sampling programs.

Advisories may completely ban consumption in severely polluted waters or limit consumption to several meals per month or year in cases of less severe contamination. Advisories may target a subpopulation at risk (such as children, pregnant women, or nursing mothers), specific fish species that concentrate toxic pollutants in their flesh, or larger fish within a species that may have accumulated higher concentrations of a pollutant over a longer lifetime than a smaller (i.e., younger) fish.

EPA evaluates the national extent of toxic contamination in noncommercial fish and shellfish by counting the total number of waterbodies with consumption advisories in effect. EPA used its database, the Listing of Fish and Wildlife Advisories (LFWA), to tabulate the number of state advisories. EPA built the database to centralize the fish consumption advisory information independently maintained by various state and tribal agencies. The database was updated by EPA in the spring of 1999. It can be accessed on the Internet at *http://www.epa.gov/ost/fish*.

The 1998 EPA LFWA listed 2,506 advisories in effect in 47 states, the District of Columbia, and American Samoa (Figure 8-1). An advisory may represent one waterbody or one type of waterbody within a state's jurisdiction.

Jessica Coffey, Grade 1, OH

Statewide advisories are counted as one advisory (see Appendix E, Table E-1, for individual state data).

EPA cannot identify states with a high proportion of toxic contamination based solely on the number of fish consumption advisories issued by each state. National statistics on advisories are difficult to interpret because the intensity and coverage of state monitoring programs vary widely. Each state can set its own criteria for issuing advisories. Simply comparing the total number of fish advisories in each state unfairly penalizes states with superior monitoring programs and strict criteria for issuing consumption warnings. In addition, it fails to present an equitable characterization of the number of fisheries affected and the severity of contamination problems.

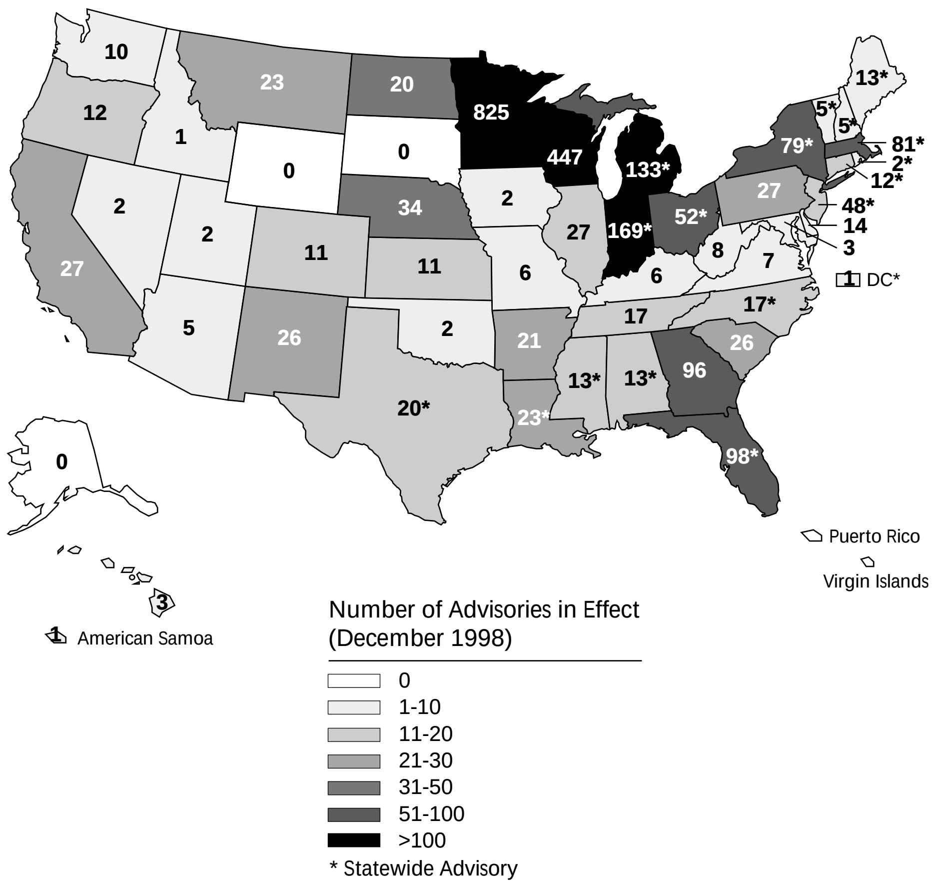
EPA has advocated consistent criteria and methods for issuing fish consumption advisories in several recent publications and workshops (see sidebar, page 195). However, it will be several years before the states implement consistent methods and criteria and establish a baseline inventory of advisories. EPA expects the states to issue more advisories as they sample more sites and detect contamination that previously went undetected.

Mercury, PCBs, chlordane, dioxins, and DDT (with its byproducts) caused 99% of all the fish consumption advisories in effect in 1998 (Figure 8-2). EPA and the states banned or restricted the use of PCBs, chlordane, and DDT over a decade ago, yet these chlorinated hydrocarbon compounds persist in sediments and fish tissues and still threaten public health.

During the 1990s, the states began reporting widespread mercury contamination in fish. As states expanded their tissue monitoring programs, they found elevated concentrations of mercury in fish inhabiting remote lakes that were previously considered unpolluted. States from Wisconsin

Figure 8-1

Fish and Wildlife Consumption Advisories in the United States



Note: States that perform routine fish tissue analysis (such as the Great Lakes states) will detect more cases of fish contamination and issue more advisories than states with less rigorous fish sampling programs. In many cases, the states with the most fish advisories support the best monitoring programs for measuring toxic contamination in fish, and their water quality may be no worse than the water quality in other states.

Based on data contained in the EPA Listing of Fish and Wildlife Advisories acquired from the states in December 1998 (see Appendix E, Table E-1, for individual state data).

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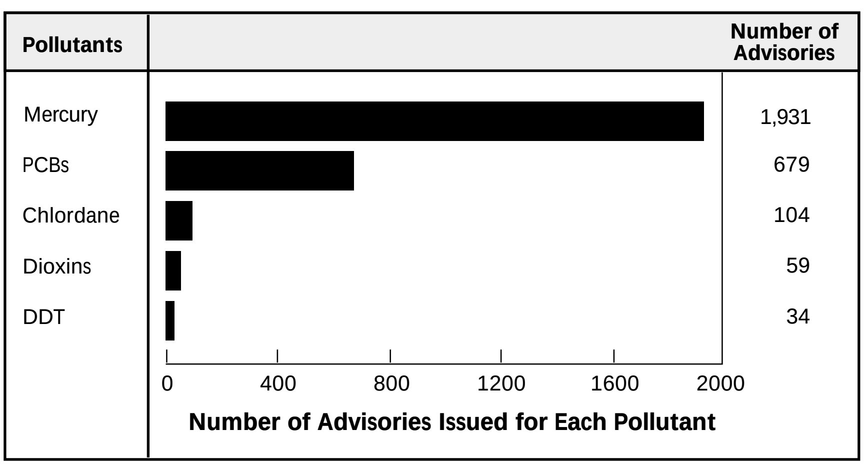
to Florida reported widespread mercury contamination in fish collected primarily from lakes. The source of the mercury contamination is difficult to identify because mercury naturally occurs in soils and rock formations. Natural processes, such as weathering of mercury deposits, release some mercury into surface waters. However, resource managers believe that human activities have accelerated the rate at which mercury accumulates in our waters and enters the food web.

Air pollution may be the most significant source of mercury contamination in surface waters and fish. According to EPA's Toxics Release Inventory, almost all of the mercury released by permitted polluters enters the air; industries and waste treatment plants discharge very little mercury directly into surface waters. Emissions from waste incinerators, coal-fired plants, smelters, and mining operations may carry mercury many miles to remote watersheds (see sidebar on air pollution impacts on water quality, page 198). Other potential sources of mercury contamination include slag heaps from metal mines and land-disturbing activities that may mobilize natural mercury deposits, such as channelization, reservoir construction, and drainage projects.

Air emissions may further aggravate mercury contamination by generating acid precipitation that increases acidity in lakes. The accumulation of mercury in fish appears to correlate with acidity in a waterbody. Slightly acidic conditions promote the chemical conversion of mercury to a methylated form that is more readily available for uptake and accumulation in fish. States, such as Louisiana, are

Figure 8-2

Pollutants Causing Fish and Wildlife Consumption Advisories in Effect in 1998



Based on data contained in Appendix E, Table E-2.

In 1990, EPA began developing technical guidance to help the states adopt consistent criteria and methods for issuing fish consumption advisories. The guidance consists of four volumes. EPA published volumes in 1993, 1994, 1995, and 1996 and second editions of two volumes in 1995 and 1997. Third editions of Volumes 1 and 2 are expected in 1999.

- *Volume I: Fish Sampling and Analysis* recommends standard methods for sampling and analyzing contaminants in fish tissue.
- *Volume II: Risk Assessment and Fish Consumption Limits* suggests protocols for selecting criteria for unsafe concentrations of contaminants in fish.
- *Volume III: Risk Management* suggests protocols for determining if the health risk justifies issuing an advisory.
- *Volume IV: Risk Communication* recommends methods for informing the public about fish consumption advisories.

The *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* is available at *http://www.epa.gov/ost/fish*.

MERCURY is the most common contaminant found in fish.

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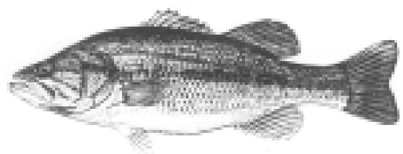
Survey of Mercury in State Fish Contaminant Monitoring Programs

The presence of mercury in fish tissue is increasingly an issue of public health concern for states. Of the more than 2,500 fish consumption advisories in effect in the United States in 1998, over 68% were related to mercury. Mercury contamination accounts for a significant fraction of the impaired waters in the United States.

Although 40 states currently have fish advisories in effect for mercury, until recently no national survey had been conducted to obtain information directly from states on the levels of mercury contamination in fish. In 1996, EPA solicited data on mercury concentrations in fish collected by the states as part of their fish contaminant monitoring programs. All states were asked to submit mercury residue data collected in their state waters from 1990 to 1995 so that EPA could assess whether there were geographic variations or trends in fish tissue concentrations of mercury nationally.

Exposure to mercury can permanently damage the brain, kidneys, and developing fetus.

EPA has assembled the data provided by 40 states and the District of Columbia. EPA's report, published in September 1999 (EPA823-R-99-014), summarizes these data and analyzes the geographic distribution of mercury in fish, mercury levels in various species of fish (see figure), and factors contributing to mercury contamination.



The most commonly sampled fish species were the largemouth and smallmouth bass; channel, flathead, and blue catfish; yellow and brown bullhead; rainbow and lake trout; carp; walleye; northern pike; and white sucker.

The fish species with the broadest geographic distribution nationally was the largemouth bass, which was collected and analyzed by 25 of the 39 reporting states. The maximum mercury concentration reported for this species exceeded the Food and Drug Administration action level (1 ppm) in 15 of the 25 states that analyzed tissue from this species. The highest maximum mercury concentration

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for this species nationally (4.36 ppm) was reported by Florida. Consumption of contaminated fish harvested from local waters exposes high-end fish consumers to potentially greater risk of mercury exposure than members of the general population. The populations most at risk because of their consumption of locally caught fish are ethnic populations, such as Native Americans, Caribbean Americans, and Asian Americans, and recreational sport and subsistence fishers.

Concentration Ranges for Selected Species

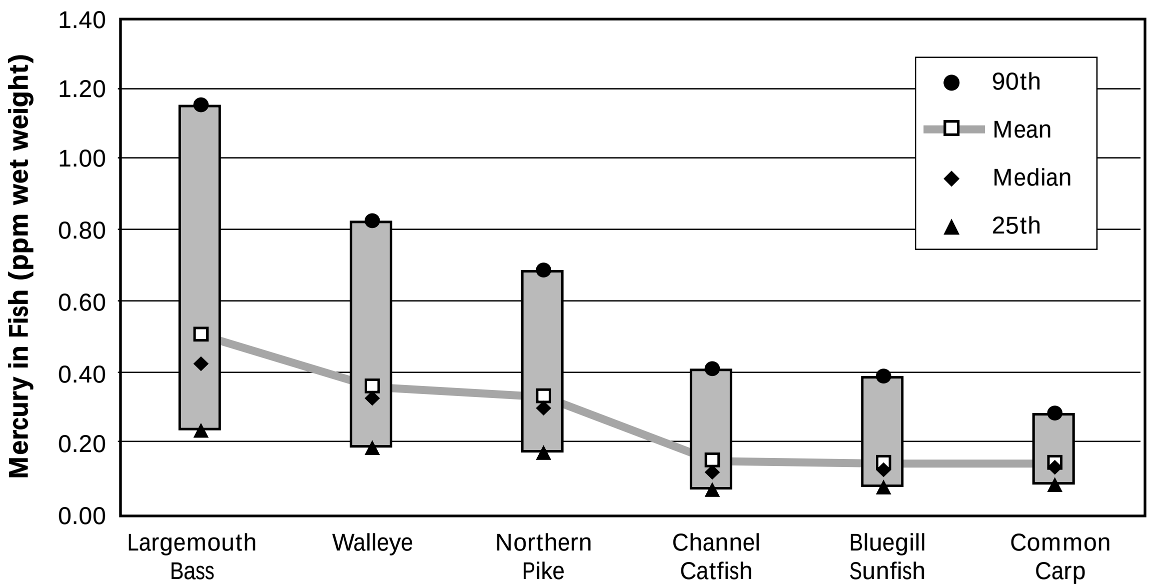

Figure 1. Mercury accumulates up the food chain from bottom feeders such as carp and catfish to top predator game fish such as bass and walleye.

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Air Pollution Impacts on Water Quality

Sources

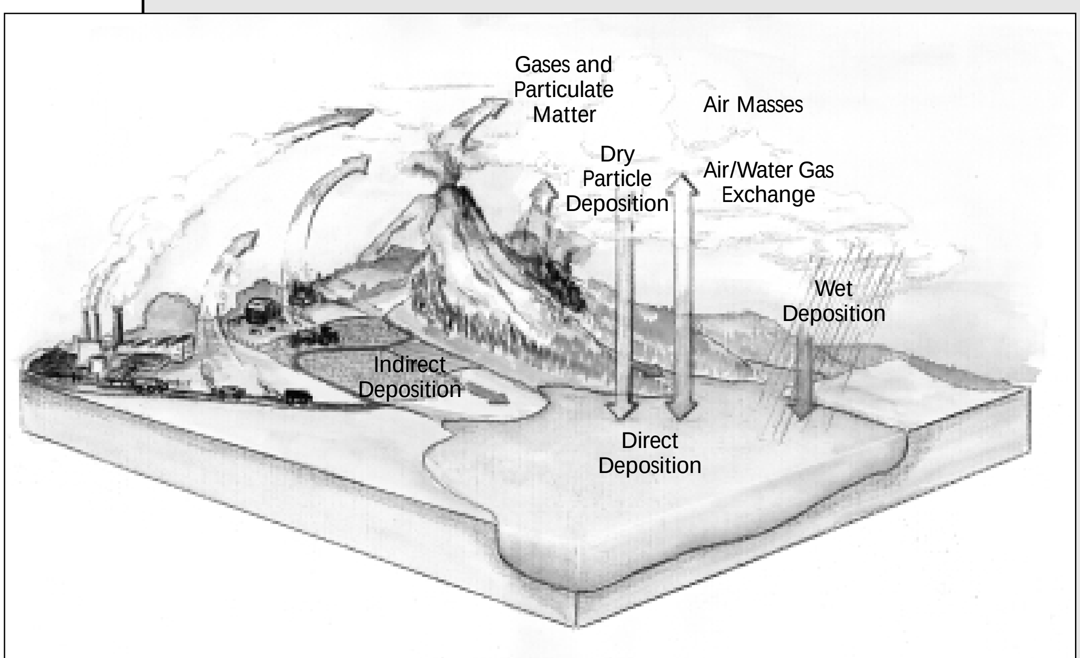
Pollutants are released into the air from anthropogenic or natural sources. Anthropogenic sources include industrial stacks, municipal incinerators, pesticide applications, and vehicle exhaust. Natural sources can be volcanic eruptions, windblown gases and particles from forest fires, windblown dust and soil particles, and sea spray.

Transport

Pollutants released to the air are carried by continental wind patterns away from their areas of origin. Depending on weather conditions and the chemical and physical properties of the pollutants, they can be carried varying distances from their sources and can undergo physical and chemical changes as they travel.

Deposition

Air pollutants are deposited to the earth or directly to waterbodies by either wet or dry deposition. Wet deposition occurs when pollutants are removed from the air by falling rain or snow. Dry deposition occurs when particles settle out of the air by gravity or when gases are transferred directly from the air into water. Air pollutants that deposit on land can be carried into a waterbody by stormwater runoff. This is called indirect deposition.



Sophie Burkheimer, RTI

Source: Adapted from U.S. EPA, 1994, *The EPA Great Waters Program: An Introduction to the Issues and the Ecosystems*, EPA-453/B-94/030, Office of Air Quality Planning and Standards, Durham, NC.

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using this correlation to target waterbodies with acidic pH and low buffering capacity for mercury sampling in fish.

The EPA LFWA database does not identify sources of contamination in fish. Sources of contamination are difficult to isolate because migratory fish may be exposed to toxic pollutants in the sediments and water column or may ingest toxic contaminants concentrated in prey miles from the sampling areas where they are collected. Furthermore, migratory or resident fish may be exposed to toxic pollutants that have been transported great distances from where they originated.

Shellfish Contamination

Contaminated shellfish pose a public health risk particularly to those who consume raw shellfish. Shellfish, such as oysters, clams, and mussels, extract their food (plankton) by filtering water over their gills. In contaminated waters, shellfish accumulate bacteria and viruses on their gills and mantle and within their digestive systems. If shellfish grown in contaminated waters are not cooked properly, consumers may ingest live bacteria and viruses.

To protect public health, the U.S. Food and Drug Administration administers the National Shellfish Sanitation Program (NSSP). The NSSP establishes minimum quality monitoring requirements and criteria for state shellfish programs that want to participate in interstate commerce of shellfish. States cannot sell shellfish outside of their state boundaries unless their shellfish sanitation program follows NSSP protocols.

Coastal states routinely monitor shellfish harvesting areas for bacterial contamination and restrict shellfish harvests in contaminated waters. Most often, states measure concentrations of fecal coliform or total coliform bacteria, which are bacteria that populate human digestive systems and occur in fecal wastes. Their presence in water samples is an indicator of sewage contamination that may pose a human health risk from pathogenic viruses and bacteria. Fecal bacteria, however, may exceed criteria even when no human sewage is present because birds and nonhuman mammals also excrete them.

The NSSP recognizes three types of shellfish harvesting restrictions:

- **Prohibited Waters** violate criteria consistently; therefore, shellfish cannot be harvested at any time.

- **Restricted Waters** may be harvested if the shellfish are transferred to clean waters to reduce concentrations of bacteria.

- **Conditionally Approved Waters** temporarily exceed bacteriological criteria following predictable events (such as a storm). Shellfish from these waters may be harvested when criteria are met.

The size of waters with shellfish harvesting restrictions does not equate with the size of polluted estuarine waters because states sometimes restrict harvesting in clean waters. The NSSP requires that a state prohibit shellfishing in clean waters if the state cannot monitor a waterbody on a routine schedule that ensures rapid detection of unsafe conditions. As a

The National Shellfish Sanitation Program addresses only bacteriological contamination of molluscan (not crustacean) shellfish that are harvested for sale in interstate commerce. The Listing of Fish and Wildlife Advisories addresses only chemical contamination of shellfish (all types) that are harvested for all purposes.

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result, funding for monitoring activities can raise or lower the size of waters classified as "prohibited" even if water quality does not change. Georgia, for example, reported in 1994 that funding for a new laboratory position during 1992 and 1993 restored shellfishing to clean waters previously classified as "prohibited" due to a lack of monitoring.

As a preventive measure, the states also automatically prohibit the harvest of shellfish near marinas and pipes that discharge wastewater. These closures protect the public from accidental releases of contaminated wastewater due to treatment plant malfunctions or overflows during severe weather. The preventive closures apply to marinas because fecal bacteria concentrations may increase during high-use periods, such as weekends. The states prohibit shellfishing in these waters even though these waters may not contain harmful concentrations of fecal bacteria most of the time.

Table 8-1. Shellfish Harvesting Restrictions Reported by the States

State	Number of Waterbodies with Restrictions	Size (square miles)
Alabama	—	—
Alaska	—	—
California	—	—
Connecticut	—	—
Delaware	—	—
Delaware River Basin	—	97.0
District of Columbia[a]	—	—
Florida	—	—
Georgia	—	395.0
Hawaii	0	0
Louisiana	26	—
Maine	—	—
Maryland	37	171.2
Massachusetts	12	541.7
Mississippi	—	—
New Hampshire	11	16.8
New Jersey	—	254.0
New York	—	312.5
North Carolina	—	—
Oregon	7	58.0
Puerto Rico	—	—
Rhode Island	39	66.5
South Carolina	122	266.5
Texas	—	—
Virginia	—	146.0
Virgin Islands	—	—
Washington	—	—
Totals	254	2,325.1

[a] The District of Columbia prohibits commercial harvest of shellfish in all of its waters.

Source: 1996 state Section 305(b) reports.

— Not reported in a numerical format.

Despite these drawbacks, the size of waters with shellfishing restrictions is our most direct measure of impacts on the shellfishing resource (Table 8-1). However, only 12 of the 28 coastal states and territories and 1 interstate commission reported the size of their estuarine waters affected by shellfish harvesting restrictions. With so few states reporting numerical data, EPA cannot summarize the national scope of shellfish harvesting conditions at this time. The National Oceanic and Atmospheric Administration is developing a database to track state restrictions that should provide a more complete profile of shellfishing conditions in the future.

The reporting states prohibit, restrict, or conditionally approve shellfish harvesting in 2,325 square miles of estuarine waters. About 14% of these waters are conditionally approved, so the public can harvest shellfish from these waters when the state lifts temporary closures. For comparison, nine states reported that over 7,000 square miles of estuarine waters are fully approved for harvesting shellfish at all times (Appendix E, Table E-3, contains individual state data).

Only eight states reported the size of shellfish restrictions caused by specific sources of pathogen indicators (Figure 8-3). Other states provided narrative information about sources degrading shellfish waters. For example, Louisiana reported that sewage treatment plant upgrades improved shellfish harvesting areas, but environmental changes that are causing negative impacts include nonpoint source pollution, sewage from camps, saltwater intrusion, and marsh erosion.

Drinking Water Source Assessments

The Safe Drinking Water Act (SDWA) calls for states to determine the susceptibility of waters to contamination, while Section 305(b) of the Clean Water Act calls for them to assess the ability of waters to support drinking water use. States may prioritize their water resources and perform drinking water use support assessments for a limited percentage of their water resources. They are then encouraged to expand their drinking water assessment efforts to include additional waters at each subsequent reporting cycle. EPA recommends prioritization based on waters of greatest drinking water demand, with further prioritization with respect to vulnerability or other state priority factors. In addition, states are encouraged to use a tiered approach in the assessment. This tiered approach accommodates the different types of data currently available to states and allows for differing levels of assessment.

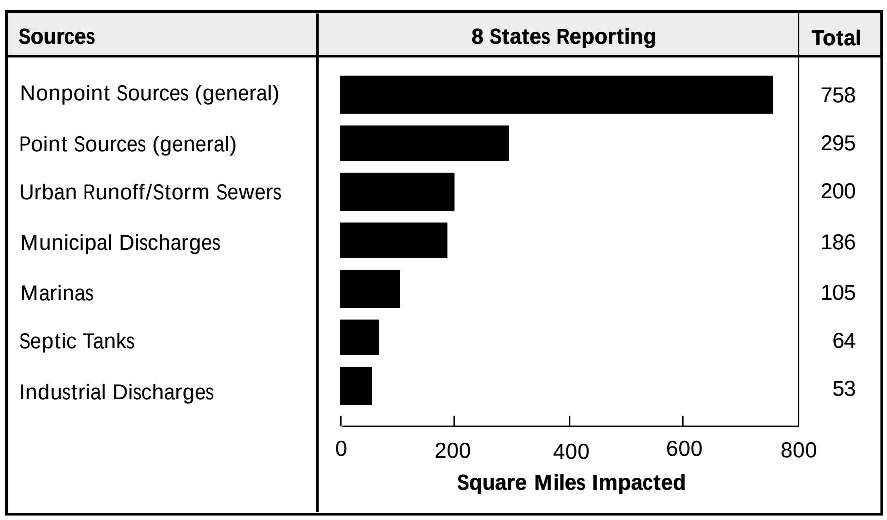
States use the general criteria outlined in Table 8-2 to determine the degree of drinking water use support for waterbodies in their state. These criteria may be modified by the states to fit their individual situations.

Summary of State Drinking Water Assessments

Thirty-eight states, tribes, or territories submitted drinking water use data in their reports. Figure 8-4 shows which states submitted drinking water data for rivers and streams and/or lakes and reservoirs. Table 8-3 shows the total number of miles of rivers and streams and

Figure 8-3

Sources Associated with Shellfish Harvesting Restrictions



Based on data contained in Appendix E, Table E-4.

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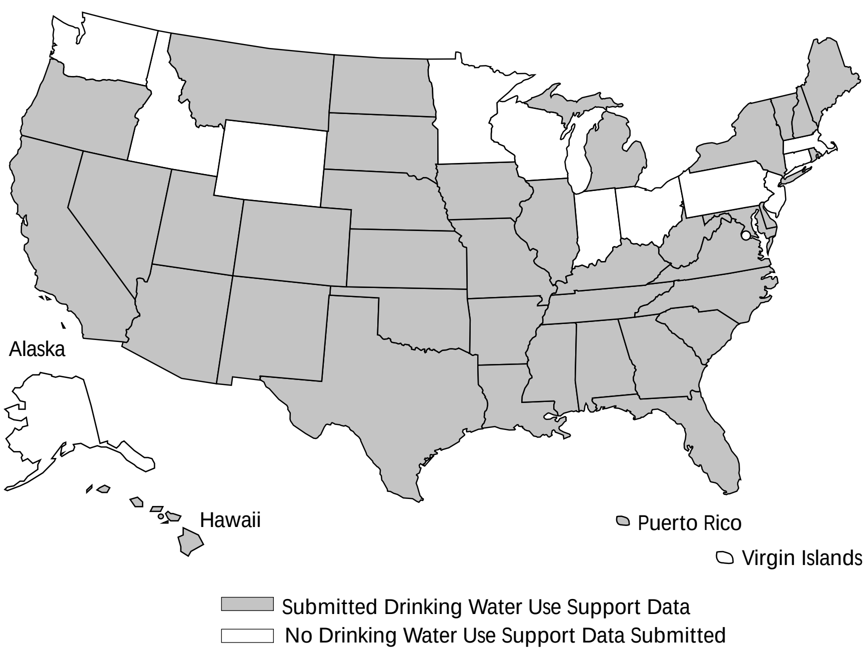
Table 8-2. Criteria to Determine Drinking Water Use Support

Classification	Monitoring Data		Use Support Restrictions
Full support	Contaminants do not exceed water quality criteria	and/or	Drinking water use restrictions are not in effect
Full support but threatened	Contaminants are detected but do not exceed water quality criteria	and/or	Some drinking water use restrictions have occurred and/or the potential for adverse impacts to source water quality exists
Partial support	Contaminants exceed water quality criteria intermittently	and/or	Drinking water use restrictions resulted in the need for more than conventional treatment
Nonsupport	Contaminants exceed water quality criteria consistently	and/or	Drinking water use restrictions resulted in closures
Unassessed	Source water quality has not been assessed		

Figure 8-4

States Submitting Drinking Water Use Support Data in Their 305(b) Reports



Source: 1998 305(b) reports submitted by states.

acres of lakes and reservoirs assessed and the degree of drinking water use support for the entire nation. The majority of waterbodies assessed, 87% of rivers and streams and 82% of lakes and reservoirs, are fully supporting of drinking water use. Only 3% of assessed rivers and streams and 5% of lakes and reservoirs do not support drinking water use.

A large improvement was seen between the drinking water use support data reported by the states in the 1998 305(b) report and that reported previously. In the early 1990s, only a small percentage of rivers, streams, lakes, and reservoirs were assessed for drinking water use. For the 1996 305(b) report, EPA developed guidelines for states to use in assessing drinking water use support. These guidelines were modified for the 1998 report to provide more flexibility to the states. It is evident that this has resulted in an increasing number of states carrying out drinking water use assessments. In addition, more states reported on how they classified waterbodies for drinking water use and on sources of water contamination. The increased data available from these assessments results in a more accurate framework for assessing drinking water use support in the nation.

However, many challenges still remain. Twelve states did not report data on drinking water use support. Many of the 38 states that reported data did not present any information on how they classified their waterbodies for drinking water use support or on sources of water contamination. This lack of information complicates data interpretation and presents challenges for accurately assessing and representing drinking water use support.

Sources of Drinking Water Use Impairment

Because of the flexibility of the guidelines for assessing drinking water use impairment, each state analyzed for different contaminants and used different criteria for assessing drinking water use impairment. In addition, many states did not identify the particular contaminants that caused drinking water use impairment. Thus, it is not possible to present quantitative data on this issue. However, based on the limited number of states identifying contaminants, Table 8-4 summarizes all of the contaminants cited as causing drinking water use impairment.

Ensuring Safe Drinking Water

Thanks to decades of effort by public and private organizations and the enactment of drinking water legislation, most Americans can turn on their taps without fear of receiving unsafe water. Ensuring consistently safe drinking water requires the cooperation of federal, state, tribal, and municipal governments to protect the water as it moves through three stages of the system—the raw source water, the water treatment plant, and the pipes that deliver finished water to consumers' taps. Polluted source waters greatly increase the level and expense of treatment needed to provide finished water that meets public health standards.

The passage of the SDWA Amendments of 1996 brought substantial changes to the national drinking water program for water utilities, states, and EPA, as well as greater protection and information to the 240 million Americans served by public water systems. The Amendments increased state flexibility, provided for more efficient investments by water systems, gave better information to consumers, and strengthened EPA's scientific work in setting drinking water standards.

Table 8-3. National Drinking Water Use Support

	Fully Supporting	Threatened	Partially Supporting	Not Supporting	Total Assessed
Rivers and Streams					
Miles	122,318	5,844	8,164	4,616	140,954
Percentage	87	4	6	3	—
Lakes and Reservoirs					
Acres	6,926,031	303,374	794,573	394,307	8,418,286
Percentage	82	4	9	5	—

Table 8-4. Sources of Drinking Water Use Impairment

Contaminant Group	Specific Contaminant	
Pesticides	Atrazine Metolachlor Triazine	Molinate Ethylene dibromide
Volatile organic chemicals	Trichloroethylene Tetrachloroethylene 1,1,1-Trichloroethane *cis*-1,2-Dichloroethylene Trihalomethanes Carbon tetrachloride Ethylbenzene 1,1,2,2-Tetrachloroethane	Dichloromethane 1,1-Dichloroethane 1,1-Dichloroethylene Toluene Benzene Dichlorobenzene Methyl(tert)butyl ether Xylene
Inorganic chemicals	Arsenic Nitrates Iron Copper Chloride	Fluoride Manganese Lead Sodium
Microbiological contaminants	Exceedance of total coliform rule	Exceedance of fecal coliform rule

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Protecting Sources of Drinking Water

Introduction

In the United States today, approximately 11,000 community water systems serving over 160 million people rely on lakes, reservoirs, and rivers as their main sources of drinking water. There is a growing recognition that addressing the quality and protection of these water sources can prevent contamination, thus reducing costly additional treatment and cleanup. Across the country, drinking water utilities are engaged in innovative and successful source water protection programs. These programs rely heavily on partnerships with local governments and often involve working closely with watershed councils, entering into land exchange agreements with land management agencies, and engaging with local farmers to implement best management practices aimed at protecting sources of drinking water.

The local actions that help protect sources of drinking water can generally be classified as: (1) creating partnerships, (2) assessing watersheds, (3) managing land use in watersheds, and (4) acquiring land.

Creating Partnerships

Instituting drinking water protection with a source water protection program involves balancing competing interests and conflicting demands within the watershed. This can be done through watershed planning committees or simply by establishing good, long-term relationships among the partners, which encourages a level playing field for reconciling the community's needs. It is important for affected parties—water utilities, local and state governments, watershed councils, nongovernment organizations, and others—to share information effectively.

Example: Creating Partnerships with Groups and Individuals, Chester Water Authority, Chester, Pennsylvania

To protect the water quality of its Octoraro Reservoir, the Chester Water Authority has forged a strong and lasting partnership with the Octoraro Watershed Association. This partnership bridges the gap between the citizens who get their drinking water from the Octoraro

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Reservoir but do not live in the watershed and the farmers and landowners who live in the watershed but do not get their drinking water from the reservoir. The Chester Water Authority and the Octoraro Watershed Association have jointly supported many education and outreach programs, and the Authority has provided a meeting place and administrative support services to the Association. The Association promotes agricultural best management practices (BMPs) such as streambank fencing, barnyard management, crop rotation, and the establishment of forested riparian buffers throughout the watershed. One of the Association's greatest challenges has been convincing farmers that the BMPs will benefit both them and the watershed. Sharing success stories is often a successful way to garner support for BMP implementation. The Association also helps willing farmers seek financial aid for their BMPs. Funds are often available from local, state, and federal partners.

Assessing Watersheds

One of the keys to a strong watershed protection program is the assessment of the area. It is important to be able to identify watershed problems and target protection efforts. Watershed delineation and assessment are tools used to achieve these goals. Many water utilities use geographic information systems (GIS) to delineate their watersheds. Afterwards, local managers can use zoning maps to identify land use patterns within the watersheds and identify potential sources of contamination that pose the greatest threats to the drinking water supply. A comprehensive monitoring plan is also useful for identifying watershed problems.

Example: Monitoring Data to Support Protective Water Quality Standards, Portland Water Bureau, Portland, Oregon

The Portland Water Bureau draws its water from the Bull Run River in the Mt. Hood National Forest. The U.S. Forest Service (USFS) administers the watershed under several legal authorities including the Bull Run Management Act (P.L. 95-200). This act sets the production of pure, clean, raw, potable water as the principal federal management objective for the area. Consequently, the USFS must adopt standards specific to the Bull Run watershed that are more stringent than its national standards. The USFS, the Portland Water Bureau, and the U.S. Geological Survey share the monitoring responsibilities of sampling, data collection and analysis, and database management. Monitoring is critical to unfiltered water systems, serving as an early warning of turbidity-producing events such as landslides and storm-induced erosion. By tracking turbidity levels during and after these events, facility operators can either divert heavily contaminated waters or temporarily switch to an alternative ground water source. The Portland Water Bureau is also using the monitoring program to estimate the sediment loading from abandoned roads in the national forest.

Managing Land Use in Watersheds

The type of land use in a drinking water supply source area, whether it is rural, urban, forested, and/or farmed, presents a challenge to managing the water source. Utilities whose water sources are in a forested area usually must contend with logging, erosion, and timber management. Systems whose sources are in rural or suburban areas may need to deal with septic systems, agricultural runoff, and erosion or recreational uses such as swimming, hiking, and mountain biking. In urban areas, utilities need to address issues such as storm water drainage, runoff from pavement, and increasing development. Solutions to the pollution from these various land uses range from simple, creative ideas that other systems can easily adopt, to capital-intensive projects that require significant funding commitments.

Example: Managing Urban Storm Water, Massachusetts Water Resources Authority, Boston, Massachusetts

Pollutant runoff from construction sites after large rainfall events can stress drinking water treatment facilities. Although the Massachusetts Water Resources Authority does not regulate storm water releases from construction sites, the Metropolitan District Commission (MDC) Division of Watershed Management works with petitioners to review all plans for the design and construction of storm water and erosion control projects. These control projects are required under the state's Watershed Protection Act and Wetlands Protection Act. In addition to reviewing plans, annual watershed sanitary surveys help MDC staff identify areas of concern. Once a specific threat to human health is identified, the MDC works with the responsible party to mitigate the situation. In the future, MDC plans to analyze pollutant loading at the subbasin level and recommend

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BMPs. The Massachusetts Water Resources Authority and MDC plan to conduct workshops to help municipalities implement the BMPs and may provide technical and financial assistance.

Acquiring Land

One way to solve the problem of competing land uses within a watershed is to acquire all the land surrounding a water source. Rather than negotiate with individual landowners, the system buys the land surrounding a surface water source. This solution is simple, yet often difficult to implement.

***Example*: Land Acquisition Program Targets High-Priority Parcels, New York City Department of Environmental Protection, New York, New York**

New York City's water utility, the Department of Environmental Protection (DEP), has embarked on a 10-year program of land acquisition within its watersheds. DEP has committed $250 million to acquire property associated with the Catskill and Delaware River supply systems. These supplies spread over 1,600 square miles west of the Hudson River and provide 90% of New York City's water. An additional $10 million has been set aside for the same purpose in the Croton Watershed, which lies east of the Hudson. This program operates under a 10-year water supply permit from the New York State Department of Environmental Conservation (NYSDEC) issued in 1997. This permit enables DEP to acquire, through purchase or conservation easements, undeveloped land near reservoirs, wetlands, and watercourses, as well as land with other features sensitive to water quality. No land will be taken through eminent domain, and fair market value is paid for all land. The watersheds have been divided into priority areas for acquisition, based on natural features and proximity to reservoirs, intakes, and DEP's distribution system.

Conclusions

The examples provided here are just a sampling of local actions being taken across the country to protect sources of drinking water. The common thread among the examples is the coordination of a drinking water utility's goals with local watershed management initiatives aimed at aquatic ecosystem restoration and protection.

This highlight was drawn from *Protecting Sources of Drinking Water: Selected Case Studies in Watershed Management* (EPA 816-R-98-019, April 1999). For more information on EPA's efforts to protect drinking water sources, visit the Office of Ground Water and Drinking Water on the Internet at *http://www.epa.gov/ogwdw/protect.html*.

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Drinking Water Standards

EPA sets national primary drinking water standards through the establishment of maximum contaminant levels (MCLs) and through treatment technique requirements.

MCLs are the maximum permissible levels of contaminants in drinking water that is delivered to any user of a public water system. The MCLs provide enforceable standards that protect the quality of the nation's drinking water.

Treatment techniques are procedures that public water systems must follow to ensure a contaminant is limited in the drinking water supply. EPA is authorized to establish a treatment technique when it is not economically or technically feasible to ascertain the level of a contaminant.

Source Water Protection

The SDWA Amendments establish a strong new emphasis on preventing contamination problems through source water protection and enhanced water system management. The states are central in creating and focusing prevention programs and helping water systems improve their operations to avoid contamination problems. States are assessing the susceptibility to contamination of the source waters supplying public water systems. These assessments will provide the information necessary for states to develop tailored monitoring programs and for water systems to seek help from states in protecting source water or initiating local government efforts.

Better Consumer Information/Right-to-Know

The consumer information provisions of the SDWA Amendments herald a new era of public involvement in drinking water protection. Community water systems are required to send customers an annual report with information on their drinking water quality. Each report must provide the following information about their drinking water:

■ The lake, river, aquifer, or other source of the drinking water

■ A brief summary of the susceptibility of the local drinking water source, based on the source water assessments that states are completing over the next 4 years

■ How to get a copy of the water system's complete source water assessment

■ Level (or range of levels) of a contaminant found in local drinking water, as well as EPA's MCL for comparison

■ Likely source of that contaminant in the local drinking water supply

■ Potential health effects of any contaminant detected in violation of EPA's MCL and an accounting of the system's actions to restore safe drinking water

■ The water system's compliance with other drinking-water-related rules.

This rule will affect 55,000 water systems, and the information in the reports will reach 248 million people nationwide. Large water systems will mail the water quality reports to their customers, either with water bills or as a separate mailing, and will take steps to get the information to people who do not receive water bills. Smaller water systems may be able to distribute the information through newspapers or by other means.

Regulatory Improvements

Recognizing that responsible flexibility, good science, and a better prioritization of effort could improve protection of public health, the 1996 SDWA Amendments established a new process for regulating drinking water contaminants.

■ **New risk-based contaminant selection.** This list establishes priorities for EPA's drinking water program (Table 8-5). EPA published the Drinking Water Contaminant Candidate List (CCL) in the March 2, 1998, *Federal Register* (63 FR

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10273). It includes 61 contaminants divided among three categories:

- Priorities for additional research
- Priorities for additional occurrence data
- Priorities for consideration for rulemaking.

■ **Occurrence Information.** The collection, organization, and ready availability of contaminant occurrence data are taking on unprecedented importance. EPA has established both a National Drinking Water Contaminant Occurrence Database (NCOD) and an Unregulated Contaminant Monitoring Regulation, as required by the SDWA amendments.

■ **Cost-Benefit Analysis and Research for New Standards.** Regulations now formalize that in developing all future drinking water standards, EPA must conduct a cost-benefit analysis, provide comprehensive and understandable information to the public, and use the best available peer-reviewed science and supporting studies.

■ **Disinfection Byproduct/ *Cryptosporidium*.** Microbial pollutants in drinking water may cause acute gastrointestinal problems. Yet some disinfection processes that reduce microbial contaminants create disinfection byproducts. To strengthen control of microbial pathogens, disinfectants, and disinfectant byproducts in drinking water, EPA is developing a group of interrelated regulations referred to as the microbial disinfection byproduct rules. These rules are intended to address risk trade-offs between the different types of contaminants and to address the waterborne pathogen, *Cryptosporidium*.

A Stage 1 Disinfectants/Disinfection Byproducts Rule and an Interim Enhanced Surface Water Treatment Rule were promulgated in December 1998. The Stage 1 Disinfectants/Disinfection Byproducts Rule establishes maximum residual disinfectant level goals and maximum residual disinfectant levels for chlorine, chloramine, and chlorine dioxide. It also establishes MCL goals and MCLs for total trihalomethanes, haloacetic acids, chlorite, and bromate.

EPA also issued an Interim Enhanced Surface Water Treatment Rule in 1998. It includes treatment requirements for *Cryptosporidium* and filter turbidity monitoring provisions.

Drinking Water State Revolving Fund

The creation of a Drinking Water State Revolving Fund (DWSRF) program to assist communities in installing and upgrading safe drinking water treatment facilities is one of the more important additions to the nation's drinking water program.

All states have received EPA funding to establish their DWSRF

The new amendments offer a unique incentive for water utilities and groups devoted to watershed protection to form partnerships and explore their common ground. After all, the goals of one group often affect the goals of the other. For instance, water utilities generally strive to keep treatment costs down, while watershed groups typically look for ways to address sources of contamination. Identifying such common pursuits stands to benefit everyone and, ultimately, the future of the nation's watersheds.

Table 8-5. Regulatory Subset List of the CCL

Chemical or Microbial Contaminant		
Acanthamoeba (guidance)	Boron	Metribuzin
1,1,2,2-Tetrachloroethane	Bromobenzene	Naphthalene
1,1-Dichloroethane	Dieldrin	Organotins
1,2,4-Trimethylbenzene	Hexachlorobutadiene	Triazines and degradation products
1,3-Dichloropropane	*p*-Isopropyltoluene	Sulfate
2,2-Dichloropropane	Manganese	Vanadium
Aldrin	Metolachlor	

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programs. The program gives states the authority to use a portion of their DWSRF resources to support new prevention programs. States are encouraged to place a high priority on use of funds for activities aimed at protection of drinking water by preventing contaminants from entering sources of drinking water.

Drinking Water Concerns

Over 90% of people in the United States get their drinking water from public water supplies. Although most public water supplies meet drinking water standards, a diverse range of contaminants can affect drinking water quality. EPA's Science Advisory Board concluded that drinking water contamination is one of the greatest environmental risks to human health. This conclusion is due, in part, to the variability in quality of the source of water supplying the drinking water. It is also due to the potential for contamination in the delivery system as the water travels from the treatment plant to the consumer's tap.

Under the Safe Drinking Water Act, a public water system is defined as a system that has at least 15 service connections or serves an average of at least 25 people for at least 60 days per year. There are three types of public water systems:

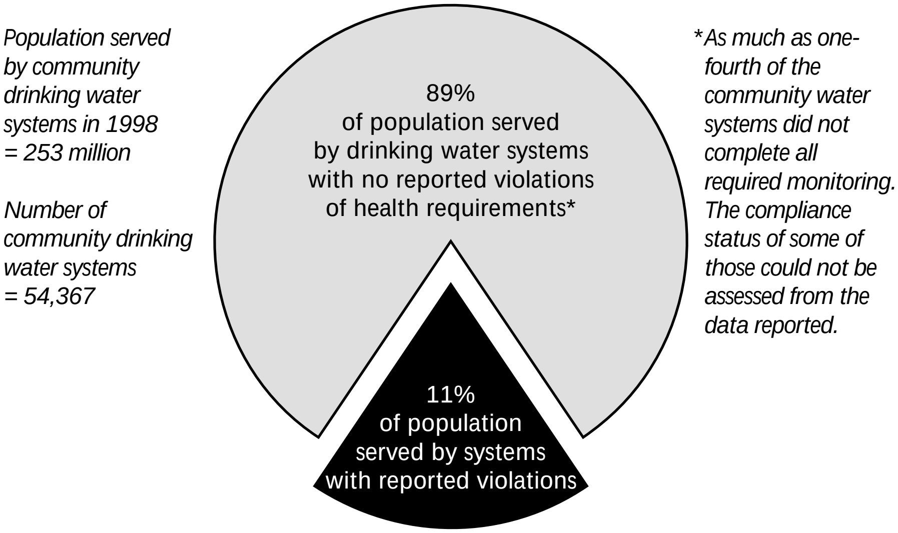
- Community water systems are those that serve the same people year-round (e.g., cities, towns, villages, and mobile home parks).
- Nontransient noncommunity water systems are those that serve at least 25 of the same people for at least 6 months of the year (e.g., schools, day care centers).
- Transient noncommunity water systems are those that serve transient populations (e.g., rest stops, campgrounds, and parks).

In 1998, 89% of the population served by community water systems received water that had no reported health violations (Figure 8-5). Of the 54,367 community water systems, 9% reported MCL or treatment technique violations. These systems served nearly 30 million people.

For all public water systems in 1998, there were 15,832 MCL or

Figure 8-5

Compliance of Community Drinking Water Systems with Health Requirements in 1998



Source: U.S. EPA, 1999, Office of Ground Water and Drinking Water, Washington, DC.

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treatment technique violations reported by 9,788 of the 170,376 systems. Most of these violations were in small systems.

The greatest risk from unsafe drinking water is exposure to waterborne pathogens, which can cause acute health problems requiring medical treatment. As shown in Figure 8-6, bacteria, viruses, parasitic pathogens, and chemical agents have all been shown to cause waterborne disease outbreaks.

For systems serving a large population, a waterborne disease outbreak can sharply impact a large number of people. The 1993 *Cryptosporidium* outbreak in Milwaukee, for example, affected more than 400,000 people, the largest waterborne disease outbreak ever reported in the United States.

Recreational Restrictions

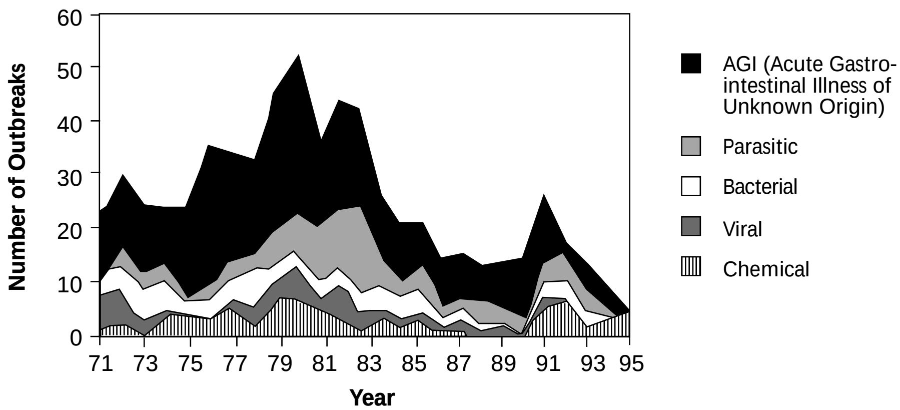
State reporting on recreational restrictions, such as beach closures, is often incomplete because most state agencies rely on local health departments to voluntarily monitor and report beach closures. Most state agencies that prepare the 305(b) reports do not have access to an inventory of beach closures. The information obtained varies in quality because health departments that monitor infrequently will detect fewer bacteria violations than health departments with rigorous beach monitoring schedules.

Nine states reported that there were no contact recreation restrictions reported to them during the 1998 reporting cycle. Sixteen states and tribes identified 240 sites where recreation was restricted at least once during the reporting cycle (Appendix E, Table E-6, contains individual state data). Local health departments closed many of these sites more than once. Pathogen indicator bacteria caused most of the restrictions. Other contaminants cited include syringes found on beaches, toxics in seaweed, floating mats of vegetation, and pollutants in urban runoff.

The states identified sewage treatment plant bypasses and malfunctions, urban runoff storm sewers, and faulty septic systems as the most common sources of elevated bacteria concentrations in bathing areas. The states also reported that natural sources and

Figure 8-6

Waterborne Outbreaks in the United States by Year and Type



Source: Levy et al., 1998, Morbidity and mortality surveillance summaries. *Surveillance for Waterborne Disease Outbreaks*, Centers for Disease Control, Atlanta, GA, V. 47(SS-5): 1-34. *http://www.cdc.gov/epo/mmwr*

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The Clean Water Action Plan and Public Health Protection

The Clean Water Action Plan (CWAP) contains several key action items designed to improve public health protection. Some of the specific actions call for increased effort to ensure that fish and shellfish are safe to eat. Federal agencies are working with states and tribes to expand programs to reduce contaminants that can make locally caught fish and shellfish unsafe to eat—particularly mercury and other persistent, bioaccumulative toxic pollutants—and to ensure that the public gets clear notice of fish consumption risks. Another main component is to ensure safe beaches. To achieve this goal, federal, state, and local governments will work to improve the capacity to monitor water quality at beaches, develop new standards, and use new technologies, such as the Internet, to report public health risks to recreational swimmers.

Actions to Reduce Fish and Shellfish Consumption Health Risks

In 1998, 2,506 public advisories restricting the consumption of locally caught fish were in effect. States and tribes issue advisories to notify and protect their citizens from unsafe levels of contaminants in fish tissue that make the fish unsafe to eat or unsafe to eat in large quantities. Numerous inland rivers and lakes, all of the Great Lakes and their connecting waters, a large portion of the nation's coastal waters, and about 20% of the national wildlife refuges with permissible fishing are under fish consumption advisories.

EPA is promoting consistent methodologies for state and local public health officials to use in issuing or rescinding advisories for specific chemical residues, fish species, and human population groups at risk. Technical handbooks and public information brochures can be ordered through a special EPA website devoted to fish and shellfish consumption advisory issues located at *http://www.epa.gov/OST/fish/*. The EPA website allows users to access a special database that includes all available information describing state-, tribal-, and federally issued fish consumption advisories in the United States for the 50 states, District of Columbia, four U.S. territories, and the 12 Canadian provinces and territories. These advisories inform the public that

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high concentrations of chemical contaminants have been found in local fish and wildlife, and they include recommendations to limit or avoid consumption of certain fish and wildlife species. EPA has upgraded this Listing of Fish and Wildlife Advisories database for interactive queries and mapping using Internet web browsers. The database has been enhanced to include information on the actual levels of the major pollutants in fish tissue that can trigger advisories. Tissue chemical residue data have been included at sites where advisories have been issued, as well as other areas showing very low levels of contamination. Watershed-oriented analysis of such tissue residue data may help define relatively "clean areas" where the public could be encouraged to fish with minimal risks.

EPA is conducting research to more accurately quantify and predict the sources, transport, fate, and exposure risks for major pollutants that can lead to fish consumption advisories. Considerable effort is being targeted on mercury, which can be transported over large areas through the atmosphere and where effective risk management will require a multimedia perspective and substantial interagency and stakeholder cooperation. Pollution prevention and more stringent regulatory controls will be advanced for major emission sources and for legacy pollutants found in sediments. Prototype studies on mercury-related fish consumption advisory concerns are in progress at lakes in Wisconsin and in Florida to define effective management approaches.

Fish advisories have also been issued for other long-lasting toxic pollutants, including polychlorinated biphenyls (PCBs), chlordane, dioxins, and DDT, even though their use was banned or drastically restricted many years ago. Many of these pollutants settle into the sediments where they can remain as a source of contamination well after the original source is controlled. Many of these chemicals are also known or suspected endocrine disruptors, which can cause reproductive or developmental problems of special concern for women and children. The CWAP will accelerate the development of strategies to address these concerns about persistent toxins and endocrine disruptors.

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Actions for Improved Beach and Recreational Health Risk Management

The CWAP has helped accelerate the implementation of EPA's *Action Plan for Beaches and Recreational Waters* (ORD and OW, EPA/600/R-98/079). There are three main action areas in this *Beach Action Plan*. First, EPA will continue to promote better recreational water programs and improved risk communication activities. An example risk communication tool is EPA's BEACH Watch website, located at *http:www.epa.gov/ost/beaches*. This website makes information available to the public and decision makers in a timely fashion.

To keep this database of beach and recreational closure information accurate, EPA will conduct a National Beach Health Survey annually to collect detailed local beach information as well as data on state and local monitoring efforts, applicable standards, water quality communication methods, the nature and extent of contamination problems, and any protection activities.

EPA will also develop a national inventory of digitized beach maps. These maps will be linked with locations of pollution sources through a geographic information system. They are expected to become an invaluable source of information to local organizations and the general public.

EPA will develop and support strong regional and local partnerships through the Environmental Monitoring for Public Access and Community Tracking Program (EMPACT). Current beach-specific EMPACT projects with EPA offices in New England, the Mid-Atlantic, the Southeast, the Great Lakes region, the South, the West, and the Gulf Coast region are investigating the use of better bacterial indicators, exploring improved monitoring methods, developing site-specific predictive tools, and making timely beach information available to the public.

The second objective of the *Beach Action Plan* is to improve the science that supports recreational water monitoring programs. The *Beach Action Plan*'s scientific research addresses three broad areas. Rapid analytical methods are needed that adequately distinguish between indicators of human versus animal pathogens and that cover indicators for a broader range of human disease organisms than do present techniques. Modeling tools are also needed to help predict conditions likely to increase exposure risks, supplement conventional monitoring in making management decisions to lift bathing area closures, and to help in the design of more sensitive and efficient monitoring approaches. Finally, studies are needed on the impacts from combined sewer overflows (CSOs).

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CSOs are widely believed to be a major contributor to bathing area problems. EPA will target research to quantify CSO exposure risks under different flow regimes (wet weather and dry weather) and will document pathogen movement and survival rates in intertidal water and beach substrates that are often the main areas of exposure for children and other sensitive population groups. EPA will coordinate its efforts with other federal agencies in addition to its extensive efforts with state and local environmental and public health departments.

John Theilgard, Lake Washington, WA

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Low oxygen concentrations, high temperatures, and high acidity can devastate aquatic communities.

waste spills restricted recreational activities.

Aquatic Ecosystem Concerns

A primary goal for waters of the United States is that they support aquatic life. As defined in Chapter 1, this means that the waterbody provides for the protection and propagation of desirable fish, shellfish, and other aquatic organisms. This section describes how states articulate this goal in their water quality standards and how pollution impacts aquatic life.

The states use a variety of approaches for setting standards to protect aquatic life. All states adopt aquatic life as a designated use for all waters unless they performed a use attainability analysis and determined the use has not and cannot be attained. Some adopt very general use designations that simply state that all waters shall support aquatic life, while others adopt detailed designations that describe the characteristics of the aquatic community that each type of water shall support.

All states adopt numeric criteria that establish thresholds for specific chemicals. All states adopt narrative criteria that prohibit the presence of toxic pollutants in toxic amounts. Most state standards include narrative criteria stating that waters will support the propagation and growth of all aquatic life.

To strengthen their ability to protect the biological integrity of aquatic ecosystems, EPA encourages states to adopt designated uses or biological criteria that define the aquatic community structure and function for a specific waterbody or class of waterbodies. These can be descriptive characteristics or a numeric score based on multiple measures of community structure and function. Currently about half of the states have or are developing refined use designations or biological criteria.

The challenge for EPA is to summarize the states' individual assessments, which are based on substantially diverse standards. The basis for EPA's summary is the final assessment status reported by the states on how supportive their waters are of the aquatic life use goal. As illustrated in the earlier chapters, states report that one of the leading reasons for waters being judged as impaired is a water's inability to meet the aquatic life use goal.

Pollution Impacts

The Clean Water Act defines pollution as any human-induced change in the chemical, physical or biological integrity of the nation's waters. Pollution includes not just toxic chemicals, but other stressors as well. States reported that some of these other stressors are the leading causes of impairment to aquatic life. These stressors include habitat alterations such as flow modifications and excessive siltation, nutrient enrichment, and contamination of sediments with persistent chemicals. Following a description of how pollution affects aquatic life, the impacts of these three stressors are explored.

A fish kill is one of the most obvious effects of pollution on aquatic life. This phenomenon is normally attributed to exceptionally low dissolved oxygen levels, usually due to excessive nutrients in the water, or to the discharge of toxic contaminants to the water column. A more insidious and less easily observable impact of pollution on aquatic life is stress on the resident aquatic biota. An indicator of aquatic life use impairment may be keyed to an individual organism's health measured in terms of growths, lesions, eroded fins, or body burden of toxic chemicals and their byproducts.

The most common impact of pollution on aquatic life is the shift of a waterbody's naturally occurring and self-sustaining biological community. An example would be the shift of a cold water trout stream to a warm water carp-dominated stream. This may occur due to a variety of reasons, but the most common are an elevation of temperature, a lowering of available dissolved oxygen, and an increase in sedimentation due to land use practices within the watershed. These perturbations to habitat and water quality may lead to an undesirable change in the aquatic community. Frequently associated with changes in the biological community structure are changes in biodiversity, e.g., loss of taxa, gain in invasive species, increase in harmful algal blooms, and loss of key food web support species such as diatoms, seagrasses, and submerged aquatic macrophytes.

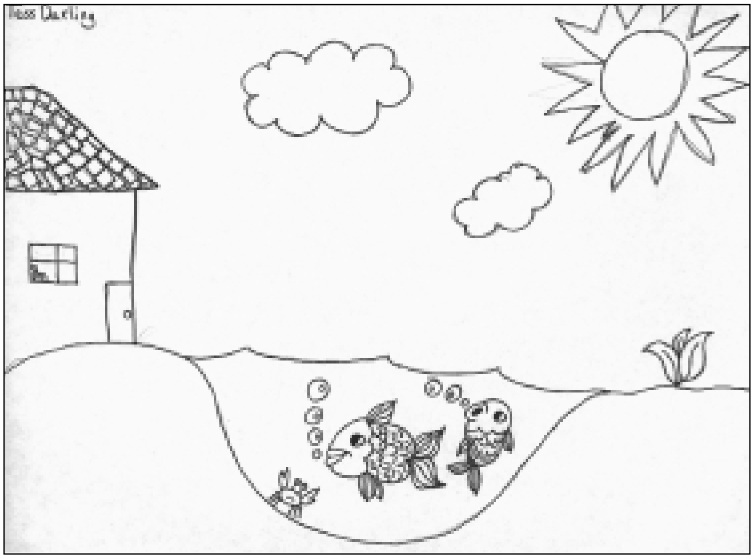
Habitat

Habitat is the place where an organism or community of organisms lives. It includes both living and nonliving elements. The immediate habitat or microhabitat for aquatic life includes the ambient water and its physical and chemical characteristics, including temperature, flow rate, and dissolved oxygen content. It also includes the substrate or bottom of the waterbody, which can be rocky, sandy, silty, grassy, etc.

The larger-scale habitat or macrohabitat includes the stream banks and the overall watershed within which the waterbody and the aquatic organisms reside. The macrohabitat plays an important role in protecting water quality and aquatic life. It can act as a buffer to the aquatic system and diminish the impact of human perturbation.

Changes in watershed habitat affect waterbody habitat. For example, changes in the amount and type of vegetation within the watershed and, in particular, alongside the waterbody frequently result in increased sediment loads, elevated temperature, and wide fluctuations in the volume and velocity of flow. These changes, in turn, alter the ambient water quality and the

EPA has currently issued guidance to the states on how to monitor the biological condition of waters: *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition* (EPA 841-B-99-002) and *Lake and Reservoir Bioassessment and Biocriteria: Technical Guidance Document* (EPA 841-B-98-007). Further guidance integrating the various monitoring methodologies into a comprehensive assessment of aquatic life use support is planned for Fiscal Year 2000.



Tess Darling, Grade 3, NC

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EPA's nutrient team is developing a series of technical guidance documents on techniques used to develop nutrient criteria for use in state and tribal water quality standards. The following draft guidance documents are undergoing peer review. They are available on the Internet at: *http://www.epa.gov/ostwater/standards/guidance/index.html*.

Draft Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs, April 1999

Draft Nutrient Criteria Technical Guidance Manual: Rivers and Streams, September 1999

substrate in which aquatic organisms and communities reside and, ultimately, the biological integrity of the aquatic ecosystem.

When rain falls within a watershed that has lost its natural vegetative cover, the rain flows more rapidly over the land. This reduces the amount of water that will percolate through the soil into ground water. It increases the volume and velocity of water entering the waterbody. It increases dirt and sediment carried into the waterbody. If excessive amounts of sediment are deposited in the waterbody, they can smother rocky, gravel, and grassy substrates within the waterbody that are critical to the propagation of aquatic life. The increased volume and velocity of water can scour the sides and bottoms of waterbodies causing erosion and compounding sedimentation problems.

Also, if the watershed historically had many trees, loss of this habitat reduces the amount of tree canopy shading the waterbody. This can cause the ambient water temperature to rise. Changes in natural habitat can also affect nutrient cycling within the waterbody. Both of these changes can cause significant shifts in the types of species that are tolerant of this new habitat and dramatically change the biological integrity of a waterbody.

Stable habitat is critical to protection and propagation of balanced indigenous aquatic communities. Habitat evaluation is one tool used to assess the vulnerability of an aquatic ecosystem. This information helps target where limited ambient monitoring resources would be best spent. The limitation of this approach is that, although poor habitat is usually an indicator of impaired aquatic life, acceptable habitat quality does not mean that aquatic life is healthy. EPA has issued basic habitat assessment guidance in the stream and lake bioassessment protocols. Additional guidance is being developed for other waterbody types including estuaries and wetlands.

Nutrient Enrichment

Nutrients are essential building blocks for healthy aquatic communities. They are necessary for metabolism. Nitrogen and phosphorous are required in relatively large amounts by plant and animal cells. Insufficient amounts of these nutrients results in less than optimal growth of plants including algae and other aquatic vegetation. Adequate plant growth is essential to support all the other organisms in a healthy, diverse, and productive aquatic community. Excess nutrients, however, can have detrimental effects on water quality and aquatic life.

Excessive amounts of nutrients, especially nitrogen and phosphorus, result in excessive growth of algae and other aquatic vegetation and potentially harmful algal blooms. Nuisance levels of algae are associated with dissolved oxygen deficiency leading to fish kills and imbalances in predator/prey relationships, decreased water clarity, loss of natural submerged aquatic vegetation (an important fish, shellfish, and wildlife habitat and nursery), odors, loss of natural biodiversity, and changes in water chemistry, e.g., increased pH in many waterbodies.

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Nitrogen and phosphorus are transported to receiving waters from stream networks, rain, overland runoff, ground water, drainage networks, and industrial and residential wastewater discharges. Sources of nitrogen and phosphorus include fertilizers, sewage treatment plants, septic systems, combined sewer overflows, sediment mobilization, runoff from animal feeding operations, atmospheric transport, and internal nutrient recycling from sediments to the water column.

Nutrient enrichment is not a new issue. State 305(b) reports consistently identify nutrients as a leading cause of water quality impairment. Traditional efforts at nutrient control have been only moderately successful.

In February of 1998, President Clinton and Vice President Gore released a comprehensive *Clean Water Action Plan*. A key part of the plan provides for expanded efforts to reduce nutrient overenrichment of waters. The *Action Plan* calls on EPA to accelerate the development of scientific information and guidance concerning the levels of nutrients that cause water quality problems in different types of waterbodies and different geographic regions of the country. It also calls on EPA to work with states and tribes to adopt criteria for nutrients as part of enforceable state water quality standards under the Clean Water Act.

EPA, the U.S. Department of Agriculture, and other partners are working to accomplish the nutrient goals of the Clean Water Action Plan. EPA published the *National Strategy for the Development of Regional Nutrient Criteria* in June of 1998. In addition to describing the approach for developing nutrient criteria, it identifies some of the other efforts of EPA and its partners to address nutrient enrichment of our nation's waters.

Sediment Contamination

Certain types of chemicals in water tend to settle and collect in sediment. For example, some chemicals such as petroleum products and chlorinated solvents do not mix with water (are hydrophobic). Some metals such as lead and mercury can settle out due to gravity or can be adsorbed onto sediment particles.

Chemicals in sediment often persist longer than those in water, in part because they tend to resist natural degradation and in part because conditions might not favor natural degradation. Bacteria degrade some chemicals in sediment, but many persist for years even after the original source has been eliminated. In the water column, these pollutants may be too dilute to measure. But because currents tend to deposit sediments in distinct depositional zones, sediment can accumulate pollutants at these locations to toxic levels.

When present at elevated concentrations in sediment, contaminants can be taken up by organisms that live in or on sediments and can bioaccumulate up the food chain (see text box on page 192). Contaminants can also be released from the sediment back into the water column. In both cases, excessive levels of chemicals in sediment might become hazardous to aquatic life and humans.

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EPA has developed methodologies for assessing the risk of toxicity to benthic dwelling organisms from metals and nonionic organic compounds. These methodologies are based on an approach called "equilibrium partitioning" that accounts for site-specific bioavailability of chemicals and has undergone full scientific peer review from EPA's Science Advisory Board. These methodologies can be used by states assessing the potential impacts of contaminated sediment on aquatic life.

In 1998, EPA reported to Congress on contaminated sediment. This report identified areas in the continental United States where sediment may be contaminated at levels that may adversely affect aquatic life and human health. The report was prepared in response to the Water Resources Development Act of 1992. It was prepared in conjunction with the National Oceanic and Atmospheric Administration, the Army Corps of Engineers, and other federal, state, and local agencies. Data from 1980 to 1993 were used in preparing this report.

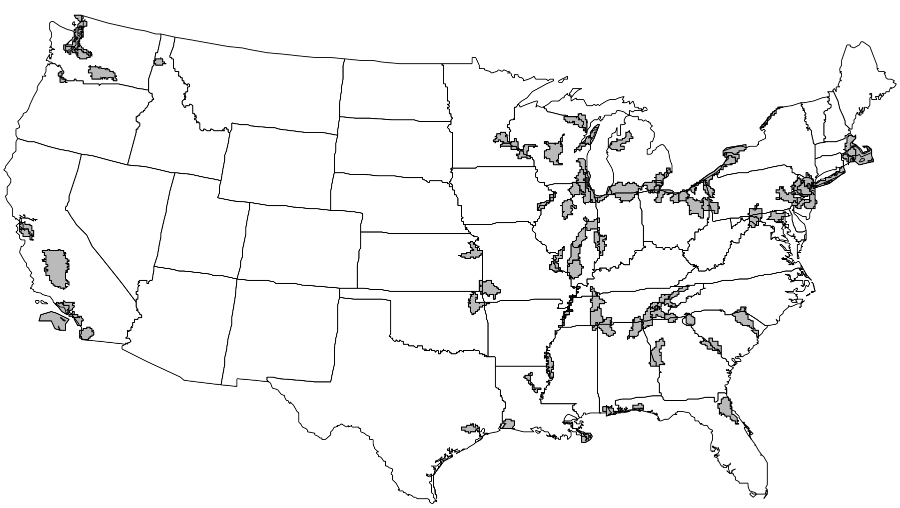
The report is based on existing data. It identified 96 watersheds that contain areas of probable concern—many of which are already well known to state and local government agencies and the general public (Figure 8-7).

According to this report, areas of sediment contamination occur in coastal and inland waterways, in clusters around larger municipal and industrial centers, and in regions affected by agricultural and urban runoff. The data and the evaluation results are intended to help local watershed managers identify local areas where additional analyses of water quality may be warranted.

EPA's Office of Science and Technology also developed the National Sediment Inventory (NSI), an extensive georeferenced database of sediment quality monitoring and pollutant source information for the nation's freshwater and estuarine ecosystems. Environmental managers can use NSI data and assessment protocols now as screening tools to help determine the incidence and severity of sediment contamination and to identify areas requiring closer inspection. In time, NSI data and assessments will

Figure 8-7

EPA's 1998 National Sediment Quality Survey Areas of Probable Concern



Other known areas of contaminated sediment (such as the Hudson River in New York and the James River in Virginia) are not depicted on this map but will be included in the year 2000 report to Congress.

From: *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (3 volumes), available at *http://www.epa.gov/ost/cs/congress.html*.

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reveal trends and help measure progress in minimizing risk.

For more information on EPA's contaminated sediment program, visit the program on the Internet at *http://www.epa.gov/OST/cs*.

In their 1998 305(b) reports, 11 states and tribes listed 115 separate sites with contaminated sediments and identified specific pollutants detected in sediments. These states most frequently listed metals (e.g., mercury, cadmium, and zinc), PCBs, pesticides, PAHs, and other priority organic toxic chemicals. These states also identified industrial and municipal discharges (past and present), landfills, resource extraction, and abandoned hazardous waste disposal sites as the primary sources of sediment contamination.

Appendix E, Table E-10, lists individual state data on sediment contamination for the 11 states reporting. Several states preferred not to list contaminated sites until EPA publishes national criteria for screening sediment data. Other states lack the analytical tools and resources to conduct extensive sediment sampling and analysis. Therefore, the limited information provided by states and tribes probably understates the extent of sediment contamination in the nation's surface waters.

EPA has developed guidance and information sources to provide states with better tools for assessing and managing sediment contamination. A list of sediment contamination materials is available on the Internet at *http://www.epa.gov/OST/pc/csn.html*. Information on equilibrium partitioning sediment guidelines (sediment quality criteria) can be found at *http://www.epa.gov/OST/pc/equilib.html*.

River of Words 1997 Finalist, Adam Hirsch, *Down by My Bay*, Grade 7, California

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The Mid-Atlantic Highlands Assessment Project

The Mid-Atlantic Highlands Assessment (MAHA) builds on a number of previous regional initiatives in the eastern United States including studies of acid rain effects under the National Acid Precipitation Assessment Project (NAPAP), the Environmental Monitoring and Assessment Program's (EMAP) Mid-Atlantic Integrated Assessment (MAIA), results from the trend analysis initiative known as the Temporally Integrated Monitoring of Ecosystems (TIME) project, and a previous Regional EMAP (R-EMAP) project coordinated by EPA Region 3.

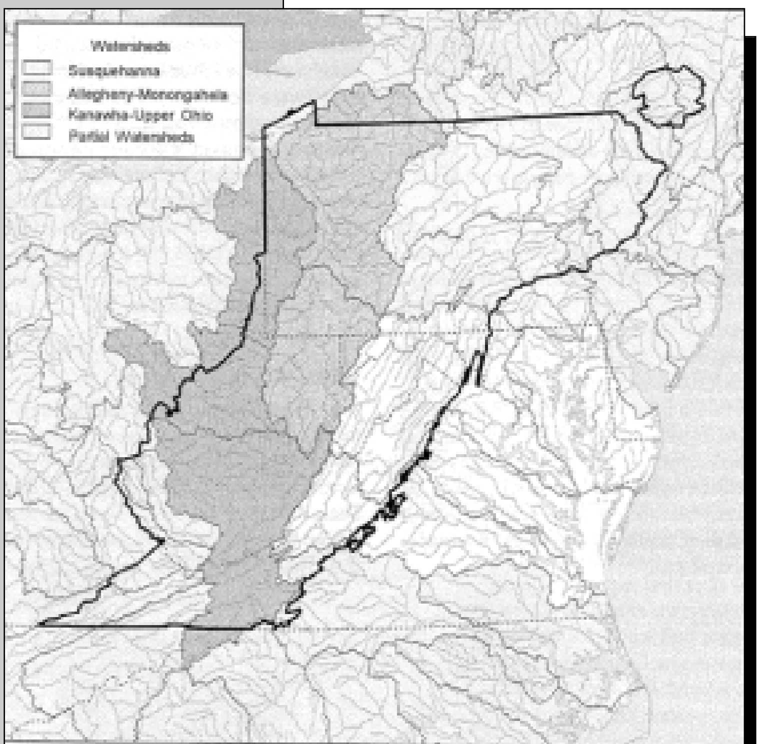

Figure 1. Three watersheds or combined drainage basins (water resources subregions) can be assessed in the Mid-Atlantic Highlands. The other watersheds extend outside the Highlands region. A watershed perspective is useful in viewing stream condition.

The geographic focus for MAHA is several large watershed areas on the upper Ohio River and Susquehanna basins extending to the west of the Blue Ridge and other mountain ranges that form the eastern Continental Divide. This 79,000-square-mile study area contains all of West Virginia, large parts of central and western Pennsylvania, portions of Maryland and Virginia, and areas outside EPA Region 3 in New York's Catskills. MAHA's scientific focus is on applying random site selection approaches to assess the ecological health of upland streams. Results can be presented according to administrative boundaries such as the states of West Virginia or Pennsylvania. Results can also be summarized for such major basins as the Susquehanna, the Allegheny-Monongahela, and the Kanawha-Upper

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Ohio; or for such major terrestrial ecoregions as Western Appalachia, the Great Valley, North-Central and Central Appalachia, and the Ridge and Blue Ridge ecoregion (see Figures 1 and 2).

Pooling resources from state environmental agencies, EPA, and other federal natural resource agencies, multiyear data collections were undertaken on headwater streams rated as first to third order. These highland streams account for over 89% of the stream mileage in these basins, but most available monitoring work has tended to concentrate on larger streams and rivers and much of the data on these larger systems involves water chemistry measurements. For MAHA, conventional water chemistry measures were made for such major parameters as nutrients (nitrogen and phosphorus) and pH (acidity). The monitoring activities also developed a variety of biological assessments on fishes and various insect macroinvertebrates that spend their early life stages in the streams. For the fishes, tissue analyses were also performed to measure concentrations of such contaminants as mercury (see Figure 3).

The information on the fishes was worked up into a series of special metrics related to species diversity, the number of pollution-intolerant (usually native) species, the total number of fish species, and so forth. These separate metrics

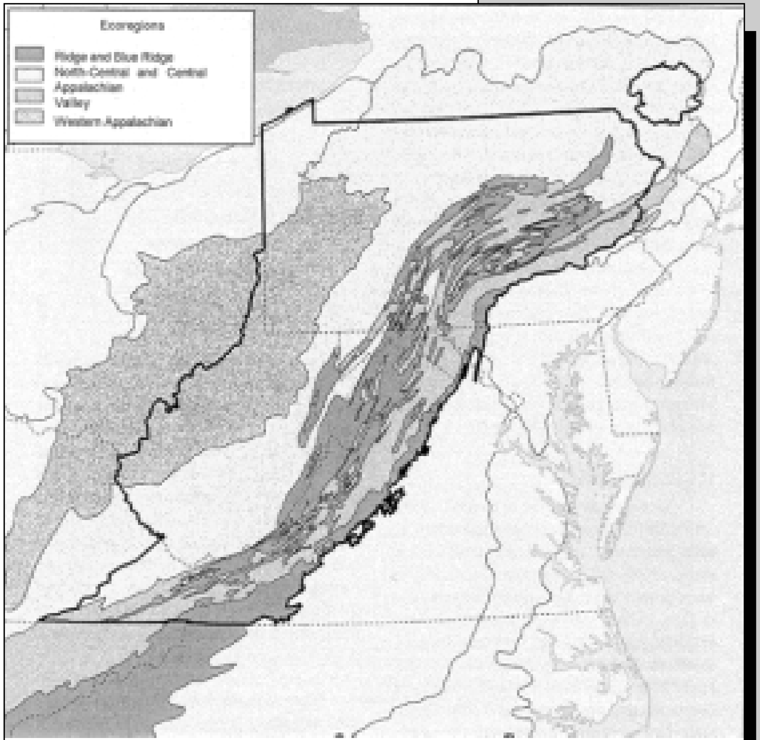

Figure 2. Ecoregions are areas with similar physical geography, soils, climate, and vegetation types. The Mid-Atlantic Highlands can be represented by four aggregated ecoregions. Ecoregions provide a useful perspective in viewing stream condition and characteristics.

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are then combined into a composite indicator called an **Index of Biotic Integrity** (Fish-IBI or IBI). For the insects, MAHA selected a macroinvertebrate index based on analysis of features of the three important taxa of the *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies) that are the main source of food for sports fish in most upland streams with hard substrates of gravels, pebbles, or rocks. An **EPT macroinvertebrate indicator** was determined based on the aquatic insect collections. Observations were also made of the condition of the stream substrate, banks, and the riparian areas close to the stream. Many of these standard biological and habitat monitoring techniques received a major boost from the initial release and ongoing updates to EPA's *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish* (available at *http://www.epa.gov/owow/monitoring/rbp*).

Monitoring sites were randomly selected to eliminate the possibility of taking samples from bridges or other easily accessed locations that often will not be representative of local stream conditions. Eliminating this sort of site selection bias makes it much easier to apply statistical tests to the assessment results. Margins of error and confidence limits can be estimated for the conclusions drawn from the MAHA project. For instance, for the FISH-IBI and EPT scores, typical margins of error were in the 10% to 12% range.

In addition to the chemical and biological sampling data, information was assembled on watershed conditions and general land use patterns for the current time period as well as available information going back several decades. Bioassessment indicators are usually compared against appropriate regional reference conditions to help define what indicator values can be classified as good, fair, or

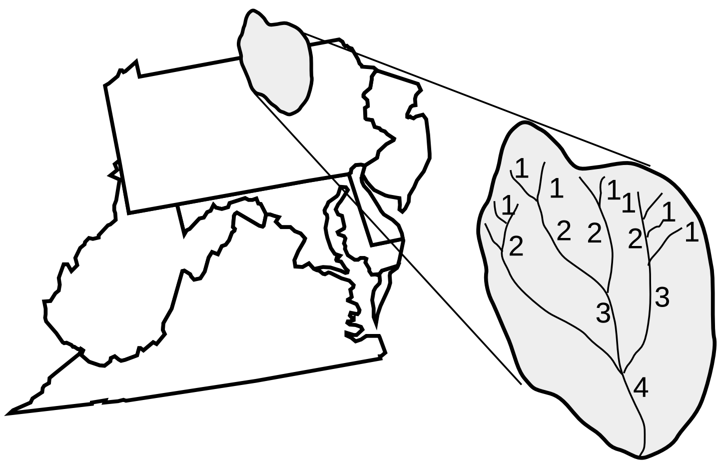

Figure 3. The majority of streams in the Mid-Atlantic Highlands (i.e., 89% or 72,200 stream miles) are classified as first- through third-order streams. This stream classification is illustrated above for one hypothetical watershed in the Highlands. The confluence (joining) of two first-order streams forms a second-order stream; the confluence of two second-order streams forms a third-order stream, etc.

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poor biological condition. For the current time period, these could be actual reference sites considered to reflect the best biological conditions currently attainable. From historical records and museum collections, MAHA also attempted to define reference conditions expected before large-scale European settlement of the area (that is, "precolonial" conditions).

The results of the MAHA biological indicators showed differences depending on the selection of the Fish-IBI or the EPT macroinvertebrate scores. Using reference sites reflecting best attainable current conditions, approximately 25% of the streams in the study area would be rated as showing good conditions, 50% fair, and 25% poor conditions. For the Fish-IBI, the results for the overall study area were 25% of the streams with good conditions, 33% fair, and 42% poor. For the Fish-IBI, shifting the reference sites to a hypothesized "precolonial" standard suggests only 10% of highland streams showing good conditions; 39%, fair; and 50%, poor (see table).

The substantial differences in the findings from the Fish-IBI and the EPT macroinvertebrate scores are the subject of ongoing investigations. Two factors that may account for the differences in performance in the two indicators are that some headwater streams either showed naturally very few different types of fishes or were essentially without fish.

MAHA also carried out preliminary analyses on major categories of pollution stressors. For eight different stressor or pollutant factors, the top four involved nonnative fish, excessive levels of nitrogen (a nutrient), and problems with either instream or riparian habitat conditions (see Figure 4).

The Mid-Atlantic Highlands Assessment project has helped states gain facility in applying bioassessment techniques in ways that encourage the analysis of the results for large landscape units such as basins or ecoregions. For waterbody

Comparison of Fish-IBI and EPT Macroinvertebrate Scores (percent)

	Good	Fair	Poor
EPT	25	50	25
Fish-IBI	25	33	42
Fish-IBI "precolonial"	10	39	50

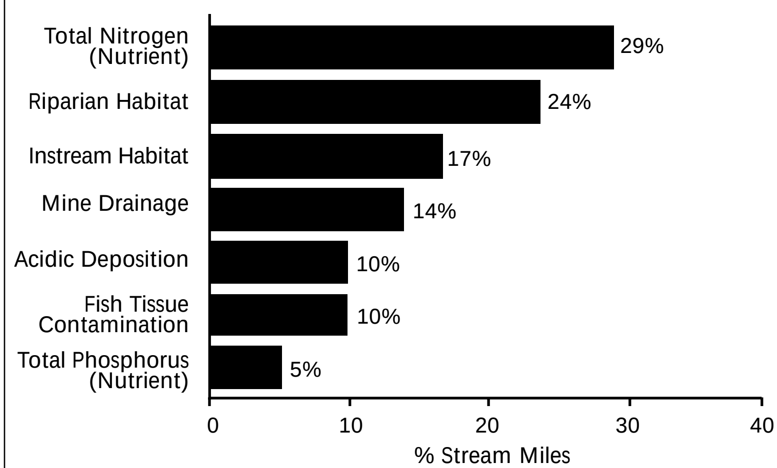

Figure 4. Overall ranking of potential stressors influencing the condition of Mid-Atlantic Highlands Streams.

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types such as small headwater streams that have traditionally not been adequately studied, random survey approaches show great promise as a way to develop a suitable baseline of information efficiently and in a fairly short span of time. While additional work is needed to clarify cause-effect relations between indicators of biological health and specific pollution factors, MAHA has considered several potential stressors and made preliminary estimates of the relative magnitudes of their impacts. In the future, regional analyses similar to MAHA will become important contributors to the Section 305(b) process and to other watershed-based management efforts by EPA and the states.

River of Words 1999 Finalist, Elaine Sullivan, Age 9, *A Frog Named Lily*, MA

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Letter to the Architect

Not even you can keep me from
mentioning the fish, their beauty of
scaled brevity, their clipped-swishing
tails funneling in everything animal.
Wintertime when I saw them, their
pursed old ladies' mouths, gaping under
pooled clarity to share some gulled-up gossip.
Their bones, pure equilateral, poked stripes
at base and height, bereft of architects' errors
or human compensation. I remembered then
your last letter; you wrote you couldn't cut
another mitre, solder another joint, peel
another bit of glue from between your fingertips.
I'm going to crack soon, you said.
There must be some way to perfection
in this grasping for centimeters. The stick
will stay straight, the model be done,
done beautifully and done well someday.
I wrote back–I only know the cod with their
paling rib bones, their geometry unwarped by cold.
I know their tunnels dug frost-time underwater,
their crossings of snowflake symmetry. When
the thaws come, their finned bodies filter
the halfway ice like clean spectra.
You must know–the sight is exquisite.
If only I could give the gift of fish-making
in as many words as this.

River of Words 1998 Grand Prize Winner (Poetry, Grades 10-12)
Rebecca Givens, Grade 11, GA