Part II

Water Quality Assessments

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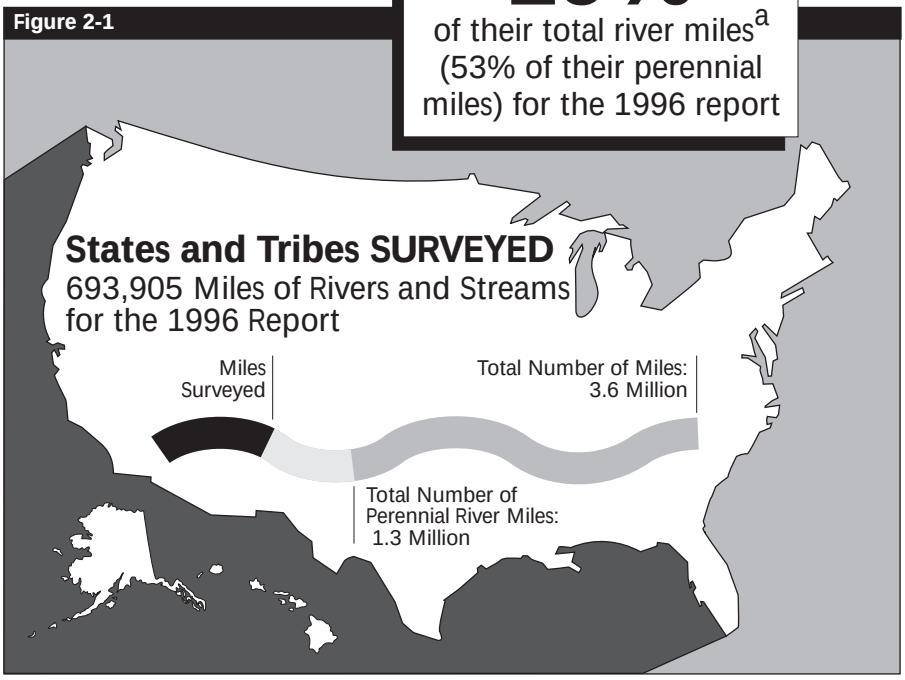
Rivers and Streams

Forty-seven States, two Interstate River Commissions, one Territory, the District of Columbia (hereafter collectively referred to as States), and three American Indian Tribes rated river water quality in their 1996 Section 305(b) reports (see Appendix A, Table A-1, for individual State and Tribal information). These States and Tribes surveyed conditions in 693,905 miles of rivers and streams; most of the surveyed rivers and streams are perennial waterbodies that flow all year. The surveyed rivers and streams represent 53% of the 1.3 million miles of perennial rivers and streams in the lower 48 States, or 19% of the estimated 3.6 million miles of all rivers and streams in the country, including nonperennial streams that flow only during wet periods (Figure 2-1).

Altogether, the States and Tribes surveyed 78,099 more river miles in 1996 than in 1994. While most States surveyed about the same number of river miles in both reporting cycles, Illinois, Maryland, North Dakota, and Tennessee collectively account for an increase of over 75,000 surveyed river miles. Since 1994, Illinois, North Dakota,

States and Tribes SURVEYED 19% of their total river miles[a] (53% of their perennial miles) for the 1996 report

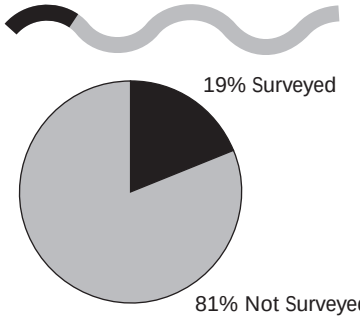
Figure 2-1



Based on data contained in Appendix A, Table A-1.

River Miles Surveyed by States and Tribes

1996 ■ 693,905 miles = 19% surveyed
Total miles: 3,634,152[a]



1994 ■ 615,806 miles = 17% surveyed
Total miles: 3,548,738[b]

1992 ■ 642,881 miles = 18% surveyed
Total miles: 3,551,247[c]

1990 ■ 647,066 miles = 36% surveyed
Total miles: 1,800,000[d]

[a]Source: 1996 State and Tribal Section 305(b) reports.
[b]Source: 1994 State and Tribal Section 305(b) reports.
[c]Source: 1992 State and Tribal Section 305(b) reports.
[d]Source: *National Water Quality Inventory:* 1990 Report to Congress, U.S. EPA, 1992.

Note: In comparison with 1990, it appears that the States and Tribes assessed a smaller percentage of the Nation's rivers in 1996. However, in 1996, most States and Tribes included intermittent streams, canals, and ditches that were excluded from the 1990 estimates of total stream miles. As a result, the national estimate of total stream miles almost doubled from 1.8 million miles in 1990 to more than 3.6 million miles in 1996.

The EPA Reach File Version 3 (RF3) is a database containing the geographic locations of over 3 million stream, lake, and estuary reaches in the continental U.S. and Hawaii. A reach is a stretch of stream between confluences or a segment of lake or estuary shoreline. RF3 provides unique identification numbers for points on these surface waters and built-in river mileages. With RF3, users can prepare computerized maps of healthy and impaired waters, monitoring sites, drinking water intakes, pollution sources, and many other features. RF3 also allows computer modeling of the movement of pollutants through its hydrologically connected network of waters.

and Tennessee have indexed all of their streams to the Reach File 3 (RF3) level in order to perform 1:100,000 scale geographic analyses (see sidebar for a description of RF3). The refined stream estimates have increased the mileage associated with surveyed streams. These States have also initiated new monitoring projects since 1994. Illinois now assesses all RF3 streams except for unnamed tributaries. North Dakota has initiated a new biological monitoring program in the Red River basin. Tennessee has also expanded its biological monitoring thanks to the Division of Water Pollution Control's ecoregion project and the Tennessee Valley Authority's River Action Teams. Maryland reported on all waters of the State for their 1996 305(b) report, of which approximately 11,000 river miles were not monitored or evaluated but were presumed to be of good water quality.

The summary information presented in this chapter applies strictly to the portion of the Nation's rivers surveyed by the States and Tribes. EPA cannot make generalizations about the health of all of our Nation's rivers based on data extracted from the 305(b) reports because most States and Tribes rate their waters with information obtained from water monitoring programs designed to detect degraded waterbodies. Very few States or Tribes select water sampling sites with a statistical design to represent a cross section of water quality conditions in their jurisdictions. Instead, many States and Tribes direct their limited monitoring resources toward waters with suspected problems. As a result, the surveyed rivers reflect conditions of targeted waters rather than a representative sampling of all waters.

In the future, increased use of statistically based monitoring programs will enable EPA and the States and Tribes to report more comprehensively on the general health of the Nation's waters. Examples of statistically based programs include probability designs implemented by Delaware, Maryland, and Indiana; EPA's Environmental Monitoring and Assessment Program (EMAP); and EPA's Regional Environmental Monitoring and Assessment Program (R-EMAP). EMAP is a long-term monitoring program with a unique approach that combines a probability-based sampling strategy with ecological indicators (quantifiable expressions of an environmental value) to assess the overall condition of ecological resources. R-EMAP applies the concepts, methods, and approach developed by EMAP to resolve specific environmental issues of importance to the EPA Regions and the States. (See highlight)

National data from other Federal agencies, such as the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), and private organizations, such as The Nature Conservancy, will also clarify national water quality trends. (See Chapter 13 for additional information about monitoring and assessment programs.)

Summary of Use Support

The States and Tribes rate whether their water quality is good enough to fully support a healthy community of aquatic organisms as well as human activities, such as swimming, fishing, and drinking. The States designate specific activities for their rivers and streams, termed "individual designated uses." EPA and the States use the following terminology to rate their water quality:

- **Good/Fully Supporting:** Good water quality supports a diverse community of fish, plants, and aquatic insects, as well as the array of human activities assigned to a river by the State.

- **Good/Threatened:** Good water quality currently supports aquatic life and human activities in and on the river, but changes when factors such as land use threaten water quality or data indicate a trend of increasing pollution in the river.

- **Fair/Partially Supporting:** Fair water quality supports aquatic communities with fewer species of fish, plants, and aquatic insects, and/or occasional pollution interferes with human activities. For example, occasional siltation problems may reduce the population of some aquatic species in a river, while other species are not affected.

- **Poor/Not Supporting:** Poor water quality does not support a healthy aquatic community and/or prevents some human activities on the river. For example, persistent PCB contamination in river sediments (originating from discontinued industrial discharges) may contaminate fish and make the fish inedible for years.

- **Not Attainable:** The State has performed a use-attainability analysis and demonstrated that use support of one or more designated uses is not attainable due to one of six specific biological, chemical, physical, or economic/social conditions (see Chapter 1 for additional information).

64% OF SURVEYED rivers have good water quality.

Most States and Tribes rate how well a river supports individual uses (such as swimming and aquatic life habitat) and then consolidate individual use ratings into a table of summary use support data. This table divides rivers into those miles fully supporting all of their uses, those fully supporting all uses but threatened for one or more uses, and those impaired for one or more uses. Impaired waters are the sum of partially and not supporting waters (see Chapter 1 for a complete discussion of use support).

Forty-three States, three Tribes, two Interstate Commissions, Puerto Rico, and the District of Columbia reported summary use support status for rivers and streams in their 1996 Section 305(b) reports (see Appendix A, Table A-2, for individual State and Tribal information). Another four States reported individual use support status but did not report summary use support status. In such cases, EPA used aquatic life use support status to represent summary water quality conditions in the State's rivers and streams.

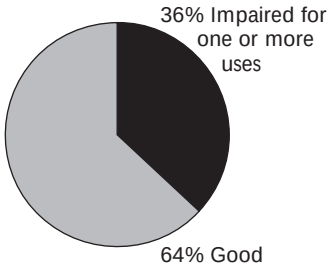
Surveyed Waters

Total rivers = 3.6 million miles[a]
Total surveyed = 693,905 miles[b]

Of the surveyed miles:

- 51% were monitored
- 41% were evaluated
- 8% were not specified

Surveyed Water Quality



[a]Source: 1996 State and Tribal Section 305(b) reports.
[b]Does not include miles assessed as not attainable (<0.5% of total rivers).

Altogether, States and Tribes reported that 64% of 693,905 surveyed river miles fully support all of their uses. Of these waters, 56% fully support designated uses and 8% have good water quality that fully supports all uses but is threatened for one or more uses. These threatened waters may deteriorate if we fail to manage potential sources of pollution (Figure 2-2). Some form of pollution or habitat degradation impairs the remaining 36% of the surveyed river miles.

Individual Use Support

Individual use support information provides additional detail about water quality problems in our Nation's surface waters. The States are responsible for designating their rivers and streams for State-specific uses, but EPA requests that the States rate how well their rivers support six standard uses so that EPA can summarize the State data.

- Aquatic life support – Is water quality good enough to support a healthy, balanced community of aquatic organisms, including fish, plants, insects, and algae?

- Fish consumption – Can people safely eat fish caught in the river or stream?

- Primary contact recreation (swimming) – Can people make full body contact with the water without risking their health?

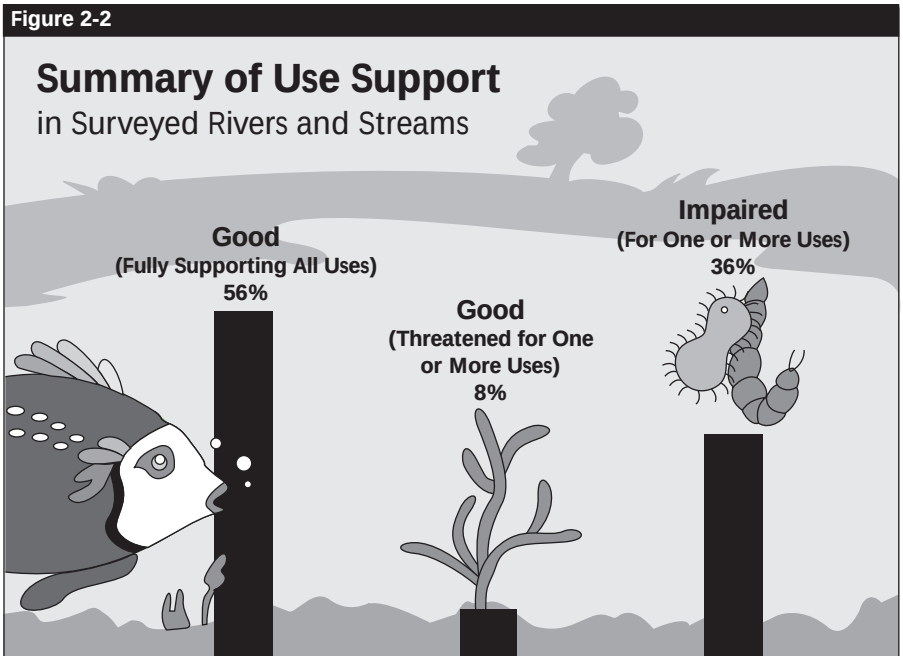
- Secondary contact recreation – Is there a risk to public health from recreational activities on the water, such as boating, that expose the public to minor contact with the water?

- Drinking water supply – Can the river or stream provide a safe water supply with standard treatment?

- Agricultural uses – Can the water be used for irrigating fields and watering livestock?

Only six States did not report individual use support status of their rivers and streams (see Appendix A, Table A-3, for individual State and Tribal information). The reporting States and Tribes surveyed the status of aquatic life and swimming uses most frequently and identified more impacts on aquatic life and swimming uses than on the other individual uses (Figure 2-3). These States and Tribes reported that fair

Figure 2-2



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

or poor water quality impacts aquatic life in 201,558 stream miles (31% of the 641,611 miles surveyed for aquatic life support). Fair or poor water quality conditions also impair swimming activities in 86,710 miles (20% of the 434,421 miles surveyed for swimming use support).

Many States and Tribes did not rate fish consumption use support because they have not codified fish consumption as a use in their standards. Some of these States consider fishing use as a component of aquatic life use, i.e., that rivers and streams can provide a healthy habitat to support fishing activities even though anglers may not be able to eat their catch in these States. EPA encourages the States to designate fish consumption as a use in their waterbodies to promote consistency in future reporting. Most States report information on fish consumption advisories (species and size of fish that should not be eaten) to EPA (see Chapter 7).

Water Quality Problems Identified in Rivers and Streams

Figures 2-4 and 2-5 identify the pollutants and sources of pollutants that impair the most river miles (i.e., prevent them from fully supporting designated uses), as reported by the States and Tribes. The two figures are based on the same data (contained in Appendix A, Tables A-4 and A-5), but each figure provides a different perspective on the extent of impairment attributed to individual pollutants and sources. Figure 2-4 compares the impacts of the leading pollutants and sources in all surveyed rivers. Figure 2-5 presents the relative impact of the leading pollutants and sources in impaired rivers, the subset of surveyed rivers with identified water quality problems.

The following sections describe the leading pollutants

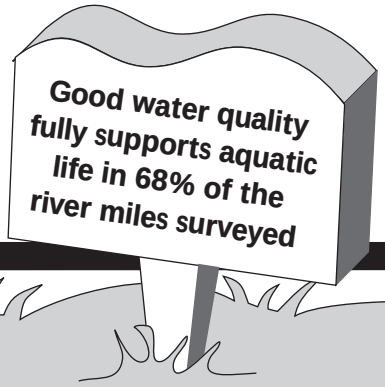


Figure 2-3

Individual Use Support in Rivers and Streams

Designated Use	Miles Surveyed	Percent: Good (Fully Supporting)	Good (Threatened)	Fair (Partially Supporting)	Poor (Not Supporting)	Not Attainable
Aquatic Life Support	641,611	60	8	23	8	<1
Fish Consumption	379,261	84	1	14	2	<1
Primary Contact – Swimming	434,421	76	3	10	10	<1
Secondary Contact	257,393	78	2	16	4	<1
Drinking Water Supply	194,660	79	5	10	6	<1
Agriculture	314,099	93	<1	3	3	<1

Based on data contained in Appendix A, Table A-3.

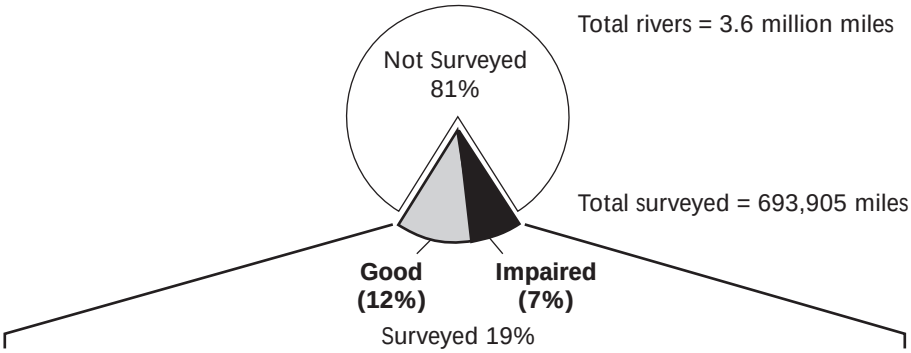
The pollutants/processes and sources shown here may not correspond directly to one another (i.e., the leading pollutant may not originate from the leading source). This may occur for a number of reasons, such as a major pollutant may be released from many minor sources or States may not have the information to determine all the sources of a particular pollutant/stressor.

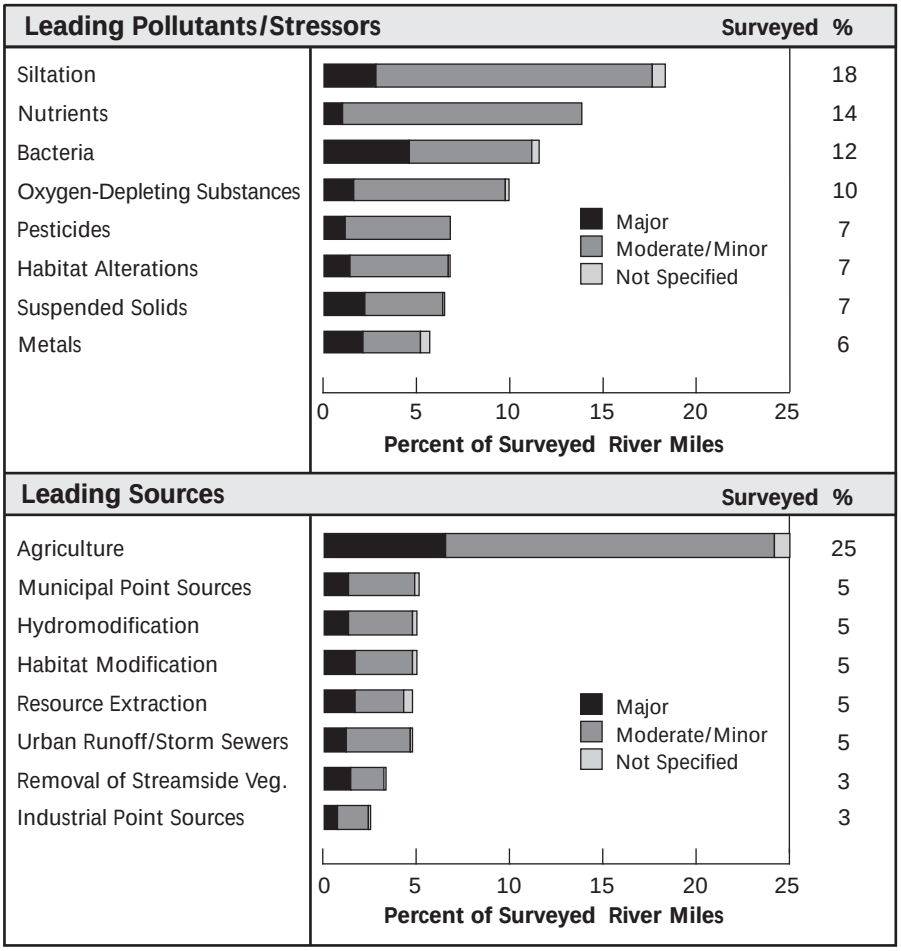
AGRICULTURE is the leading source of pollution in surveyed rivers and streams. According to the States, agricultural pollution problems

- affect 25% of all rivers and streams surveyed, and
- contribute to 70% of all water quality problems identified in rivers and streams (see Figure 2-5).

Figure 2-4

SURVEYED River Miles: Pollutants and Sources



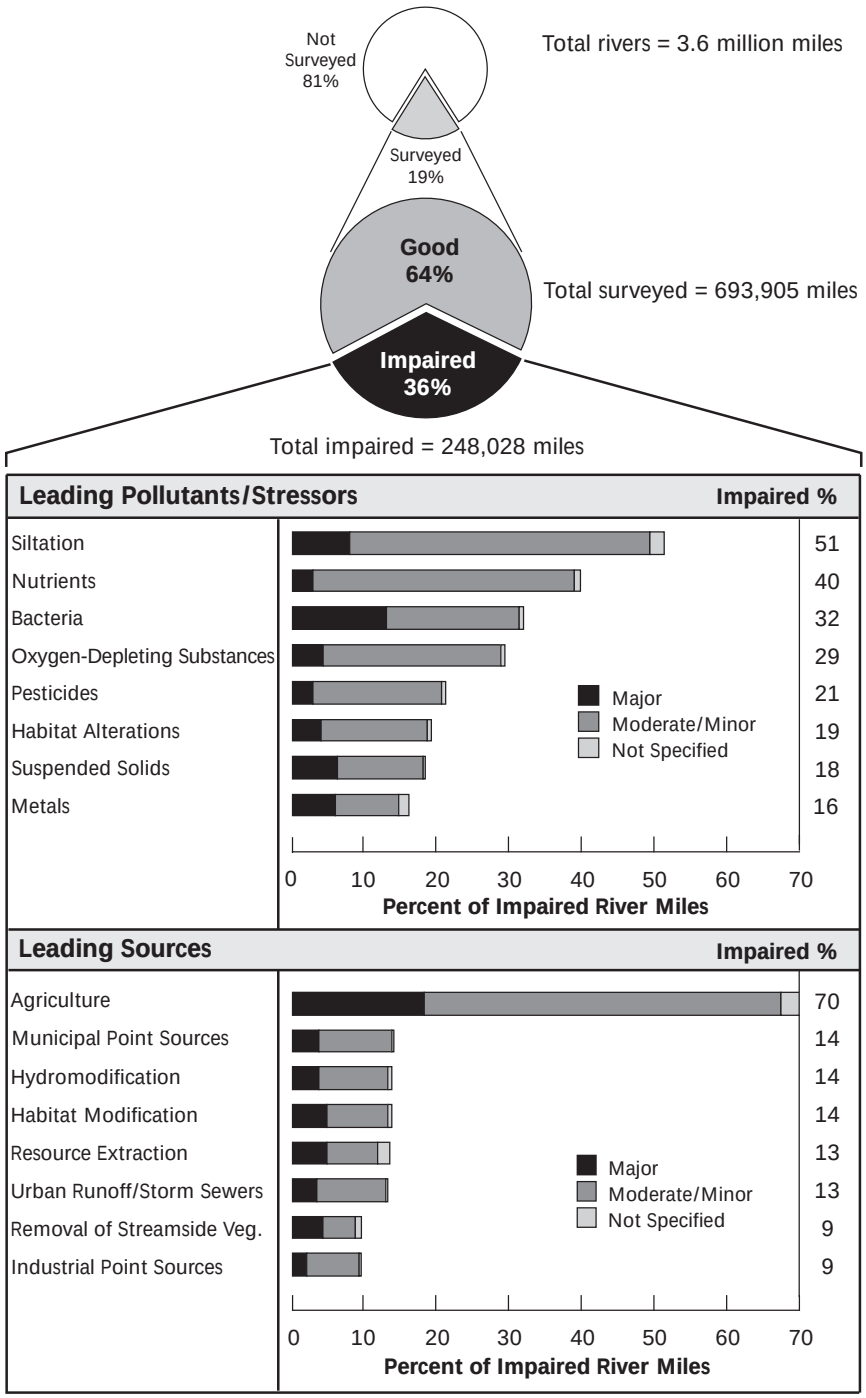


Based on data contained in Appendix A, Tables A-4 and A-5.

Note: Percentages do not add up to 100% because more than one pollutant or source may impair a river segment.

Figure 2-5

IMPAIRED River Miles: Pollutants and Sources



Based on data contained in Appendix A, Tables A-4 and A-5.

SILTATION is the most common pollutant affecting surveyed rivers and streams. Siltation

- is found in 18% of all rivers and streams surveyed (see Figure 2-4), and
- contributes to 51% of all the water quality problems.

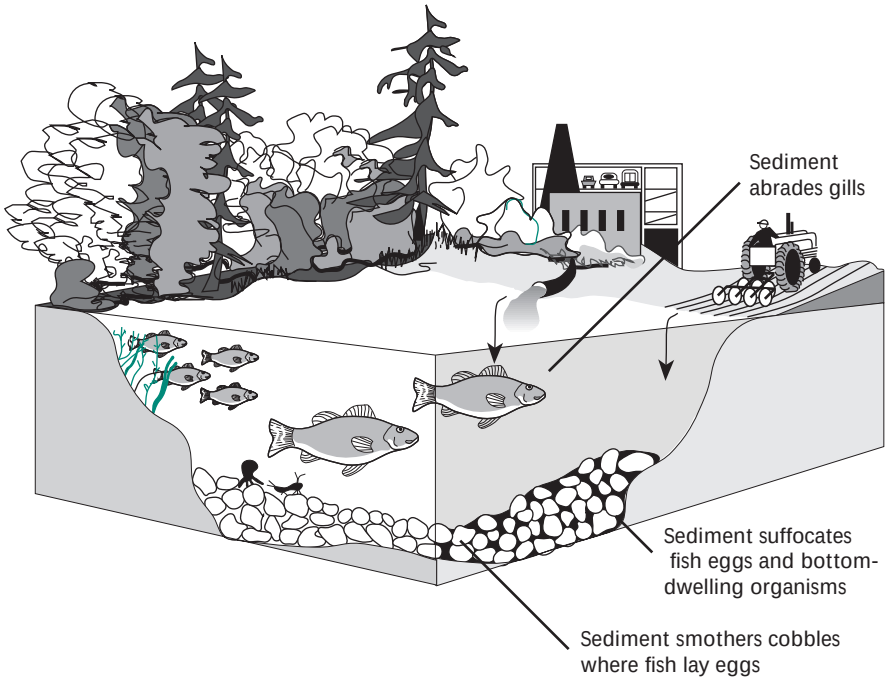
Note: Percentages do not add up to 100% because more than one pollutant or source may impair a river segment.

and sources of impairment identified in rivers. It is important to note that the information about pollutants and sources is incomplete because the States do not identify the pollutant or source of pollutants responsible for every impaired river segment.

In some cases, a State may recognize that water quality does not fully support a designated use, but the State may not have adequate data to document that a specific pollutant or process is responsible for the impairment. Sources of impairment are even more difficult to identify than pollutants and processes.

Figure 2-6

The Effects of Siltation in Rivers and Streams



Siltation is one of the leading pollution problems in the Nation's rivers and streams. Over the long term, unchecked siltation can alter habitat with profound adverse effects on aquatic life. In the short term, silt can kill fish directly, destroy spawning beds, and increase water turbidity resulting in depressed photosynthetic rates.

Pollutants and Stressors Impacting Rivers and Streams

Fifty-one States and Tribes reported the number of river miles impacted by individual pollutants and stressors, such as invasion by exotic species (see Appendix A, Table A-4, for individual State and Tribal information). EPA ranks the pollutants and stressors by the geographic extent of their **impacts** on aquatic life and human activities (i.e., the number of river miles impaired by each pollutant or stressor) rather than actual pollutant **loads** in rivers and streams. This approach targets the pollutants and stressors causing the most harm to aquatic life and public use of our waters, rather than the most abundant pollutants in our rivers and streams.

The States and Tribes report that siltation, composed of tiny soil particles, remains one of the most widespread pollutants impacting rivers and streams, impairing 126,763 river miles (18% of the surveyed river miles). Siltation alters aquatic habitat and suffocates fish eggs and bottom-dwelling organisms (see Figure 2-6). Aquatic insects live in the spaces between cobbles, but their habitat is destroyed when silt fills in these spaces. The loss of aquatic insects adversely impacts fish and other wildlife that eat these insects. Excessive siltation can also interfere with drinking water treatment processes and recreational use of a river. Sources of siltation include

agriculture, urban runoff, construction, and forestry.

Nutrient pollution emerges as a significant cause of water quality impairment in the 1996 305(b) reports, with States and Tribes reporting impacts to 98,040 river miles (14% of the surveyed river miles). While nutrient pollution has commonly been a problem in the Nation's lakes and ponds (see Chapter 3), water quality managers have given significant attention to its effects on rivers and streams, particularly those that flow to sensitive estuarine and coastal waters (see Chapter 4). Excessive levels of nitrogen and phosphorus may accelerate growth of algae and underwater plants, depleting the water column of dissolved oxygen necessary to maintain populations of fish and desirable plant species. Nutrients may enter surface waters from municipal and industrial wastewater treatment discharges and runoff from agricultural lands, forestry operations, and urban areas.

The States and Tribes also report that bacteria (pathogens) pollute 79,820 river miles (12% of the surveyed river miles). Bacteria provide evidence of possible fecal contamination that may cause illness if the public ingests the water. States use bacterial indicators to determine if rivers are safe for swimming and drinking. Bacteria commonly enter surface waters in inadequately treated sewage, fecal material from wildlife, and runoff from pastures, feedlots, and urban areas.

In addition to siltation, nutrients, and bacteria, the States and Tribes also reported that oxygen-depleting substances, pesticides, habitat alterations, suspended solids, and metals impact more miles of rivers and streams than other pollutants and stressors. Often, several pollutants and processes impact a single river segment. For example, a process such as removal of shoreline vegetation may accelerate erosion of sediment and nutrients into a stream. In such cases, the States and Tribes count a single mile of river under each pollutant and process category that impacts the river mile. Therefore, the river miles impaired by each pollutant or process do not add up to 100% in Figures 2-4 and 2-5.

Most States and Tribes also rate pollutants and processes as major or moderate/minor contributors to impairment. A major pollutant or process is solely responsible for an impact or predominates over other pollutants and processes. A moderate/minor pollutant or process is one of multiple pollutants and processes that degrade aquatic life or interfere with human use of a river.

Currently, EPA ranks pollutants and processes by the geographic extent of their impacts (i.e., the number of miles impaired by each pollutant or process). However, less abundant pollutants or processes may have more severe impacts on short stream reaches. For example, a toxic chemical spill can eliminate aquatic life in a short stream while widely distributed bacteria do not affect aquatic life but occasionally indicate a potential human health hazard from swimming. The individual State and Tribal 305(b) reports provide more detailed information about the severity of pollution in specific locations.

It is relatively easy to collect a water sample and identify pollutants causing impairments, such as fecal coliform bacteria indicating pathogen contamination. However, detecting and ranking sources of pollutants can require monitoring pollutant movement from numerous potential sources, such as failing septic systems, agricultural fields, urban runoff, municipal sewage treatment plants, and local waterfowl populations. Often, States are not able to determine the particular source responsible for impairment. In these cases, many States report the source of impairment as "unknown."

Some pollutant sources play a more significant role at a regional level.

Sources of Pollutants Impacting Rivers and Streams

Fifty-one States and Tribes reported sources of pollution related to human activities that impact some of their rivers and streams (see Appendix A, Table A-5, for individual State and Tribal information). These States and Tribes reported that agriculture is the most widespread source of pollution in the Nation's surveyed rivers. Agriculture generates pollutants that degrade aquatic life or interfere with public use of 173,629 river miles (which equals 25% of the surveyed river miles) in 50 States and Tribes (Figures 2-4 and 2-5).

Twenty-two States reported the size of rivers impacted by specific types of agricultural activities:

- Nonirrigated Crop Production – crop production that relies on rain as the sole source of water.

- Irrigated Crop Production – crop production that uses irrigation systems to supplement rainwater.

- Rangeland – land grazed by animals that is seldom enhanced by the application of fertilizers or pesticides, although land managers sometimes modify plant species to a limited extent.

- Pastureland – land upon which a crop (such as alfalfa) is raised to feed animals, either by grazing the animals among the crops or harvesting the crops. Pastureland is actively managed to encourage selected plant species to grow, and fertilizers or pesticides may be applied more often on pastureland than rangeland.

- Feedlots – generally facilities where animals are fattened. By EPA's definition, feedlots are large sites where many animals are confined at high densities for market. These facilities are often located near packing plants or railroad access points.

- Animal Holding Areas – facilities for confining animals briefly before slaughter. By EPA's definition, animal holding areas confine fewer animals than feedlots.

- Animal Operations – generally livestock facilities other than large cattle feedlot operations. They may contain facilities for supplemental feeding or rearing animals, primarily poultry or swine.

Nonirrigated crop production leads the list of agricultural activities impacting rivers and streams, followed by irrigated crop production, rangeland, pastureland, feedlots, animal operations, animal holding areas, and riparian grazing (Figure 2-7). Runoff from irrigated and nonirrigated cropland may introduce commercial fertilizers (that contain nitrogen and phosphorus), pesticides, and soil particles into rivers and streams. Manure applied to cropland as a fertilizer may also wash off of irrigated and nonirrigated fields and prevent rivers and streams from fully supporting designated uses.

Sources of pollution from intensive animal operations include feedlots, animal operations, and animal holding areas. Animal waste runoff from these operations can

introduce pathogens, nutrients (including phosphorus and nitrogen), and organic material to nearby rivers and streams. Rangeland may generate both soil erosion and animal waste runoff. Pastureland usually has good ground cover that protects the soil from eroding, but pastureland can become a source of animal waste runoff if animals graze on impermeable frozen pastureland during winter. Riparian grazing may generate streambank erosion and animal waste runoff and result in modification of streamside habitat.

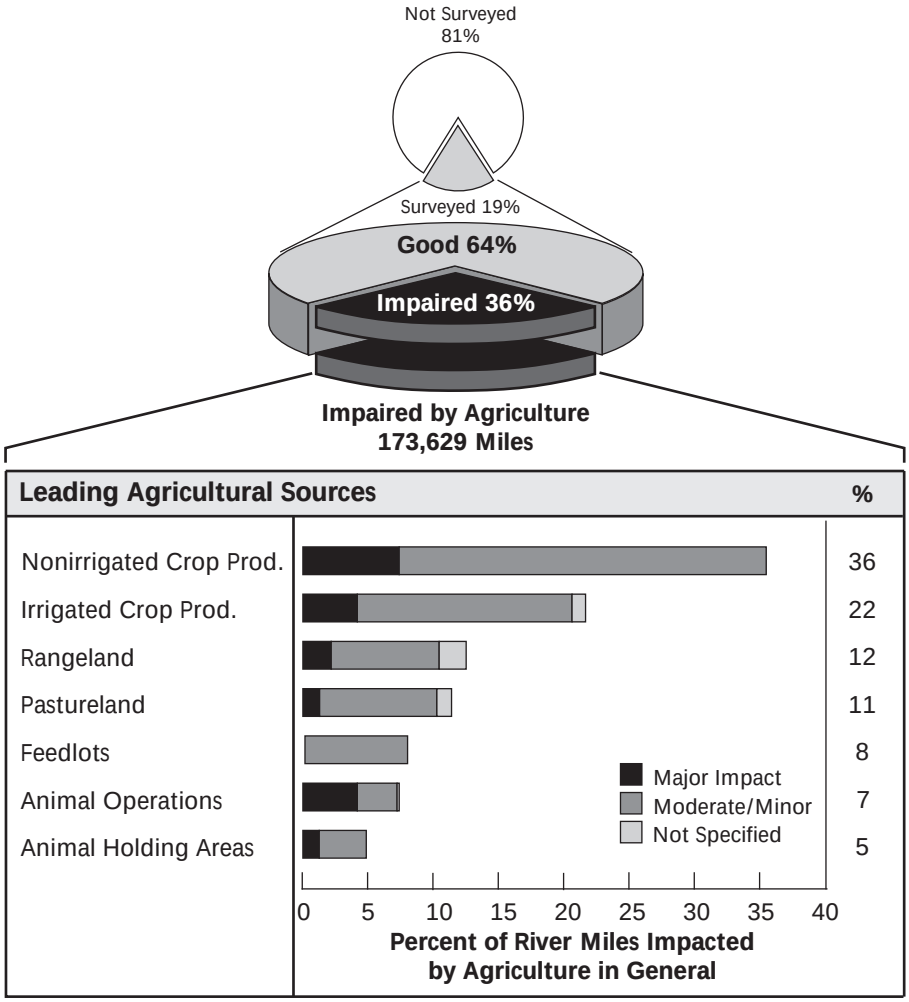
The States and Tribes also report that municipal sewage treatment plants pollute 35,087 river miles (5% of the surveyed river miles), hydrologic modifications degrade 34,190 river miles (5% of the surveyed river miles), habitat modifications degrade 34,127 river miles (5% of the surveyed river miles), resource extraction (e.g., mining and oil production) pollutes 33,051 river miles (5% of the surveyed river miles), urban runoff and storm sewers pollute 32,637 river miles (5% of the surveyed river miles), and removal of streamside vegetation pollutes 23,349 river miles (3% of the surveyed river miles).

The States and Tribes also report that "natural" sources impair many miles of rivers and streams in the absence of human activities. Natural sources include soils with natural deposits of arsenic or salts that leach into waterbodies, waterfowl (a source of nutrients), and low-flow conditions and elevated water temperatures caused by drought. The total size of rivers impaired by natural sources is probably exaggerated because some States may automatically attribute water quality impairments to natural sources if the State cannot identify a human activity responsible for a water quality problem.

Sources such as mining and forestry activities can play a more

Figure 2-7

Agricultural Impairment: Rivers and Streams
(22 States Reporting Subcategories of Agricultural Sources)



Based on data contained in Appendix A, Table A-6.

Note: Percentages do not add up to 100% because more than one pollutant or source may impair a river segment.

significant role in degrading water quality at a regional or local level than at the national level. For example, resource extraction (including acid mine drainage) contributes to the degradation of 36% of the impaired river miles in the coal belt States of Kentucky, Maryland, Ohio, Pennsylvania, and West Virginia. These States report that resource extraction impairs about 6,550 miles of rivers and streams. Yet, at the national level, resource extraction contributes to the degradation of only 13% of all the impaired river miles in the Nation. At the local level, streams impacted by acid mine drainage are devoid of fish and other aquatic life due to low pH levels and the smothering effects of iron and other metals deposited on stream beds. The primary sources of acid mine drainage are abandoned coal refuse disposal sites and surface and underground mines.

In the Pacific Northwest State of Washington, water quality managers identify forestry activities as responsible for almost a third (32%) of the impaired river miles, but, at the national level, States report that forestry activities contribute to the degradation of only 7% of the Nation's total impaired river miles. Forestry activities include harvesting timber, constructing logging roads, and stand maintenance. California, Florida, Louisiana, Mississippi, Montana, and West Virginia also report that forestry activities degrade over 1,000 miles of streams in each State.

Many States reported declines in pollution from sewage treatment plants and industrial discharges since enactment of the Clean Water Act in 1972. The States attributed improvements in water quality conditions to sewage treatment plant construction and upgrades and permit controls on industrial discharges. Despite the improvements, municipal sewage treatment plants remain the second most common source of pollution in rivers because population growth increases the burden on our municipal facilities.

Several States reported that they detected more subtle impacts from nonpoint sources, hydrologic modifications, and habitat alterations as they reduced conspicuous pollution from point sources. Hydrologic modifications and habitat alterations are a growing concern to the States. Hydrologic modifications include activities that alter the flow of water in a stream, such as channelization, dewatering, and damming of streams. Habitat alterations include removal of streamside vegetation that protects the stream from high temperatures and scouring of stream bottoms. Additional gains in water quality conditions that address these concerns will be more subtle and require innovative management strategies that go beyond point source controls.

Maryland Biological Stream Survey

The Maryland Biological Stream Survey (MBSS), initiated by the Maryland Department of Natural Resources in 1993, is one of the first statewide probability-based monitoring networks in the United States. The MBSS is intended to provide environmental decisionmakers with the information they need to most effectively design policies to protect and restore Maryland's rivers and streams.

The MBSS is different from most other stream monitoring surveys in Maryland for three reasons. First, the probability-based sampling design allows accurate estimates of variables, such as the number of miles of stream with degraded habitat, that can be extrapolated to the watershed, drainage basin, or statewide level. The design also permits reliable estimation of sampling variance, so that estimates of status can be made with quantifiable confidence. Second, MBSS monitoring and assessments focus on biological indicators of response to stress; measures of pollutant stress and habitat condition are taken simultaneously to provide a context for interpreting biological response. MBSS fish abundance estimates allow the State to track the population of a living resource. Third, the scale of MBSS is basinwide and statewide, rather than site-specific.

Objectives and Questions

The primary objectives of the MBSS are to assess the current status of biological resources in Maryland's nontidal streams and establish a benchmark for long-term monitoring of trends. The secondary

To meet its objectives, the MBSS has established a list of questions of interest to environmental decisionmakers. The survey is designed to answer these questions. Examples include:

Fishability

- What is the size range of smallmouth bass in third-order streams in the Patuxent basin? How many legal size smallmouth per mile of stream are there?
- What percentage of first- and second-order streams in the Patapsco basin support natural reproduction of brown trout?

Biological Integrity

- Does the percentage of streams with nonsupporting or partially supporting habitat differ among basins in the State?
- Rare or endangered fish or amphibian species are most likely to occur in what size of stream and in what basins of the State? What is the "best" basin for nongame species? The worst?

Holistic

- Based on their observed impacts, which anthropogenic stressors need to receive intensified management and enforcement activities?
- What types of land use are compatible with preventing the deterioration of water quality and stream resources?

objectives of the survey are to quantify the extent to which acidic deposition has affected or may be affecting critical biological resources in the State; examine which other water quality, physical habitat, and land use factors are important in explaining the current status of biological resources in streams; and focus habitat protection and restoration activities.

Sampling Design

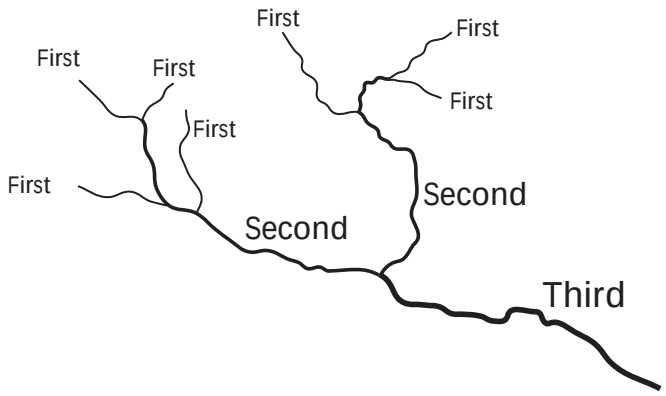
One common problem to many monitoring projects is that there is often no scientifically rigorous basis for extrapolating monitoring results beyond individual sampling sites. MBSS employs a special probability-based design called lattice sampling to schedule sampling of basins over a 3-year period. This design optimizes the efficiency of field efforts by minimizing the travel time between sampling locations.

The MBSS study area is divided into three geographic regions with five to seven basins each: western, central, and eastern. Each basin is sampled at least once during a given 3-year cycle, and all basins have some probability of being resampled.

The MBSS survey design is based on random selections from all streams in the State that can be physically sampled. Sampling within each basin is restricted to nontidal, first-, second-, and third-order stream reaches (i.e., headwater streams), excluding unwadeable or otherwise unsampleable areas. Stream reaches are further divided into nonoverlapping 75-meter segments for sampling.

About 300 stream segments are selected for sampling each year. An approximately equal number of segments are selected from each of the three stream orders across basins. Within each basin, segments

Each basin consists of many watersheds with varying degrees of complexity. The smallest permanent flowing stream in a watershed is termed first-order, and the union of two first-order streams creates a second-order stream. A third-order is formed where two second-order streams join.



are randomly selected from the three stream orders, with the number of segments selected for a particular stream order approximately proportional to the number of stream miles in the basin. For example, if Basin A has 200 miles of first-order streams, and Basin B has 100 miles of first-order streams, twice as many first-order segments are randomly selected from Basin A as from Basin B.

This type of study design, often referred to as subsampling with units of unequal size, allows the estimation of summary statistics (e.g., means and proportions) for the entire basin, or for subpopulations of special interest.

Data Collection and Measurement

The MBSS field studies involve collecting biological, physical habitat, and water quality data. Biological measurements include abundance, size, and health of fish; taxa composition of benthic invertebrates; and presence of herpetofauna (reptiles and amphibians). Water chemistry samples include pH, acid-neutralizing capacity (ANC), sulfate, nitrate, conductivity, and dissolved organic carbon (DOC). Physical habitat measurements include stream gradient, maximum depth, wetted width, streamflow (discharge), embeddedness, in-stream habitat structure, pool and riffle quality, bank stability, shading, and riparian vegetation. Other qualitative habitat parameters include aesthetic value, remoteness, and land use, based on the surrounding area immediately visible from the segment.

Results

The major findings of MBSS projects to date include:

- Low pH and low ANC streams were primarily limited to the eastern shore and to the mountainous western portion of the State.
- Moderate sulfate and relatively low DOC values throughout the State suggest that acidic deposition is far more prevalent as a source of low ANC than is acid mine drainage.
- The abundance and diversity of fish was positively related to ANC.
- Fish surveys detected a wider distribution of several fish species than have been reported previously, and two species thought to be extirpated were collected.
- In four of the six basins sampled during 1995, more than 40% of stream miles were acidic or acid-sensitive (ANC $\leq$ 200 µeq/L).

HIGHLIGHT HIGHLIGHT HIGHLIGHT

- In four of the six basins sampled during 1995, more than 50% of stream miles had in-stream habitat structure in poor to marginal condition.
- A large percentage of streams sampled had impaired physical habitat.

For Further Information

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