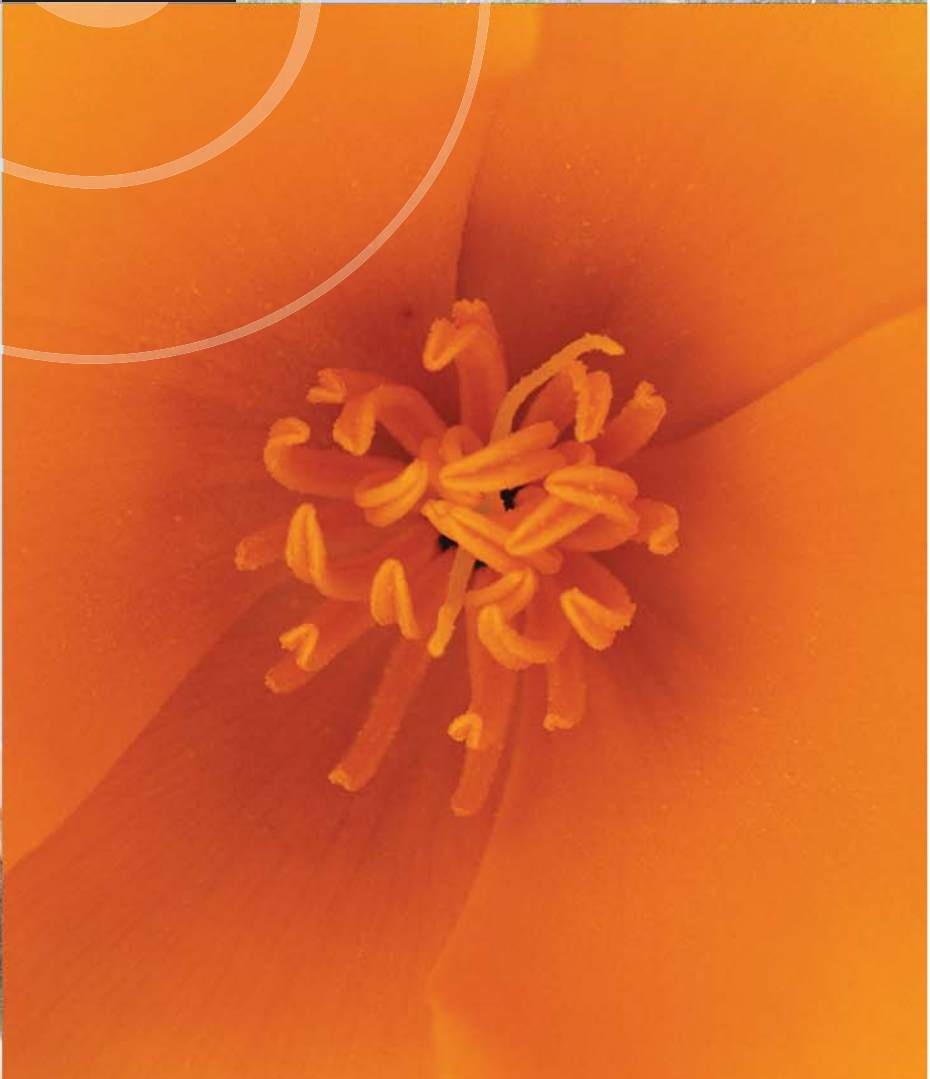




Draft Report on the Environment 2003



Message from the Administrator

I am pleased to present the U.S. Environmental Protection Agency's *Draft Report on the Environment*, a key step toward building a set of environmental indicators that will help answer the important questions Americans have about the environment, and that will guide our environmental decision-making in the future. This draft report provides a frank discussion of what we know—and what we don't know—about the condition of our nation's environment.

As we look over the past three decades, we see a real record of success in cleaning up and protecting our nation's environment. By many measures, our environment is healthier today than it was in 1970. The nation's commitment to environmental protection has produced cleaner air, safer drinking water for more Americans, and a much improved approach to managing wastes. Where we once took our environment for granted, we now intuitively understand the importance of environmental quality for our future. Much work remains to be done, however, and we must continue to build on our record of progress.

With this draft report, we begin an important national dialogue on how we can improve our ability to assess the nation's environmental quality and human health, and how we use that knowledge to better manage for measurable environmental results. I invite you to participate in this dialogue with us and our partners. Your comments and feedback are essential to our future efforts.

The President has called for a government focused on priorities and dedicated to excellence in public service. His Management Agenda is designed to improve the ability of the federal government to manage for results.

I thank the many EPA staff members from every program and region, our federal, tribal, state and local government partners, and the independent scientists and research institutions that contributed to this draft report.

We are all stewards of this shared planet, responsible for protecting and preserving a precious heritage for our children and grandchildren. As long as we work together and stay firmly focused on our goals, I am confident we will make our air cleaner, our water purer, and our land better protected for future generations.



Christine Todd Whitman


Administrator

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Executive Summary

In this *Report on the Environment*, the U.S. Environmental Protection Agency (EPA) presents its first-ever national picture of the U.S. environment. The report describes what EPA knows—and doesn't know—about the current state of the environment at the national level, and how the environment is changing. The report highlights the progress our nation has made in protecting its air, water, and land resources, and describes the measures that can be used to track the status of the environment and human health. Key conclusions from this report are summarized below.

This report is the first step in EPA's Environmental Indicators Initiative. Launched in November 2001, this initiative seeks to develop better indicators that EPA can use to measure and track the state of the environment and support improved environmental decision-making. As a first step in developing this report, EPA identified a series of key questions about the environment—questions such as: What is the condition of waters and watersheds in the United States? What is the quality of outdoor air in the United States? The Agency then carefully examined data sources, including those from other federal agencies, to identify indicators (e.g., the extent of wetlands and the concentrations of criteria pollutants in air) that could answer these questions on a national level.

These indicators provide the basis for this report. They also reveal that there is much we don't know about the status of our environment because we currently lack sufficient information to provide a more complete picture. An important next step in EPA's initiative will be working closely with other federal agencies, tribes, states, local governments, non-governmental organizations, and the private sector to create a long-term strategy for developing an integrated system of local, regional, and national indicators. This work will involve a number of challenges, including developing better data to support better indicators, making indicators more understandable and usable, and more fully elucidating the linkage between the causes and effects of environmental pollution and stressors.

EPA is issuing this report as a draft to stimulate dialogue and invite input into developing and improving environmental indicators in the future. EPA welcomes your suggestions about how well this report communicates environmental status and trends and how to better measure and manage for environmental results. To learn more about the Environmental Indicators Initiative, to access the Technical Document that provides the detailed scientific foundation for this report, or to provide comment and feedback on this report, please visit <http://www.epa.gov/indicators/>.

Cleaner Air

The nation's air is much cleaner today than it was 30 years ago. Remarkably, this progress has occurred even while, during the same 30-year period, the U.S. Gross Domestic Product increased 161 percent, energy consumption increased 42 percent, and vehicle miles traveled increased 149 percent. Notwithstanding this progress, challenges remain in attaining health based-standards for ozone and particulate matter, in improving visibility, and in understanding the nature and magnitude of issues posed by indoor air pollution.

Outdoor Air

Emissions of the six principal air pollutants have decreased. Over the last 30 years, total emissions of six principal air pollutants have decreased by nearly 25 percent, resulting in lower concentrations of these pollutants in ambient air. Many people live in areas of the country that do not always meet the health-based standards for certain pollutants. More than 133 million people live in areas where monitored air quality in 2001 was unhealthy at times because of high levels of at least one criteria air pollutant. At the same time, the percentage of days across the country that air quality violated a health standard dropped from almost 10 percent in 1998 to 3 percent in 2001.

Air toxics emissions have declined. The National Toxics Inventory, which tracks 188 toxic pollutants, estimates that nationwide air toxics emissions decreased almost 24 percent from baseline levels (1990–1993) to 4.7 million tons annually in 1996. Although data and tools for assessing the impacts of air toxics are limited, available evidence suggests that emissions of air toxics may still pose health and ecological risks in certain areas of the U.S.

One of the major components of acid rain, wet sulfate deposition, has declined. Wet sulfate deposition levels for 1999–2001 showed reductions of 20 to 30 percent compared to levels for 1989–1991 over widespread areas in the Midwest and the eastern U.S., where acid rain has had its greatest impact. Wet nitrogen deposition decreased slightly in some areas of the eastern U.S. but increased in others, including those with significant agricultural activity.

Indoor Air

Indoor air quality remains a concern. Because the American public spends most of its time indoors, indoor air quality is a serious issue. While more information is needed about pollutant exposures and their effects in indoor environments, national studies have shown that levels of some pollutants indoors can be much higher than outdoor levels. Two indoor air pollutants of particular concern are radon and environmental tobacco smoke (ETS), the latter especially for children. We are achieving, however, decreases in exposure to ETS. In 1998, young children were exposed to ETS in approximately 20 percent of homes in the U.S.—down from approximately 39 percent in 1986.

Global Issues

The stratospheric ozone layer has become thinner in recent decades, principally over the Antarctic. While acknowledging high uncertainties in the data, scientists calculate that since the 1980s, ultraviolet radiation levels at 10 stations in both the northern and southern hemispheres have increased by 6 to 14 percent. However, it is believed that because of the phase-out of ozone-depleting substances, the stratospheric ozone layer will recover, and ultraviolet radiation levels from human-induced stratospheric ozone depletion are close to the maximum they will reach.

Purer Water



Pristine waterways, safe drinking water, lakes for swimming and fishing, and aquatic life habitat are treasured resources. The nation has made significant progress in protecting these resources in the last 30 years. For example, concerted action to protect the nation's waters has reduced discharges of pollutants to surface water and improved safety of drinking water supplies. Challenges remain, however, including polluted runoff, landscape modification, changes to water flow, airborne pollutants settling into surface water, and the aging of both wastewater and drinking water infrastructures. The precise scope and scale of these challenges—at the local and the national scale—are uncertain.

Waters and Watersheds

We know a great deal about the condition of the nation's waters at the regional, state, tribal, and local levels, but we do not have enough information to provide a comprehensive picture at the national level. The way in which the nation collects water quality data does not support a comprehensive picture of watershed health at the national level.

The nation's estuaries are in fair to poor condition, varying from poor conditions in the northeast, Gulf, and Great Lakes regions to fair conditions in the West and Southeast, based on measurements of seven coastal condition indicators.

Rates of annual wetland losses have decreased from almost 500,000 acres a year three decades ago to a loss of less than 100,000 acres averaged annually since 1986. Nevertheless, in key parts of the U.S., we continue to lose valuable wetlands.

Drinking Water

An increasing number of people are served by community water systems that meet all health-based drinking water standards. In 2002, states reported that 94 percent of the population served by community water systems were served by systems that met all health-based standards, up from 79 percent in 1993. Underreporting and late reporting of data affect the accuracy of this information.

Recreation in and on the Water

The number of beach closings has increased, but this likely reflects more consistent monitoring, reporting, and use of state-wide advisories over time, rather than a decline in the condition of recreational waters. From 1997 to 2001, the percentage of beaches affected by advisories or closings rose from 23 to 27 percent. During that same period, the number of agencies reporting to EPA on beach advisories and closings rose from 159 to 237.

Consumption of Fish and Shellfish

The percentage of U.S. fresh waters under fish consumption advisories has increased in recent years. Similar to beach closings, these increases may be the result of more consistent monitoring and reporting, so they do not necessarily indicate that conditions are getting worse. An estimated 14 percent of river miles, 28 percent of lake acreage, and 100 percent of the Great Lakes and their connecting waters were under fish consumption advisories for at least some portion of 2001. Following the U.S. ban in the mid-1970s, PCB concentrations significantly declined in Lake Michigan fish and concentrations of PCBs in lake trout declined consistently through the year 2000 in Lakes Ontario, Huron, and Michigan.

Better Protected Land

The U.S. is a nation rich in land resources. Much like air and water, land is a resource that must be carefully protected. Protecting land resources means ensuring that lands meet current societal needs and support healthy communities and ecosystems. To this end, EPA's land protection activities focus on prevention, management, control, and cleanup of various substances that are released to or used on land. Many other governmental and private agencies at the federal, state, and local levels manage land for natural resource and conservation purposes.

Land Use

The U.S. contains approximately 2.3 billion acres of land.

That total area includes 1,055 million acres of grasslands and shrublands, 749 million acres of forests, 410 million acres of agricultural lands, and 98 million acres of developed land.

The majority of land within the U.S. is privately owned.

Almost 1.5 billion acres of private and tribal land are managed solely by their owners, with zoning and other land use regulations as the only constraints. The federal government manages nearly 28 percent of the nation's land.

While land conservation efforts continue, the amount and rate of land development has increased.

More than 4 percent of the nation is designated as wilderness, and millions of other acres are protected in parks, refuges, or other classifications of reserved land. In 1997, 4.3 percent of U.S. total land area—98 million acres—was developed, up from 3.2 percent in 1982. The pace of land development in the 1990s was 1.5 times that in the 1980s.

Chemicals in the Landscape

Industrial releases of toxic chemicals as reported to the Toxics Release Inventory have declined in recent years.

EPA's Toxics Release Inventory (TRI) tracks releases of more than 650 chemicals. The original set of chemicals (332 of the 650 TRI chemicals) from industries that have reported consistently since 1988 shows that total on- and off-site releases decreased 48 percent between 1988 and 2000, a reduction of 1.55 billion pounds. In addition, between 1998 and 2000, toxic releases of all 650 TRI chemicals decreased by approximately 409 million pounds.

Testing of foods for pesticide residues in 2000 found that no more than 1.4 percent of samples exceeded regulatory limits.

Each year, the U.S. Department of Agriculture works with states to collect and analyze samples of a variety of foods for pesticide residues using methods that can detect concentrations orders of magnitude lower than levels that might cause health concerns.

Waste and Contaminated Lands

Over the last 40 years, the total amount of municipal solid waste generated in the U.S. has increased, though per capita generation has remained relatively constant over the last decade.

While the nation is generating more waste, its waste management practices have improved, particularly through increased recycling. The amount of municipal solid waste recovered (recycled or composted) increased more than 1,100 percent in the last decade.

The nation is making progress in dealing with hazardous waste.

In 1999, EPA estimated that the 20,000 businesses within the U.S. classified as "large quantity generators" (defined as those that generate more than 2,200 pounds of hazardous waste each month) collectively generated 40 million tons of Resource Conservation and Recovery Act (RCRA) hazardous waste. Between 1991 and 1998, for 17 of the most toxic chemicals in hazardous waste, the total amount fell by 44 percent. Between 1998 and 2000, 12 billion pounds—approximately one third—of all toxic chemicals used in industrial processes were recycled. Today, virtually all hazardous waste is either recycled, or processed by treatment that destroys the toxic pollutants or reduces the ability of the pollutants to enter the environment. Once treated, this waste is disposed of in landfills designed to prevent any releases. This represents a vast improvement over the disposal practices used 25 years ago.

The nation is making progress in cleaning up contaminated lands. As of October 2002, there were 1,498 sites on the Superfund National Priorities List (NPL)—a list of the most toxic waste sites in the nation. Of these, 846 sites are construction completion sites (i.e., sites where physical construction of all cleanup actions are complete, immediate threats are addressed, and all long-term threats are under control). This is up from 149 construction completes in

1992. In addition, approximately 3,700 hazardous waste management sites are subject to RCRA corrective action which would provide for investigation and cleanup and remediation of releases of hazardous waste and constituents. Of these, 1,714 high-priority sites are targeted for immediate action by federal, state, and local agencies.



Human Health

Protecting the health of the American public from environmental pollutants is a key part of EPA's mission. People need clean air, water, and land to live, breathe, eat, and drink. Over the past 100 years, our understanding of the potential threats to our health from environmental pollution has grown, but there is still much to learn about environmental condition and human health.

The health of the American public is generally good and improving. People are living longer than ever before—in the last century, life expectancy at birth increased from 51 to 79.4 years for women and from 48 to 73.9 years for men. Infant mortality has dropped to the lowest level ever recorded in the United States. Infant mortality is still higher in this country than in other developed nations, however, and life expectancy is somewhat lower. The death rate for the nation's main health threats—heart disease, cancer, and stroke—is decreasing, although the number of people developing some diseases, such as childhood asthma, is increasing.

Many studies in people have demonstrated an association between environmental exposure and certain diseases or health problems. Examples include radon and lung cancer; arsenic and cancer in several organs; lead and nervous system disorders; disease-causing bacteria such as *E. coli* O157: H7 (e.g., in contaminated meat and water) and gastrointestinal illness and death; and particulate matter and aggravation of heart and respiratory diseases.

There are still unanswered questions about the links between some environmental pollution and health problems. Factors such as the amount and frequency of exposure and a person's age, health, genetic make-up, and lifestyle affect whether a person will show symptoms of exposure or

develop disease. Better disease data that could be linked directly with environmental monitoring data would support efforts to determine stronger connections between disease and environmental exposure.

Some segments of the population, especially children and the elderly, may be more susceptible to adverse health effects from some environmental pollutants. People with existing health problems and with compromised immune systems may also be at higher risk. Understanding the potential impacts of pollutants on such sensitive groups is important in shaping national health standards and policies.

Biomonitoring has helped document the reduction in blood lead levels of young children in the past 25 years due largely to the ban of leaded gasoline, as well as the reduction of cotinine, a measure of the exposure to environmental tobacco smoke, in children, partly due to declining numbers of adult smokers. Using biomonitoring to measure pollutant residues in the body is one way to identify the levels of pollutants that may cause health problems and can help gauge the success of actions to limit exposure. Biomonitoring involves taking samples (usually in blood or urine) from people to measure individual exposure.

Ecological Condition

The nation's air, water, land, and living things interact in diverse and complex ways to shape the nation's ecological condition. Currently, we lack the means of capturing all of the appropriate measures for the physical, chemical, and biological factors that influence ecological condition on a national basis. Recognizing that ecological condition is best described by considering the integration of all of the environment's parts and processes, we are beginning to get a sense for how the conditions of our air, water, and land impact the health of our ecosystems.

EPA is moving in the direction of using ecological condition to measure for results. For example, efforts to reduce acid rain have had significant results: One-quarter to one-third of lakes and streams in three regions previously affected by acid rain are no longer acidic. Measuring for ecological results will require data about both ecological stressors (e.g., air and water pollutants) and ecological condition. It will also require an understanding of the relationship between the two.

The EPA Science Advisory Board's framework for assessing ecological condition provides a key organizational tool for assessing ecological condition. This tool contains six essential ecological attributes that characterize the health and diversity of every ecosystem type. In this report, EPA has examined various indicators that address these six attributes.

Assessments of condition that use many variables can be summarized to make them more understandable and usable. The index of biotic integrity (IBI), for example, is a useful approach that combines multiple variables that reflect the ecological condition of a place, such as biological diversity and the health of individual organisms. For example, a Fish IBI, used to assess the condition of mid-Atlantic streams, showed that 53 percent of these streams were in good or fair condition and 31 percent were in poor condition (evaluation of the remaining 16 percent was inconclusive).

Currently, there are significant gaps in our ability to describe ecological condition at the national level. Ultimately, we want to have indicators that provide a national picture and that can be used across the various ecosystem types. Rare and at-risk species and population trends in bird communities are promising indicators that may be used across different ecosystems.

Introduction

How clean are our nation's air, water, and land? How healthy are its people and ecosystems? How can we measure the success of policies and programs to protect health and the environment?

This report provides the U.S. Environmental Protection Agency's (EPA's) response to these questions, with the aim of sparking a broader dialogue and discussion about how to answer them in the future. The report has two key purposes:

- To describe what EPA knows—and doesn't know—about the current state of the environment at the national level, and how the environment is changing.
- To identify measures that can be used to track the status of and trends in the environment and human health, and to define the challenges to improving those measures.

This report is the first step in EPA's Environmental Indicators Initiative. Launched in November 2001, this initiative seeks to develop an improved set of environmental indicators that will enable EPA to better manage for results and better communicate the status of the environment and human health. These indicators will provide critical tools for EPA to define environmental management goals and measure progress toward those goals. Early drafts of this report have already been helpful in developing EPA's strategic plan for 2003 to 2008.

An important next step in EPA's initiative will include working closely with partners—other federal agencies, states, tribes, local government, non-governmental organizations, and the private sector—to create a long-term strategy for developing an integrated system of local, regional, and national indicators. This report is issued as a draft to stimulate dialogue and invite input into developing and improving environmental measures in the future. EPA welcomes your suggestions about how well this report communicates environmental status and trends and how to better measure and manage for results. To learn more about the initiative and to provide your comments and feedback, please visit <http://www.epa.gov/indicators/>.

Using Indicators to Measure Results

This report uses the lens of environmental and health indicators to bring the current state of the U.S. environment into focus. Environmental indicators are measures that track environmental conditions over time. For example, they help measure the state of air, water, and land; the pressures on those resources; the status of human health; and the integrity of our nation's ecosystems. Examples of environmental indicators include concentrations of criteria air pollutants in ambient air, the extent of wetlands, and the levels of lead in the blood of Americans.

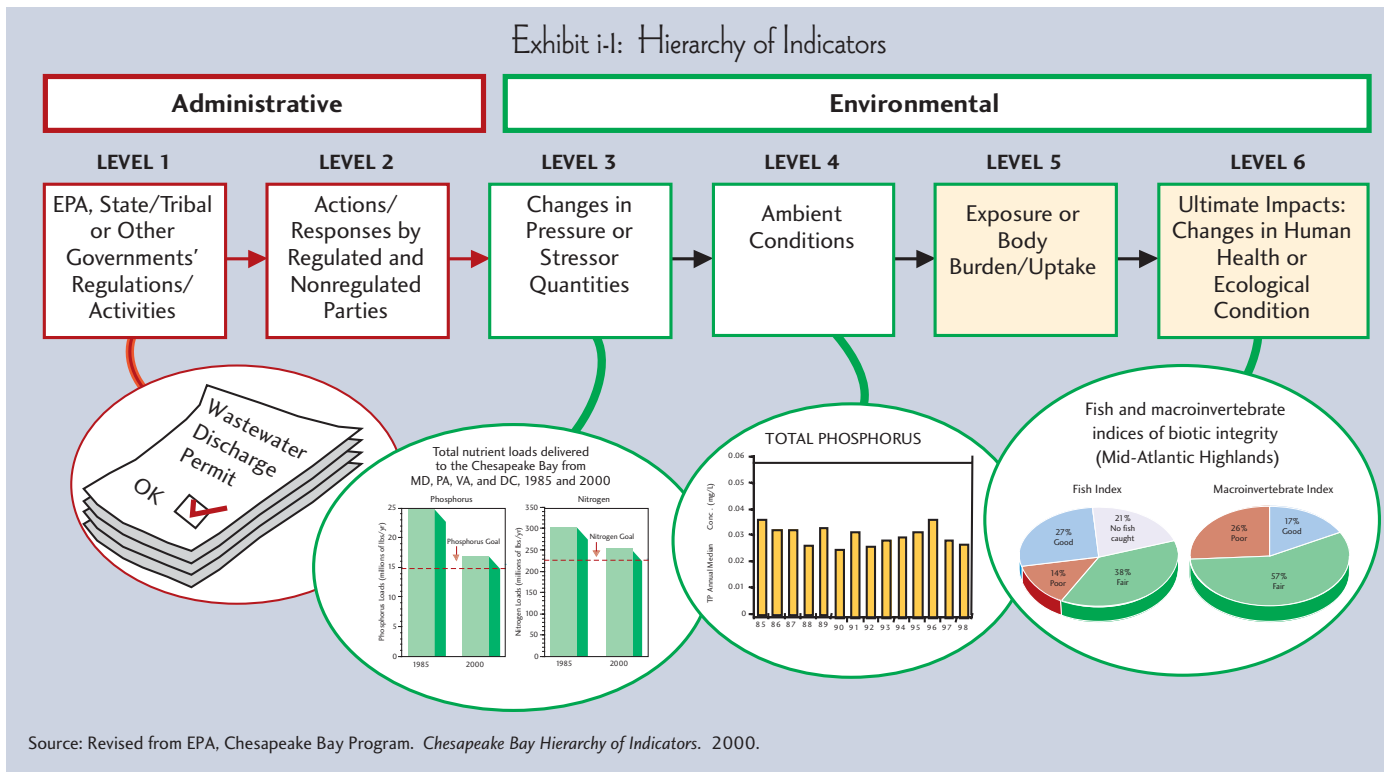
Environmental and human health indicators focus on outcomes—actual environmental results, such as cleaner air and

Working with Partners

Protecting the environment and human health is not EPA's task alone. Many federal departments implement legislation and manage programs that contribute directly to those goals. State, local, and county governments, along with federally recognized tribes, administer environmental programs as well. Many other factors influence human and environmental health: individual choices, collective actions by citizens, and decisions made by industry all contribute to the health of society as a whole, and of its surrounding environment.

In developing this draft report, EPA learned much from the experiences of others: the White House Council on Environmental Quality, other federal departments and agencies, tribes, and states; The H. John Heinz III Center for Science, Economics and the Environment; NatureServe; the EPA Science Advisory Board; and the National Research Council. This draft report is much stronger as a result of the comments, advice, and data they made available to EPA.

Exhibit i-1: Hierarchy of Indicators



Source: Revised from EPA, Chesapeake Bay Program. *Chesapeake Bay Hierarchy of Indicators*. 2000.

water or improved human health or ecosystem condition—rather than on administrative actions, such as the number of permits issued. At one time, administrative measures of performance were considered sufficient indicators of progress. While administrative measures track what actions have been taken, they don't tell us whether those actions actually improved the environment or human health. Understanding the effectiveness of environmental programs, and measuring actual progress, requires indicators of health and environmental conditions.

Exhibit i-1 depicts this “hierarchy” of measures. Levels 1 and 2 are indicators of “response”—government administrative actions, such as the issuing of discharge permits, and responses to those actions. Level 3 indicators measure pressures on the environment, such as changes in the quantities of discharges to water. Levels 4, 5, and 6 all measure the state of the resource—such as changes in ambient levels of a pollutant or changes in the health of an ecosystem. To link environmental protection with real-world results, indicators and performance measures at each level of the hierarchy are required.

This report focuses, where possible, on indicators that describe environmental status and trends at a national level. In many cases, however, national-level indicators do not yet exist or are not supported by adequate data. In some of these cases, local and regional indicators do exist and are featured as examples in this report; these indicators are valuable for a number of reasons. They serve as examples of what national indicators might look like in the future. They provide important perspective on conditions at the local and regional levels, they are critical to understanding cause-and-effect relationships in the environment, and they provide an important tool for local decision-making.

Invitation to a Dialogue

EPA invites your participation in the discussion about this draft report. We welcome your suggestions about this draft report, the future directions for EPA's Environmental Indicators Initiative, how best to measure and manage for results, and how to effectively communicate about environmental status and trends to the public. To learn more about the initiative and to provide your comments and feedback, please visit <http://www.epa.gov/indicators/>.

Introduction

About This Report

This report is organized around five core chapters (see chart below). The first three describe the current state of the primary components of the physical environment—air, water, and land—and the principal stressors that can affect their conditions. The final two chapters present indicators on human health and ecological condition.

The report was driven by a series of questions, developed by EPA, that address three themes: what is happening, why is it happening, and what are the effects. For example, in the area of outdoor air, the questions address the quality of the nation's air (*what is happening*), the factors contributing to outdoor air pollution (*why*), and the human health and ecological effects of outdoor air pollution (*what are the effects*).

Once the questions were developed, EPA examined data sources to identify potential indicators to address these questions on a national level. Scientists from inside and outside EPA then screened these indicators for their scientific soundness and relevance to the questions. Only indicators judged to be scientifically sound were included in this report. The questions posed in each chapter, and the indicators

selected to answer them, are listed in Appendix A. Chapter 6 describes some of the challenges in developing and using indicators at the national level. The scientific foundation and more detailed information for the indicators listed in this report are presented in the accompanying Report on the Environment Technical Document (available online at <http://www.epa.gov/indicators/>).

This report provides significant information about the nation's environment; however, its scope is limited in several ways. First, the report focuses primarily on the U.S.; it does not address international environmental conditions or issues that may affect environmental quality in this country. Second, the report provides information on status and condition, but does not describe the many important initiatives that EPA and its partners are undertaking to protect the environment and human health. More information about specific program initiatives and other indicator-related background materials, as well as links to EPA partners, can be found online at <http://www.epa.gov/indicators/>.

Introduction				
Chapter 1 - Cleaner Air	Chapter 2 - Purer Water	Chapter 3 - Better Protected Land	Chapter 4 - Human Health	Chapter 5 - Ecological Condition
Outdoor Air Quality	Waters and Watersheds	Land Use	Health Status of the United States	Landscape Condition
Indoor Air Quality	Drinking Water	Chemicals in the Landscape	Environmental Pollution and Disease	Biotic Condition
Global Issues	Recreation on and on the Water	Waste and Contaminated Lands	Measuring Exposure to Environmental Pollution	Chemical and Physical Characteristics
Limitations of Air Indicators	Consumption of Fish and Shellfish	Limitations of Land Indicators	Challenges in Developing Human Health Indicators	Ecological Processes
	Limitations of Water Indicators			Hydrology and Geomorphology
				Natural Disturbance Regimes
				Ecological Condition as an Environmental Result
				Challenges in Developing Ecological Condition Indicators
Chapter 6 - Working Together for Environmental Results				

Introduction

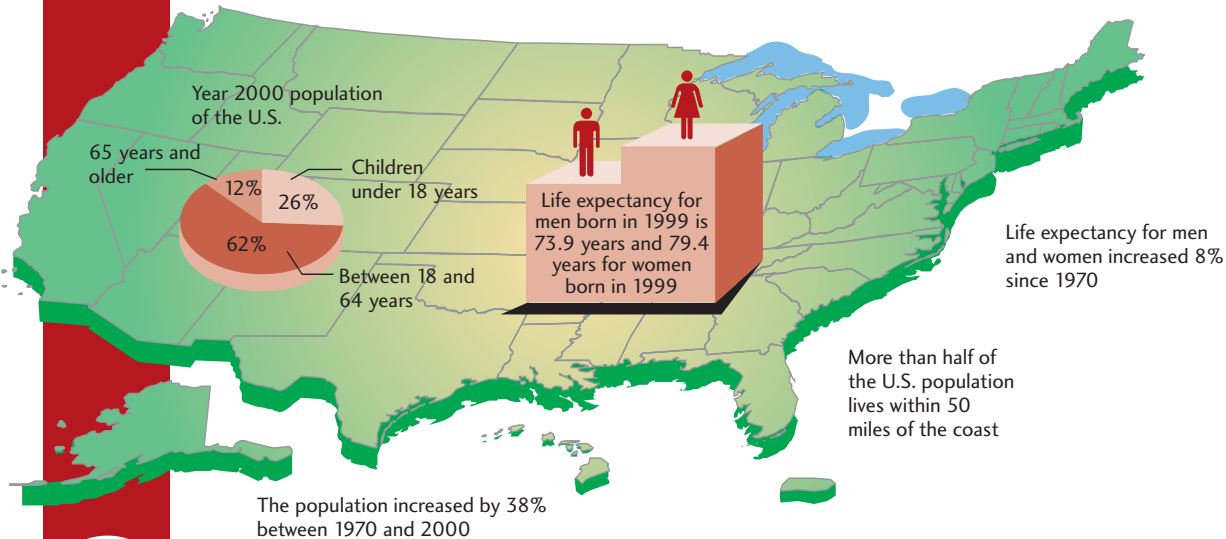
Exhibit i-2 Environmental Protection in Context

EPA recognizes the importance of quality of life and sustainability in any effort to measure outcomes. The nation's environmental protection laws aim to improve Americans' quality of life by simultaneously protecting health and environmental resources and promoting economic prosperity. This exhibit provides some statistical context for understanding environmental progress. *See Appendix E for all source information.*



PEOPLE

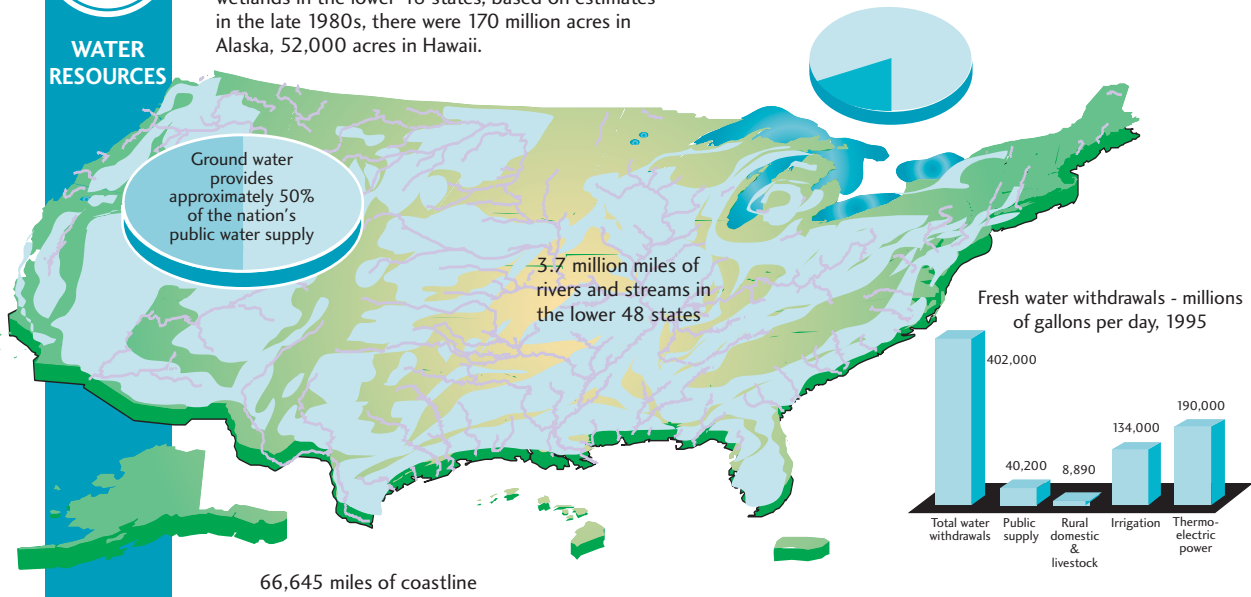
2000 Census recorded 281 million people in the U.S.



WATER RESOURCES

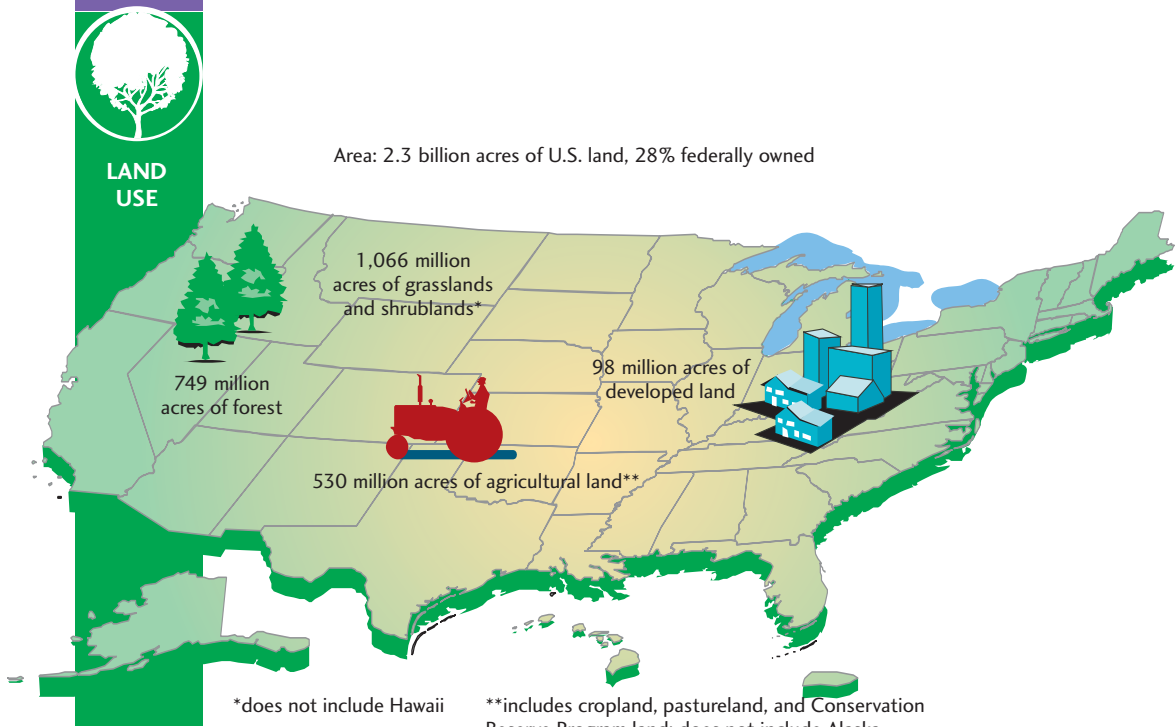
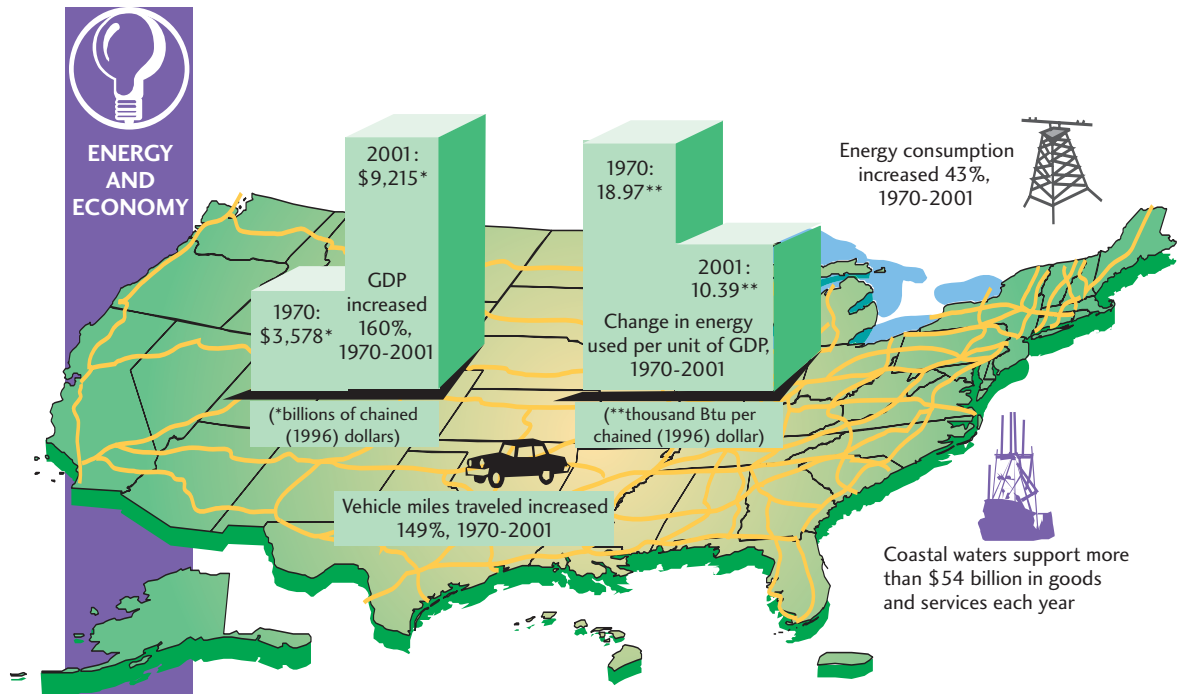
In the mid 1990s, there were 105.5 million acres of wetlands in the lower 48 states; based on estimates in the late 1980s, there were 170 million acres in Alaska, 52,000 acres in Hawaii.

The Great Lakes are 60.2 million acres and contain 18% of the world's fresh water



Introduction

Exhibit i-2 Environmental Protection in Context



More than 4% of the nation is designated as wilderness and millions of other acres are protected in national parks, state parks, wildlife refuges, or other classifications of conserved land.

Introduction

Chapter 1 - Cleaner Air

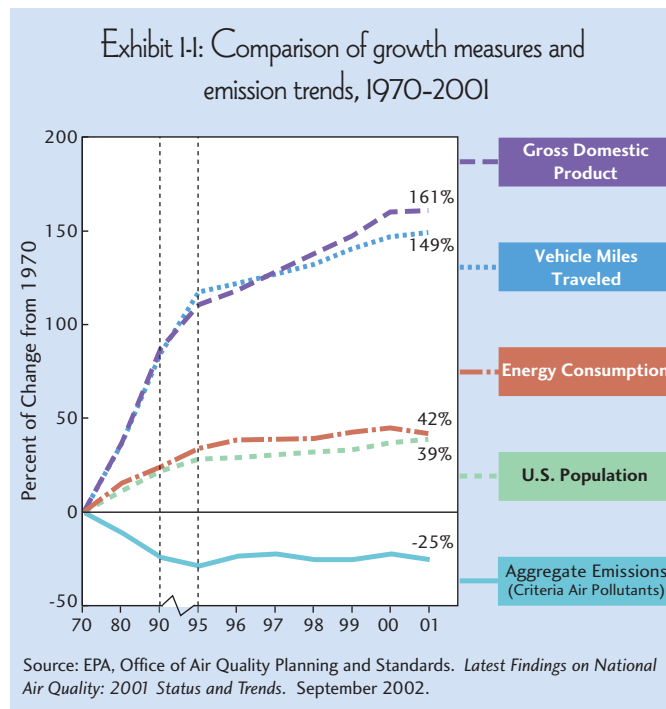


Introduction

How clean is the air we breathe outdoors? How does pollution in the air affect the quality of land and water? How healthful is the air in our homes and offices?

The air we breathe today is cleaner and more healthful than it was 3 decades ago. Since 1970, total national emissions of the six most common air pollutants have been reduced 25 percent. Remarkably, this improvement in national air quality has occurred even while, during the same 30-year period, the U.S. Gross Domestic Product increased 161 percent, energy consumption increased 42 percent, and vehicle miles traveled increased 149 percent (Exhibit 1-1).¹

Building on this progress, work remains to ensure steady improvements in air quality. For example, certain areas of the country at times exceed national health-based air quality



Chapter I: Cleaner Air



standards. We have much to learn about the levels of toxic air pollutants and the quality of air indoors.

This chapter has three main sections: outdoor air quality, indoor air quality, and global issues. Each section tries to answer two general questions: What are the current conditions? What are the major contributors to change? Questions about health and ecological effects are posed and explored for a number of air quality issues. The chapter concludes with a section on the limitations of the indicators to address these questions.

Outdoor Air Quality

In the 1970s, the U.S. Environmental Protection Agency (EPA) identified six common—or “criteria”—air pollutants for which it established National Ambient Air Quality Standards (NAAQS) under the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and lead.

At elevated ambient levels, these pollutants—both alone and in combination—are associated with adverse effects on human health and on the environment. Breathing those pollutants at harmful levels can result in respiratory problems, hospitalization for heart or lung disease, and even premature

death. They can also harm aquatic life, vegetation, and animals, as well as create haze and reduce visibility. In setting the national primary standards for each of the pollutants, EPA intended to protect public health and the environment, as required by the Clean Air Act. By law, the standards are to be periodically reviewed and revised as appropriate.

Information on air quality trends for criteria air pollutants is based on actual measurements of pollutant concentrations in the ambient air at more than 5,000 monitoring sites across the country. The data from those readings support EPA's key indicators for measuring outdoor air quality trends and determine which areas meet Clean Air Act standards.

Outdoor Air Quality Indicators

Number and percentage of days that metropolitan statistical areas have Air Quality Index (AQI) values greater than 100

Number of people living in areas with ozone (8-hour) and particulate matter (PM_{2.5}) levels above the NAAQS

Ambient concentrations of ozone, 8-hour

Ambient concentrations of particulate matter (PM_{2.5})
Visibility

Deposition: wet nitrogen and wet sulfate

Ambient concentrations of selected air toxics

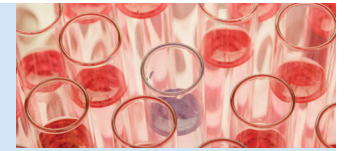
Emissions of particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds

Lead emissions

Air toxics emissions

Emissions (utility): sulfur dioxide and nitrogen oxides

Concentrations versus Emissions



Ambient—or surrounding—air concentration levels are the key measure of air quality and are based on the monitored amount (e.g., in units of micrograms per cubic meter [$\mu\text{g}/\text{m}^3$] or parts per million [ppm]) of a pollutant in the air. Emissions levels are based on estimates and monitored measurements of the amount (e.g., in units of tons) of a pollutant released to the air from various sources, such as vehicles and factories. Some emissions travel far from their source to be deposited on distant land and water; others dissipate over time and distance. The health-based standards (National Ambient Air Quality Standards) for criteria pollutants are based on concentration levels. The pollutant concentration to which a person is exposed is just one of the factors that determines if health effects occur—and their severity if they do occur.

What is the quality of the outdoor air in the United States?

Trends in criteria air pollutants, visibility, acid deposition, and toxic air pollutants provide a picture of the nation's air quality. The nation's air quality is generally improving as measured by declining concentrations of criteria air pollutants. Acid deposition levels of sulfate are declining in the eastern U.S., the area most affected by deposition. Toxic air pollutants, though not as widely measured as criteria pollutants, also appear to be declining. Visibility in parks and other protected areas remained relatively steady over the last decade, and challenges remain in improving visibility.



Criteria Air Pollutants

Average ambient concentrations of the six criteria pollu-

tants have shown improvements over the past 20 years.² For most parts of the country, the average ambient levels of lead, CO, SO₂, and NO₂ are lower than the standards. But many people live in areas of the country that do not always meet the health-based standards for certain pollutants, especially ozone and particulate matter.

In fact, more than 133 million people lived in areas where monitored air quality in 2001 was unhealthy at times because of high levels of at least one criteria air pollutant (Exhibit 1-2).³ Based on EPA's Air Quality Index (AQI) data the percentage of days across the country on which air quality exceeded a health standard dropped from almost 10 percent in 1988 to 3 percent in 2001 (Exhibit 1-3).^{4,5} Also, EPA has conducted an analysis of 260 metropolitan statistical areas (MSAs) for the 1990 to 1999 time period. This study shows that in 212 MSAs the average ambient concentrations for at least one of the criteria pollutants had downward trends, and in 57 MSAs there were upward trends for at least one pollutant (with 34 of the 57 MSAs showing significant upward

Air Quality Index

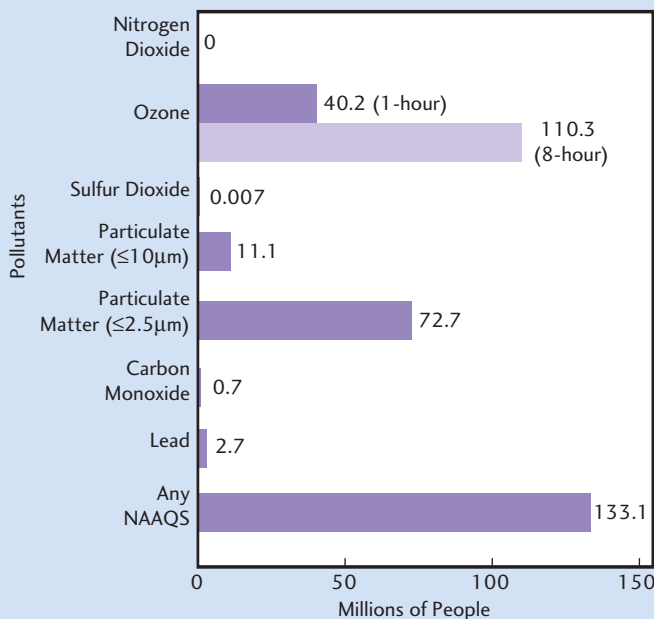
The Air Quality Index (AQI) is used for daily reporting of air quality as related to ozone, PM, CO, SO₂, and NO₂. It describes the health effects that may be associated with exposure to different levels of these pollutants, the groups likely to be most sensitive to the pollutant, and simple measures that can be taken to reduce exposure.

AQI values range from 0 to 500. The higher the AQI value, the greater the level of air pollution—and the greater the health danger. An AQI value of 100 generally corresponds to the national air quality standard for a pollutant. Thus, AQI values of less than 100 are usually considered satisfactory. When AQI values are higher than 100, air quality is deemed unhealthy for certain sensitive groups of people; as values rise, everyone becomes at risk. However, unusually sensitive people may experience health effects when AQI values are between 50 and 100.

The AQI scale is divided into six categories, each of which is identified with a particular color that corresponds to a level of concern for health. "Code orange," for example, means that the air is "unhealthy for sensitive groups," and "code red" means that the air may be unhealthy for everyone. The highest of the AQI values for the individual pollutants becomes the AQI value for that day. For example, if one day a certain area had AQI values of 150 for ozone and 120 for particulate matter, the AQI value would be 150 for the pollutant ozone on that day. Appropriate sensitive groups are always cautioned about any AQI value higher than 100.

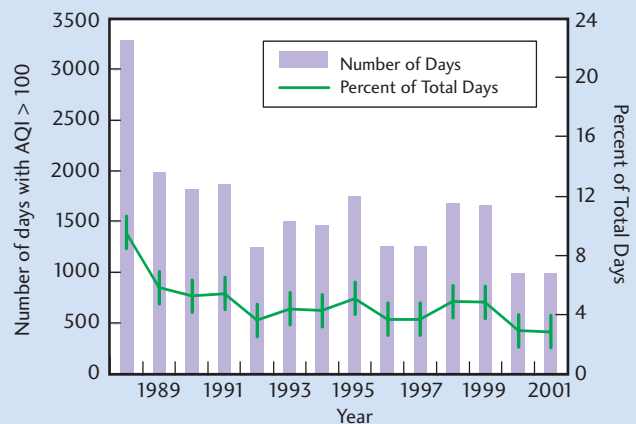
In a recent "Roper Green Gauge Report," based on a nationwide poll of more than 2,000 people, 54 percent of those surveyed said they had heard of "ozone days" or "code orange"/"code red" air quality days, and 46 percent said they had reduced their exposure to air pollution by modifying outdoor exercise or work habits.⁷

Exhibit 1-2: People living in areas with air quality concentrations at times above the level of the National Ambient Air Quality Standards (NAAQS) in 2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Exhibit 1-3: Number and percentage of days with Air Quality Index (AQI) greater than 100, 1988-2001



Note: Data are for MSAs > 500,000.

Source: Data used to create graphic are drawn from EPA, Office of Air Quality Planning and Standards. *National Air Quality and Emissions Trends Report, 1997*. Table A-15. December 1998; EPA, Office of Air Quality Planning and Standards. *Air trends: Metropolitan area trends*, Table A-17. 2001 (February 25, 2003; <http://www.epa.gov/airtrends/metro.html>).

Chapter I - Cleaner Air

Outdoor Air Quality

trends). Taken as a whole, the results of the study demonstrate significant improvements in urban air quality over the past decade.⁶

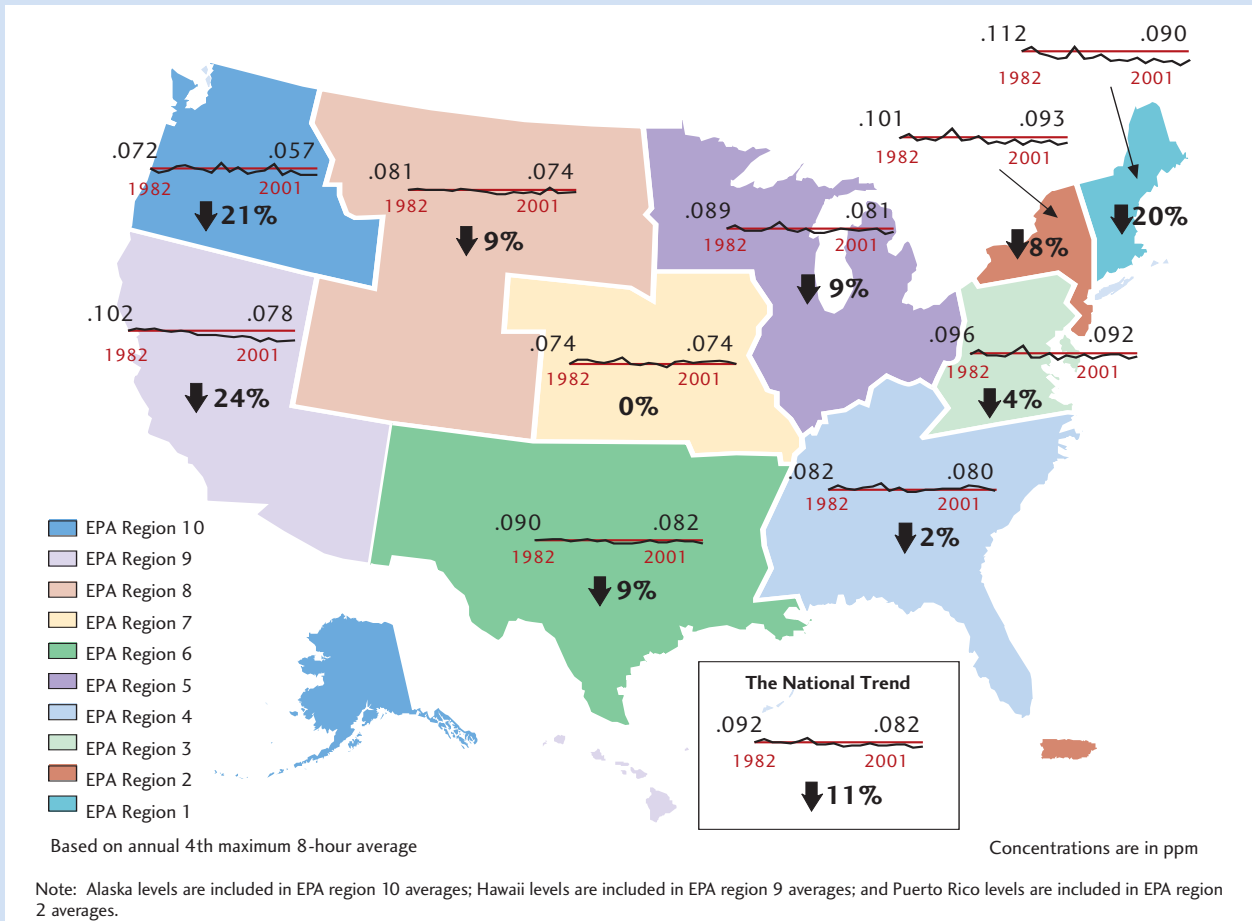
Ozone is not emitted directly into the air but formed by the reaction of volatile organic compounds (VOCs), nitrogen oxides (NO_x), and other chemical compounds in the presence of heat and sunlight, particularly in hot summer weather. Chemicals such as those that contribute to formation of ozone are collectively known as ozone "precursors." Particulate matter is emitted directly, and is also formed when emissions of NO_x, SO₂, and other gases react in the atmosphere.

With decreases in emissions of VOCs and other ozone precursors, 8-hour ozone concentrations fell by 11 percent

nationally between 1982 and 2001.⁸ All regions experienced improvement in 8-hour ozone levels during the last 20 years except the North Central region, which showed little change (Exhibit 1-4). However, in 2001 more than 110 million people lived in counties with concentrations higher at times than the 8-hour standard for ozone.⁹ Southern California, the eastern U.S., and many major metropolitan areas have continuing ozone problems.

In 2001, some 73 million people lived in counties where monitored air quality at times exceeded the standard for fine particulate matter (PM_{2.5})—those particles less than or equal to 2.5 micrometers (μm).¹⁰ Concentrations of PM_{2.5} vary regionally. California and much of the eastern U.S. have annual average PM_{2.5} concentrations higher than the level of the

Exhibit 1-4: Trends in ozone levels, 1982-2001, averaged across EPA Regions



annual PM_{2.5} standard (Exhibit 1-5). The number of people living in counties with air quality levels that exceed the standards for ozone and PM signals continuing problems.



Visibility

Pollution is impairing visibility in some of the nation's parks and other protected areas. In 1999, average visibility for the worst days in the East was approximately 15 miles. In the West, average visibility for the worst days was approximately 50 miles in 1999.¹¹ Particulate matter is the major contributor to reduced visibility, which can obscure natural vistas.

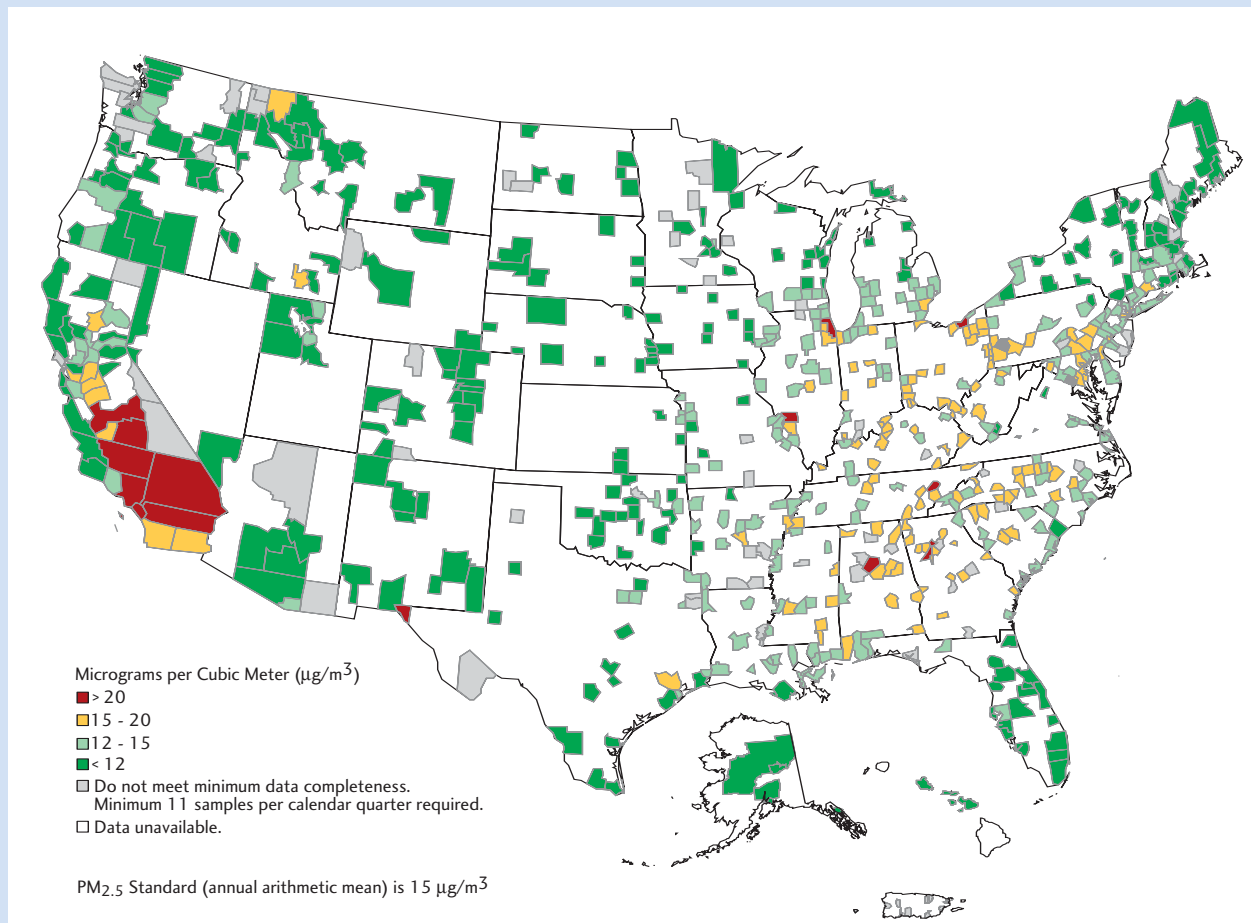
Without the effects of pollution, the natural visibility in the U.S. is approximately 47 to 93 miles in the East and 124 to 186 miles in the West. The higher relative humidity levels in the East result in lower natural visibility.



Acid Deposition

Two of the key pollutants that contribute to the formation of particulate matter—SO₂ and NO_x—react in the atmosphere with water, oxygen, and oxidants to form acid droplets. Rain, snow, fog, and other forms of precipitation containing the mixture of sulfuric and nitric acids fall to the

Exhibit 1-5: 2001 annual average particulate matter (PM_{2.5}) concentrations



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends*. September 2002.

Chapter 1 - Cleaner Air

Outdoor Air Quality

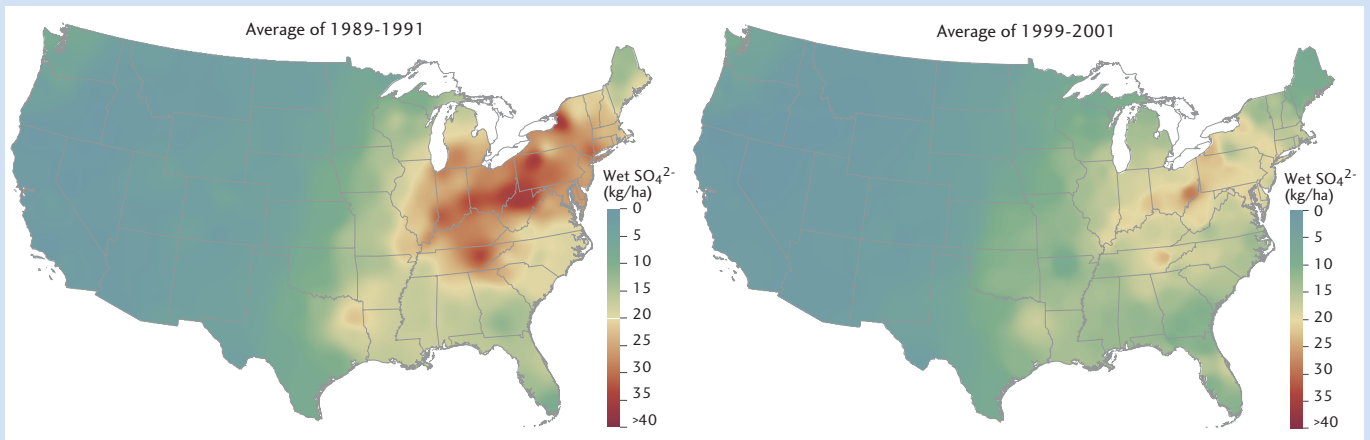
earth as acid rain (wet deposition). The particles also may be deposited without precipitation, known as “dry deposition.” Wet sulfate deposition has decreased substantially—20 to 30 percent—throughout the Midwest and Northeast, where acid rain has had its greatest impact, between the periods 1989–1991 and 1999–2001 (Exhibit 1-6). During the same period, wet nitrogen deposition decreased slightly in some areas of the eastern U.S. but increased in other areas, including those with significant agricultural activity (Exhibit 1-7).¹²



Toxic Air Pollutants

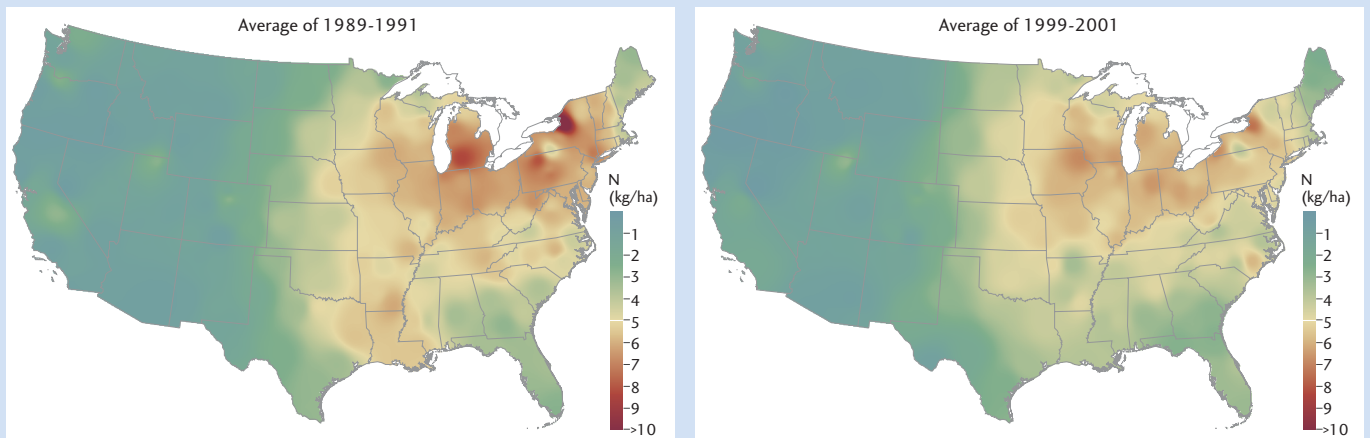
In addition to the six criteria pollutants, the Clean Air Act identifies 188 toxic air pollutants to be regulated. Among those pollutants are benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries. Often referred to as “air toxics,” these are pollutants that may cause cancer or other serious health effects—reproductive effects or birth defects, for example—and may also cause adverse ecological effects.

Exhibit 1-6: Wet sulfate deposition, 1989–1991 vs. 1999–2001



Source: EPA, Office of Air and Radiation, Clean Air Markets Program. EPA Acid Rain Program: 2001 Progress Report. November 2002.

Exhibit 1-7: Wet nitrogen deposition, 1989–1991 vs. 1999–2001



Source: EPA, Office of Air and Radiation, Clean Air Markets Program. EPA Acid Rain Program: 2001 Progress Report. November 2002.

Because there is currently no national monitoring network for toxics, concentrations of toxic air pollutants cannot be quantified on a comprehensive, national level. Data from several metropolitan areas do show downward trends in selected toxic air pollutants. For example, the levels of benzene measured at 95 urban monitoring sites decreased 47 percent from 1994 to 2000.¹³ Although data and tools for assessing the impacts of air toxics are limited, available evidence suggests that emissions of air toxics may still pose health and ecological risks in certain areas of the U.S.¹⁴

What contributes to outdoor air pollution?

Both manmade and natural sources contribute to criteria and toxic air pollutants. Emissions from factories, electric utilities, oil refineries, waste incinerators, smelters, dry cleaners, agricultural facilities, construction equipment, woodstoves, slash pile burning, cars, buses, planes, trucks, trains, and lawn mowers—among many other sources—contribute to outdoor air pollution. Applying commercial products such as paints and strippers can also produce air pollution through the release of VOCs. Air pollution can also stem from natural processes such as volcanoes, windblown dust, and wildfires.

Most of the six criteria air pollutants show declining emissions since 1982 (Exhibit 1-1). But as reported in *Latest Findings on National Air Quality: 2001 Status and Trends*, emissions of NO_x, a contributor to ozone, particulate matter, and acid rain formation, increased by 9 percent between 1982 and 2001, with a slight decrease (3 percent) between 1992 and 2001.¹⁵ A significant amount of that increase is attributed to growth in emissions from non-road engines, including construction and recreation equipment and diesel vehicles.¹⁶ Data from the National Emissions Inventory (NEI) are used for tracking trends in emissions over time. State and local agencies, tribes, and industry provide input to the NEI database, which includes estimates of annual emissions, by source, of air pollutants in each area of the country, on an annual basis. EPA continuously reviews and improves estimates of pollutant emissions. Emissions estimates for criteria pollutants are currently under such evaluation and may be updated.

Actual emissions of SO₂ and NO_x from electric utility plants, which are significant sources of both pollutants, are monitored for a program designed to reduce acid rain. Sulfur diox-

ide emissions from sources affected by the Acid Rain Program declined from nearly 16 million tons in 1990 to 10.6 million tons in 2001.¹⁷ NO_x emissions from utility sources decreased from 6.7 million tons in 1990 to 4.7 million tons in 2001.¹⁸ The National Toxics Inventory, which uses data from the Toxics Release Inventory and other sources, estimates that nationwide air toxics emissions dropped approximately 24 percent between their baseline (1990 to 1993) and 1996 to 4.7 million tons annually.¹⁹

What human health effects are associated with outdoor air pollution?

Outdoor air pollution can cause a wide variety of adverse health problems. Some of the criteria pollutants, particularly ozone, NO₂, and SO₂, are primarily associated with respiratory-related effects, including aggravation of asthma and other respiratory diseases, irritation of the lungs, and respiratory symptoms (e.g., cough, chest pain, difficulty breathing). Short-term exposure to ozone has also been linked to lung inflammation and an increased number of hospital admissions and emergency room visits.^{20,21,22,23,24} Repeated short-term exposures to ozone may damage children's developing lungs and may lead to reduced lung function later in life, whereas long-term exposures to high ozone levels are a possible cause of an increased incidence of asthma in children who engage in outdoor sports.²⁵ Carbon monoxide, on the other hand, primarily affects people with cardiovascular disease by reducing oxygen in the blood, which aggravates angina.²⁶

Particulate matter is associated with both respiratory-related and cardiovascular effects, exhibiting a broader range of effects. For example, short-term exposures to particulate matter may aggravate asthma and bronchitis and have been associated with heartbeat irregularities and heart attacks.²⁷ Such exposures have been linked to increased school absences and lost workdays, hospital admissions, and emergency room visits, and even death from heart and lung diseases.²⁸ Long-term exposures have also been linked to deaths from heart and lung disease, including lung cancer.^{29,30}

People exposed to certain toxic air pollutants at sufficient concentrations may also experience harmful health effects, including cancer, respiratory and cardiovascular effects, dam-

age to the immune system, and neurological, reproductive, and developmental problems. Even at low doses, lead—both a criteria and toxic air pollutant—is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ.³¹ Exposure to benzene, a widely monitored air toxic, has been linked to increases in the risk of two types of cancer: leukemia and multiple myeloma.³² (For additional information on health effects associated with outdoor air pollution, see Chapter 4 – Human Health.)

What ecological effects are associated with outdoor air pollution?

Many health effects are associated with breathing polluted air, but air also transports pollutants and deposits them onto soils or surface waters, where they can potentially affect plants, crops, property, and animals. Toxic substances in plants and animals can move through the food chain and pose potential risks to human health. Airborne mercury from incineration, for example, can settle in water and contaminate fish. People and other animals higher on the food chain (e.g., bald eagles, bears, and cougars) that eat contaminated fish are then exposed to potentially harmful levels of mercury, which is known to affect the nervous system. (For additional information, see the section on “Contaminated Fish and Shellfish” in Chapter 2 – Purer Water.)

Direct exposure to ozone under certain conditions can be harmful to plants and forests; it reduces overall plant health and interferes with the ability of plants to produce and store food. Such weakened plants are in turn more susceptible to harsh weather, disease, and pests. Through its effects on plants, ozone can also pose

risks to ecological functions such as water movement, cycling of mineral nutrients, and habitats for various animal and plant species. Airborne particles also can have an adverse impact on vegetation and ecosystems.³³

Increased acid levels damage soils, lakes, and streams, rendering some waterbodies unfit for certain fish and wildlife species. Indirect effects of acid deposition are also responsible for damage to forest ecosystems. Excess deposition of acid ions in the soil causes calcium and other essential plant nutrients to be leached from the soil, and thus no longer available to sustain normal plant growth and maintenance. The calcium depletion also causes a scarcity of worms and other prey, affecting the ability of some birds to lay eggs and bring them to term.

Acid ions also can increase the movement of aluminum in soil, which competes with calcium and other nutrients in plant roots during absorption, further limiting plant growth. Acid deposition can also produce elevated levels of aluminum in waterbodies. This results either from direct deposits acidifying the waterbody itself or from water passing through soil that is high in aluminum and then entering the waterbody from adjacent terrestrial systems. Those elevated levels of aluminum in water can be toxic to fish and other aquatic life.³⁴



The nitrogen in acid rain is one of the sources contributing to the total amount of nitrogen in terrestrial and aquatic systems. Although nitrogen is a necessary nutrient in productive ecosystems, too much nitrogen in terrestrial systems can cause changes in biodiversity. In aquatic systems, it fuels excessive growth of algae in coastal waters. When the dense algal blooms die, bacteria decay them. That process uses up the oxygen that is needed by fish to survive. (For additional information on the effects of nitrogen on waterbodies, see the section on “Waters and Watersheds” in Chapter 2 – Purer Water.)



Indoor Air Quality

Air pollution is also an issue indoors. There are many potential sources of indoor pollution, such as tobacco smoke, building materials, cleaning fluids, pesticides, and outdoor air pollution that seeps inside. But few studies have examined the overall presence of indoor pollutants or the extent of human exposure to them. Scientists know that indoor air pollutants can cause long- and short-term health effects, but experts face challenges in determining the consequences of exposure to various indoor air pollutants at low levels for long periods of time.

What is the quality of the air in buildings in the United States?

There is no comprehensive monitoring of the quality of indoor air in the U.S., and the actual levels for many pollutants are not well understood. Nonetheless, studies have demonstrated that indoor levels of some pollutants can be much higher than outdoor levels. Because most people spend the majority of their time indoors, the indoor air quality of the nation's homes, work places, and schools is a serious issue.

Two indoor air pollutants of particular concern are environmental tobacco smoke (ETS) and radon. A 1998 survey estimated that young children were exposed to ETS in approximately 20 percent of homes in the U.S.—down from approximately 39 percent in 1986.³⁵ Based on a representative 1991 survey of all homes in the U.S., an estimated 6 million homes had high radon levels—levels equal to or greater than EPA's action level of 4 picocuries per liter.³⁶ Those homes represented about 6 percent of housing units in the U.S.

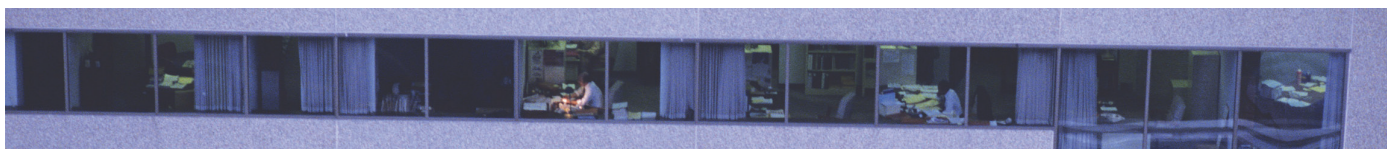
Indoor Air Quality Indicators

U.S. homes above EPA's radon action levels

Percentage of homes where young children are exposed to environmental tobacco smoke

What contributes to indoor air pollution?

Indoor air pollutants include naturally occurring radon, ETS, particulate matter, asbestos, molds, dust mites, lead and other toxic air pollutants, VOCs, pesticides, and gases emitted from



Indoor Air Quality in Office Buildings

The goal of the EPA's Building Assessment Survey and Evaluation (BASE) Study was to define the status of U.S. office buildings with respect to indoor air quality and occupants' perceptions of that quality. In this study, conducted between 1994 and 1998, a sample of 100 office buildings was used to characterize the central tendency—mean or median levels—of indoor air quality in commercial or public office buildings, representing the size building in which 73 percent of all office employees work. In a subset of the first 56 of those buildings, EPA measured the indoor concentrations of 48 VOCs. In a preliminary analysis, 34 VOCs were detected in 81 percent or more of the samples. All measurable VOCs were present at higher levels indoors than outdoors, suggesting the presence of indoor sources.³⁷ In most buildings, the indoor concentration of particulate matter was lower than or nearly equal to the measured outdoor level. However, 11 of the buildings had PM₁₀ (particles less than or equal to 10 μm) levels at least 50 percent higher than outdoor levels, which could be a significant factor in a person's total exposure.³⁸

inadequately vented heaters and pilot lights. Sources also include certain furnishings and improperly stored solvents, cleaners, pesticides, paints, and other household chemicals. Concentrations of certain chemical compounds and radon can become particularly problematic when homes or buildings are tightly sealed and have little exchange of indoor and outdoor air. Like many other air pollutants, concentrations of indoor radon vary widely from one location to another, and around the country as well.



What human health effects are associated with indoor air pollution?

Poor indoor air quality can cause short-term problems, including headaches, fatigue, dizziness, nausea, and a scratchy throat. But its other effects include cancer—particularly from long-term exposures to high ETS and radon concentrations—and aggravation of chronic respiratory diseases such as asthma. Exposure to naturally occurring radon gas is the second leading cause (after smoking tobacco) of lung cancer among Americans.³⁹ The most sensitive and vulnerable population groups—older people, the young, and the chronically ill—tend to spend the most time indoors and may therefore face higher-than-usual exposures.



Global Issues

Ozone depletion has global consequences for human health and the environment. Ozone depletion takes place when pollution damages the thin layer of beneficial ozone in the stratosphere, about 6 to 30 miles above the Earth, which protects living beings from harmful ultraviolet (UV) radiation from the sun.

The issue of global climate change involves changes in the radiative balance of the Earth—the balance between energy received from the sun and emitted from Earth. This report does not attempt to address the complexities of this issue. For information on the \$1.7 billion annual U.S. Global Climate Research Program and Climate Change Research

Initiative, please find *Our Changing Planet: The Fiscal Year 2003 U.S. Global Climate Research Program* (November 2002) at <http://www.usgcrp.gov> and the *Draft Ten-Year Strategic Plan for the Climate Change Science Program* at <http://www.climate-science.gov>.

Ozone depletion in the stratosphere and climate change are separate environmental issues but are related in some ways. Specifically, some substances that deplete the stratospheric

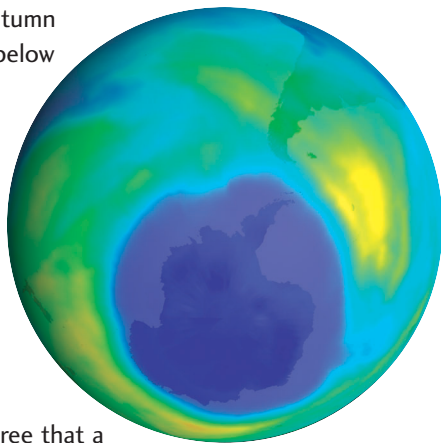
Global Issues Indicators

*Ozone levels over North America
Worldwide and U.S. production
of ozone-depleting substances*

ozone layer also are potent and very long-lived greenhouse gases that absorb outgoing radiation and warm the atmosphere. Ozone itself is a greenhouse gas when it absorbs incoming solar radiation and its depletion in the stratosphere over the polar zones results in localized cooling at times.

What is happening to the Earth's ozone layer?

In recent decades, the Earth's stratospheric ozone layer has become substantially thinner. The thinning has occurred principally over Antarctica and is referred to as the "ozone hole." The ozone layer over the Northern Hemisphere's middle latitudes is about 2 percent below normal during summer and autumn and about 4 percent below normal in winter and spring.⁴⁰ Between 1979 and 1994, the ozone layer thinned 8 percent over Seattle, 10 percent over Los Angeles, and 2 percent over Miami.⁴¹



Scientists generally agree that a thinning of the stratospheric ozone layer causes an increase in the amount of ultraviolet (UV) radiation. While acknowledging high uncertainty in the data, scientists have calculated that UV radiation levels at more than 10 sites in both hemispheres have increased by 6 to 14 percent since the 1980s.⁴² EPA, in partnership with the National Weather Service, publishes an index that predicts UV intensity levels for different cities on a scale of 0 to 10+, where 0 indicates a minimal risk of overexposure and 10+ means a very high risk.

What is causing changes to the ozone layer?

Stratospheric ozone depletion is associated with the use of chlorofluorocarbons (CFCs), halons used to extinguish fires, and other chemicals used as solvents. Air conditioners, refrigerators, insulating foams, and some industrial processes all emit those substances. Air currents carry molecules with chlorine and bromine from those pollutants into the stratosphere, where they react to destroy ozone molecules.

The U.S. virtually ceased production of most ozone-depleting substances in January 1996, because of its participation in an international agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer. Nonetheless, ozone-depleting substances are still being released into the environment, as reported in the Toxics Release Inventory. Along with other developed countries, the U.S. makes substitutes for the strong ozone-depleting CFCs. These substitutes are themselves less ozone-depleting than the substances they replace. Also, because the Montreal Protocol controls production but not use, emissions continue from materials made before January 1996. Even though scientists believe that recovery is under way, full restoration of the stratospheric ozone layer will take decades because of the continued use of products manufactured before the ban.

What are the human health and ecological effects of stratospheric ozone depletion?

Thinning of the stratospheric ozone layer allows more of the sun's UV radiation to reach Earth, where it contributes to increased incidences of human skin cancers, the most common of all cancers. Cataracts and suppression of the human immune system may also result from increased exposure to UV radiation. In addition, productivity of some marine phytoplankton, essential to the ocean's food chain, may be unduly stressed by high levels of UV radiation.⁴³

Limitations of Air Indicators

Many sources of data support indicators that help to answer questions about the trends in outdoor and indoor air quality and stratospheric ozone. But there are limitations in using the indicators to fully answer the questions.



Outdoor Air

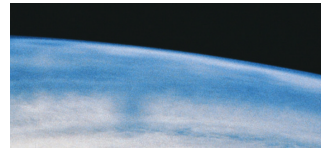
In general, there are some very good measures of outdoor air quality. Although the national air monitoring network for the six criteria air pollutants is extensive, there are far more monitors in urban areas than in rural areas. That helps to characterize population exposures, because population tends to be concentrated in developed areas, but it may make it more difficult to assess effects associated with the transport of air pollutants and ecological effects. Recently, EPA and states have begun evaluating and planning a nationwide monitoring network for air toxics. With a few notable exceptions such as power plants, emissions quantities for both the criteria pollutants and air toxics are based on engineering estimates derived from more limited actual data. There is a need for measures to compare actual and predicted human health and ecological effects related to exposure to air pollutants.



Indoor Air

Although environmental indicators have been developed for some aspects of indoor air, significant gaps exist in knowledge about the conditions inside the nation's buildings. For schools and residences, a large amount of information on indoor air quality is available, but it comprises primarily case studies and small, at best, regional studies. More comprehensive data from national exposure studies for schools and residential indoor environments, including multiple-family residences, would be helpful in understanding the condition of indoor air environments. Ideally, such studies would collect exposure data on air toxics and particulate matter in those indoor environments, as

well as data for molds and other biological contaminants found in indoor air.



Global Issues

In general, high quality data exists with which to predict the human health effects of increased ultraviolet exposure resulting from depletion of the stratospheric ozone. These include robust satellite data on stratospheric ozone concentrations and UV levels, comprehensive and well documented incidence and mortality rates for cutaneous melanoma, and well characterized action spectra for skin cancers and cataracts. However, there are areas where additional data would be useful. First, no national system exists that collects incidence data for squamous cell carcinoma and basal cell carcinoma, the non-melanoma skin cancers caused by increased UV exposure. Thus, our incidence estimates are modeled using data from a nation-wide survey of non-melanoma skin cancer incidence and mortality, and may not represent the most current non-melanoma skin cancer rates. Second, there is a lack of adequate ground level UV monitoring with which to compare the satellite data. Satellites cannot directly measure ground level UV, and are sensitive to pollution. Therefore, while satellite data compare fairly well to ground level UV measurements in clean locations, this is not the case in polluted areas. Additional UV monitoring in cities is crucial to support future epidemiological research on the human health effects of UV exposure. Third, increased UV levels have been associated with other human and non-human endpoints including immune suppression and effects on aquatic ecosystems and agricultural crops. However, additional research on these topics is necessary before these effects can be modelled or quantified. Finally, the future behavior of the ozone layer will be affected by changing atmospheric abundances of various atmospheric gases. It remains unclear how these changes will affect the predicted recovery of the ozone layer. Additional research on the interaction between climate and stratospheric ozone could provide more accurate predictions of ozone recovery and the human health effects resulting from ozone depletion.

Endnotes

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¹⁶ Ibid.

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¹⁸ Ibid.

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²¹ U.S. Environmental Protection Agency. *Air Quality Criteria for Oxides of Nitrogen*, EPA 600-8-91-049aF-cF. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, August 1993.

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- ²³ U.S. Environmental Protection Agency. *Second Addendum to the Air Quality Criteria for Particulate Matter and Sulfur Oxides (1982): Assessment of Newly Available Health Effects Information*, EPA-450-5-86-012. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, 1986.
- ²⁴ U.S. Environmental Protection Agency. *Supplement to the Second Addendum (1986) to Air Quality Criteria for Particulate Matter and Sulfur Oxides (1982): Assessment of New Findings on Sulfur Dioxide Acute Exposure Health Effects in Asthmatic Individuals*, EPA 600-FP-93-002. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, August 1994.
- ²⁵ McConnell, R., K. Berhane, F. Gilliland, S.J. London, T. Islam, W. Gauderman, A. James, M. Edward, H.G. Margolis, and J.M. Peters. Asthma in exercising children exposed to ozone: a cohort study. *The Lancet* 359: 386-391 (2002).
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- ²⁸ Ibid.
- ²⁹ U.S. Environmental Protection Agency. *Air Quality Criteria for Particulate Matter, Third External Review Draft, Volume II*, EPA 600-P-99-002bC. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, April 2002.
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- ³⁵ U.S. Department of Health and Human Services, National Center for Health Statistics. *Healthy People 2000 Final Review*, DHHS Publication No. 01-0256. Hyattsville, MD: Public Health Service, October 2001.
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- ³⁷ Girman, J.R., G.E. Hadwen, L.E. Burton, S.E. Womble, and J.F. McCarthy. "Individual volatile organic compound prevalence and concentrations in 56 buildings of the building assessment survey and evaluation (BASE) study." In Proceedings of the 8th International Conference on Indoor Air Quality and Climate. *Indoor Air 2*: 460-465 (1999). London, UK: Construction Research Communications, Ltd.

³⁸ Burton, L.E., J.G. Girman, and S.E. Womble. "Airborne particulate matter within 100 randomly selected office buildings in the United States (BASE)." *In Proceedings of Healthy Buildings 2000* 1: 157-162 (2000). Helsinki, Finland: SIY Indoor Air Information OY.

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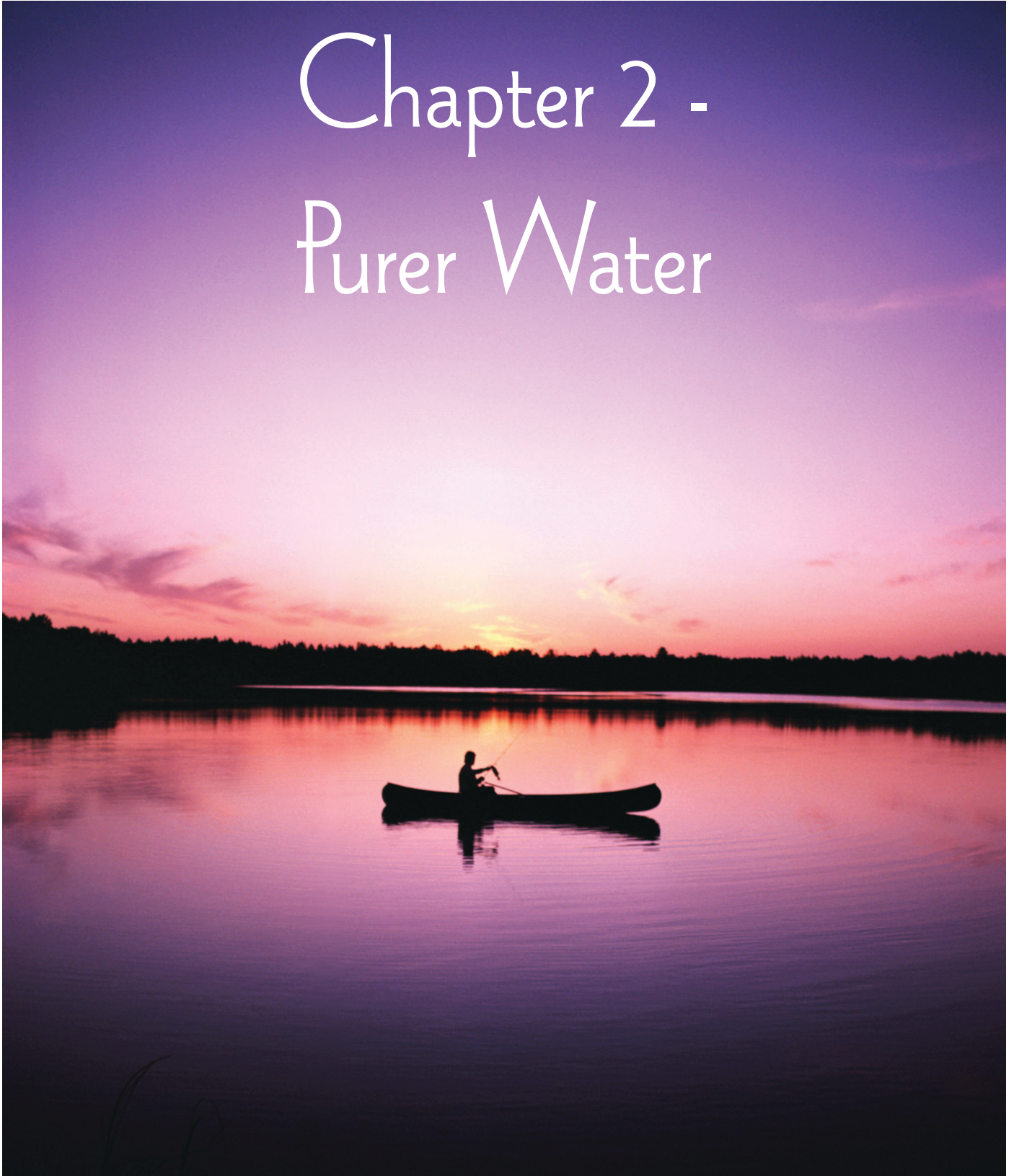
⁴⁰ Scientific Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer. *Scientific Assessment of Ozone Depletion: 2002, Executive Summary*, Report No. 47. Geneva, Switzerland: World Meteorological Organization, Global Ozone Research and Monitoring Project, 2003.

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⁴² Scientific Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer. *Scientific Assessment of Ozone Depletion: 2002, Executive Summary*, 2003. op. cit.

⁴³ DeMora, S., S. Demers, and M. Vernet. *The Effects of UV Radiation in the Marine Environment*, Cambridge, UK: Cambridge University Press, 2000.

Chapter 2 - Purer Water





Introduction

Pristine waterways, safe drinking water, lakes for swimming and catching fish, and aquatic life habitat are treasured resources. The nation has made significant progress in protecting these resources in the last 30 years. Many Americans remember the burning of the severely polluted Cuyahoga River in the late 1960s, and the strong actions taken by many to reduce pollution to the nation's waters in the years since.

These actions have resulted in real progress, but water pollution problems and threats to surface and drinking water remain. For example, the aging of the nation's wastewater and drinking water infrastructure has highlighted the need to

ensure that these critical resources are managed in a sustainable way. Other threats to water resources include landscape modification, invasive species, changes to water flow, overharvesting of fish and shellfish, and deposition of pollutants from the air.

This chapter describes what is known about the condition of waters, watersheds, coastal waters, and wetlands nationwide; the quality of the nation's drinking water; the condition of waters used for recreation; and the condition of waters supporting fish and shellfish consumption. Because the data are lacking—and often inconsistent—the picture is not complete. The chapter, therefore, also discusses the shortcomings of the data and the challenges that remain.



Chapter 2 - Purer Water

Introduction



Waters and Watersheds

A watershed is a geographic area in which all the water drains to a common waterbody (e.g., river, lake, or stream). Watersheds may be as small as a few acres or larger than several states. For example, the Chesapeake Bay

watershed extends across six states and the District of Columbia, whereas a small stream running through a farmer's field in Pennsylvania may drain only a few acres within the larger Susquehanna River watershed, which is a portion of the even larger Chesapeake Bay watershed.

Healthy watersheds lead to cleaner water. Maintaining that health requires careful identification and management of human and natural activities that affect water. Although federal and state governments provide technical and financial support for watershed protection and restoration efforts, local stakeholders have led many such efforts.

Details on the extent of the nation's water resources (e.g., lakes, ponds, reservoirs, streams, rivers, wetlands, Great Lakes, and coastal areas) can be found in the Introduction of this report (see Exhibit i-2, "U.S. Environmental Protection in Context").

Waters and Watershed Indicators

Water clarity in coastal waters
Dissolved oxygen in coastal waters
Benthic Community Index (coastal)
Wetland extent and change
Sources of wetland change/loss
Altered fresh water ecosystems
Percent urban land cover in riparian areas
Agricultural lands in riparian areas
Changing stream flows
Atmospheric deposition of nitrogen
Nitrate in farmland, forested, and urban streams and ground water
Total nitrogen in coastal waters
Phosphorous in farmland, forested, and urban streams
Total phosphorous in coastal waters
Phosphorous in large rivers
Atmospheric deposition of mercury
Chemical contamination in streams
Sediment contamination of inland waters
Sediment contamination of coastal waters
Pesticides in farmland streams and ground water
Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs

Water Quality Standards

The Clean Water Act sets a national goal to restore and protect the biological, chemical, and physical integrity of the nation's waters. Meeting that goal involves maintaining water quality that protects balanced indigenous populations of fish, shellfish, and wildlife and preserves recreational use of those waters. States, territories, and authorized tribes have the authority and responsibility to establish water quality standards for their waters. EPA assists by developing recommendations for criteria to protect human health and aquatic life. Pollutant standards are not the same from state to state because they address different designated uses and government policies, variations in natural conditions and ecosystem characteristics, and geological influences on the natural chemistry of water.



Ground Water

Of all the fresh water that exists, about 75 percent is estimated to be stored in polar ice and glaciers, about 25 percent is estimated to be stored as ground water, and less than 1 percent is stored as surface water. Ground water is the source of much of the water used for irrigation, is the principal reserve of fresh water, and represents much of the potential future water supply. It is a major contributor to flow in many streams and rivers. Indeed, hydrologists estimate that the ground water contribution to stream flow in the eastern U.S. may be as large as 40 percent.¹ Underground aquifers (or ground water) supply drinking water to about 50 percent of the U.S. population.²

Approximately 77 billion gallons per day of fresh ground water was pumped in the U.S. in 1995.³ This amounts to about 18 percent of the estimated 1 trillion gallons per day of natural recharge to the nation's ground water systems.⁴ The availability of ground water varies widely on a local scale.

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Waters and Watersheds

What is the condition of waters and watersheds in the United States?

At this time, there is not sufficient information to provide a national answer to this question with confidence and scientific credibility. A great deal is currently known, however, about the condition of regional, state, and local waters due to the tremendous monitoring efforts of state and local authorities and watershed groups and citizens. What they have learned from these efforts has been useful in managing water resources.

States, territories, and authorized tribes have major responsibilities under the Clean Water Act, including the task of assessing the quality of their waters. That information is compiled by EPA and sent to Congress every two years in the National Water Quality Inventory. The assessments performed under Section 305(b) of the Act are to determine if water quality is supporting "designated uses" in state water quality standards. Typically, water quality is protected for use by aquatic life, for use as drinking water supplies, to support

water for fish and shellfish for consumption, and for recreational, agricultural, industrial, and domestic uses.

Yet a number of factors limit what the Section 305(b) data can say about condition at the national level. Most states, territories, and tribes collect data and information on only a portion of their waterbodies. Also, their programs, sampling techniques, and standards differ. Many have targeted their monitoring programs to known problem areas. Although the use of targeted sampling informs local decision-making, it does not present a comprehensive understanding of the condition of water resources.

To confidently assess the condition of the nation's waters using regional and state information, a consistent, representative sample design and comparable data collection and analysis procedures are needed. A number of states are implementing such programs (see box, "New Directions in State Water Quality Assessment Programs").

A number of other programs collect information that contributes to our understanding of the condition of the nation's waters (see box "Who Is Assessing Water and Watershed Conditions?"). Many of them specifically address the impor-

New Directions in State Water Quality Assessment Programs

- In its "2002 State of the Environment Report,"⁵ the Indiana Department of Environmental Management used a statistical survey to report stream-water quality assessments by major watersheds. Since 1996, the department's Watershed Monitoring Program has assessed 20 percent of the state's streams each year for their ability to support aquatic life. Indiana completed the first comprehensive assessment of more than 99 percent of its streams and rivers in 2001. Of the 35,430 stream miles assessed, approximately 64.5 percent were estimated to fully support the maintenance of well-balanced aquatic communities.
- Maryland Biological Stream Survey (MBSS) uses a probability-based survey design to assess the status of biological resources in Maryland's non-tidal streams. In the fifth year of the survey, it intends to (1) characterize biological resources and ecological conditions, (2) assess their condition, and (3) identify the likely sources of degradation. The state has developed an interim framework to apply "biocriteria" in its water quality inventory (its 305[b] report) and list of impaired waters (its 303[d] list). To date, the proposed biocriteria rely on two biological indicators from the MBSS, the Fish and Benthic Indices of Biotic Integrity. (Benthic organisms include worms, clams, and crustaceans that live at the bottom of streams, lakes, ponds, estuaries, and the sea.) A preliminary evaluation using MBSS 2000 data was conducted to identify watersheds that fail to meet the requirements of the interim biocriteria framework. For a portion of the state, three larger watersheds that were assessed passed, and six assessments were inconclusive. Of the 123 sub-watersheds studied, 69 failed, 32 passed, and 22 were inconclusive.
- Kentucky has published the results of probabilistic surveys on the first three of its basin management units. The state's 2004 water quality report is expected to include results of additional surveys covering the watersheds of the entire state.
- Other statistically designed studies are under way in Alabama, Delaware, Florida, Idaho, Iowa, Kansas, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, Oregon, South Carolina, Virginia, West Virginia, and Wisconsin. The studies will allow those states to provide statewide characterizations of the waters being sampled.



Chapter 2 - Purer Water

Waters and Watersheds

tance of watersheds as geographical groupings of waters and landscapes. This allows a better characterization of conditions than focusing on the waters alone, as well as a better understanding of how stressors affect water quality and the plants and animals that depend on water. An improved ability to report nationally on the condition of surface waters would also require a collaboration of states, tribal authorities, and federal agencies.

What is the condition of coastal waters?

The 2001 *National Coastal Condition Report* found the nation's estuaries to be in "fair" to "poor" condition, varying from region to region (Exhibit 2-1). The study determined the overall condition of the estuaries based on measurements of seven coastal condition indicators: eutrophication, dissolved oxygen, water clarity, sediments, benthic condition, fish contamination, and loss of coastal wetlands. No overall assessments were completed for Alaska, Hawaii, or the island territories.

Estuaries are the most productive surface waters for plant and animal life. Near-coastal habitats provide critical spawning grounds, nurseries, shelter, and food for fish, shellfish, birds, and other wildlife. Coastal areas also provide essential nesting, feeding, and breeding habitat for 85 percent of the nation's waterfowl and other migratory birds.⁶ Benthic organisms are important to the food chain. They are also key indicators of the health of coastal waters because they do not migrate and tend to have more concentrated interactions with their surroundings (e.g., sediment, water) than do many fish (Exhibit 2-1).

All seven indicators can help describe the condition of the nation's estuaries and near-coastal waters in more detail; this report focuses on three of them: eutrophication, dissolved oxygen, and water clarity.



Eutrophication

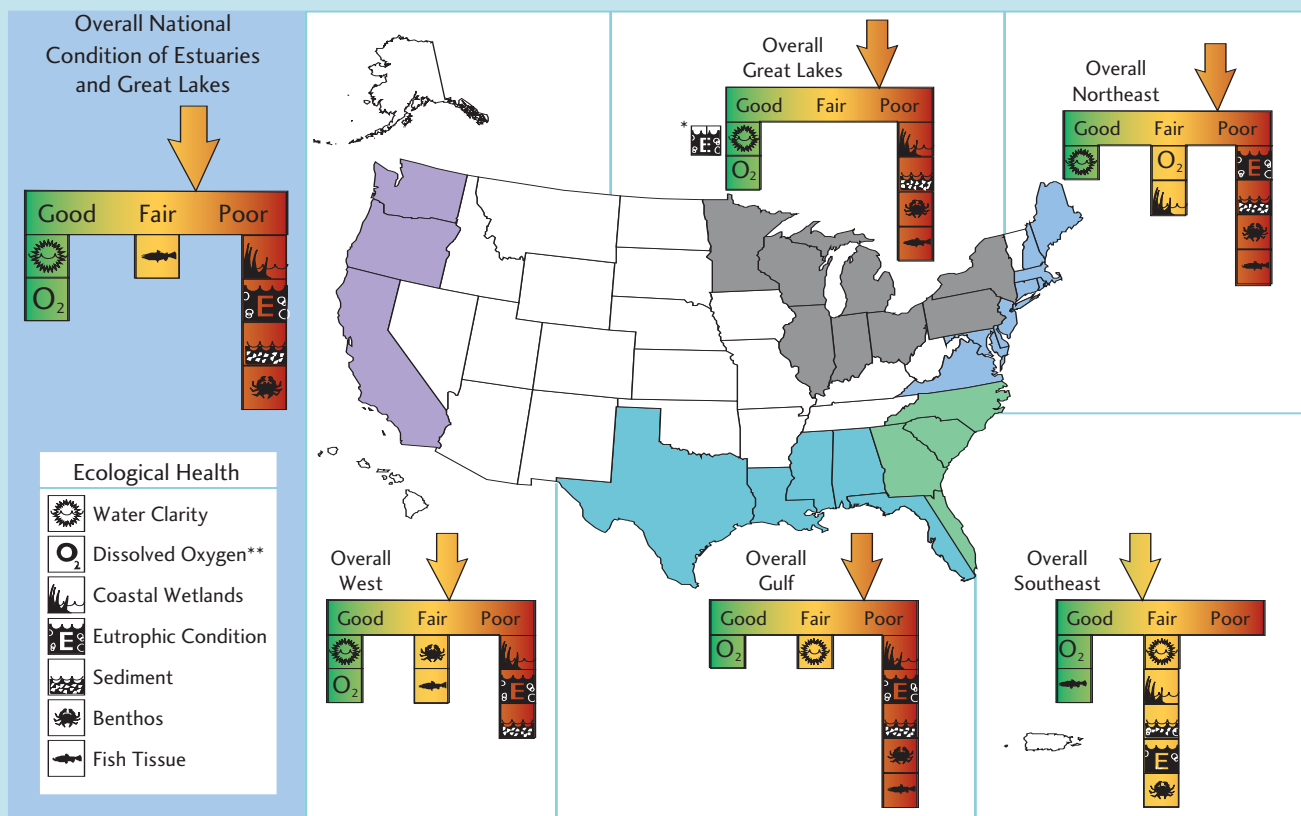
Eutrophication is a natural process characterized by a high rate of algal production. In recent years, human activities have substantially increased the delivery rate of nutrients to



Who Is Assessing Water and Watershed Conditions?

- The U.S. Geological Survey's (USGS's) National Water-Quality Assessment (NAWQA) Program is a perennial program designed to provide consistent descriptions of the status and trends in some of the largest and most important streams and aquifer systems of the nation and to link the status and trends with an understanding of the natural and human factors that affect the quality of water. The studies cover 42 large hydrologic systems; however, the sampling for surface waters may not present statistically valid data for those systems.
- EPA's Environmental Monitoring and Assessment Program (EMAP) has conducted representative sampling of estuarine and stream resources, and then incorporated biological measures in estimates of condition. In most cases, however, those were one-time only assessments. In addition, geographic coverage for fresh water resources is limited to the mid-Atlantic region and the western states. Also, studies of estuarine resources were primarily limited to eastern areas south of Cape Cod, Gulf of Mexico coastal areas, and some western states.
- The National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends Program collects information on the chemical contamination of sediments and organisms, and on potential biological effects in the nation's coastal areas. Although the NOAA coastal studies of chemicals in sediments and bivalve tissues are multiyear in nature, most of the detailed chemical and toxicity assessments of estuarine areas are single point-in-time studies that were not meant to be repeated.
- The Natural Resources Conservation Service's (NRCS's) National Resources Inventory (NRI) is a statistically based sample of land use and natural resource conditions and trends on U.S. non-federal lands. NRI periodically collects data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes. No samples are taken on federally owned land.
- The U.S. Fish and Wildlife Service's (USFWS's) National Wetlands Inventory produces information on the characteristics, extent, and status of the nation's wetlands.
- Other major watershed protection programs collect data of local significance. The EPA Great Lakes National Program Office, for example, conducts statistically based monitoring of the open waters of the five Great Lakes covering trophic (nutrient level) conditions, nutrient concentrations, and biological indicators. Similar programs are found in the Chesapeake Bay, the Florida Everglades, Long Island Sound, and other areas. Atmospheric deposition of nutrients and toxic contaminants is monitored in many of these watersheds as well.

Exhibit 2-1: Overall condition of estuaries and Great Lakes, 2000



* No indicator data available.

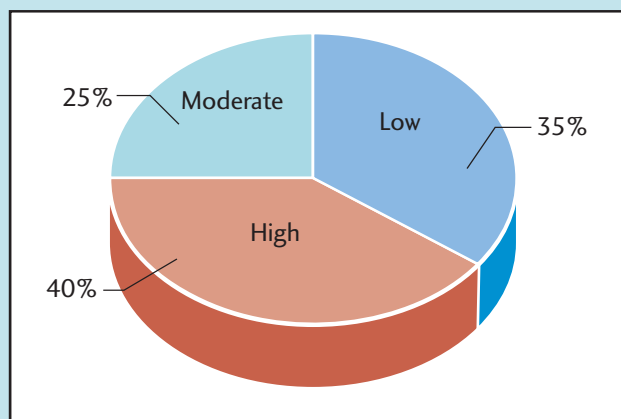
** Does not include the hypoxic zone in offshore Gulf of Mexico waters.

Note: no assessments were completed for Alaska, Hawaii, or island territories.

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report*. September 2001.

many coastal waters, resulting in greater algal production than would have occurred naturally. A NOAA survey between 1992 and 1998 assessed symptoms of eutrophication, including high levels of algae and toxic algal blooms, lack of oxygen, and loss of aquatic plants that provide shelter and habitat for many species of bottom-living organisms (Exhibit 2-2).⁷ Although the assessments were more a subjective determination of expert opinion than a systematic data analysis, they suggest that 40 percent of U.S. estuarine waters—as measured by surface area—are degraded by excess nutrients. That condition can lead to high levels of algae, and eventually to lower levels of oxygen in the water.

Exhibit 2-2: Percent of estuaries with high, moderate, and low levels of eutrophic condition, 1998



Source: Bricker, S.B. et al. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*. 1999; EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report*. September 2001.

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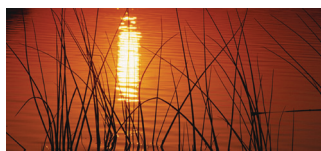
Waters and Watersheds



Dissolved Oxygen

Dissolved oxygen is a fundamental requirement for aquatic life. Low levels of dissolved oxygen, a condition called “hypoxia,” are a problem in some coastal areas. This condition occurs when too many nutrients flow into coastal waters, overstimulating the growth of algae. The organic matter produced by the algae eventually decomposes, using up oxygen in the process. Hypoxia can contribute to algal scums, fish kills, noxious odors, habitat loss, and diminished aesthetic values. During hypoxic periods—which usually occur in the summer when high temperatures impede the mixing of oxygen from surface to deeper layers—dissolved oxygen levels fall below 2 parts per million (ppm, or 2 milligrams per liter [mg/L]), well below the 5 ppm needed to support healthy populations of aquatic life.⁸ As oxygen levels fall, the effects on aquatic life become more severe. At about 3 ppm, bottom-living fish start to leave the area and the growth of some species is reduced. At levels less than 2 ppm, some juvenile fish and crustaceans start to die. At levels less than 1 ppm, fish totally avoid the area or begin to die in large numbers.

Generally, dissolved oxygen conditions in the nation's estuaries are good, judging from data gathered through EMAP. Similarly, according to the *National Coastal Condition Report*, 80 percent of sampled estuaries were in good condition with respect to levels of dissolved oxygen (more than 5 ppm dissolved oxygen), and 4 percent were in poor condition (less than 2 ppm dissolved oxygen). Low dissolved oxygen levels, however, are a seasonal problem in many estuarine systems such as the Neuse River Estuary in North Carolina and parts of Chesapeake Bay, Long Island Sound, and Tampa Bay. Further, although the report describes dissolved oxygen conditions in Gulf of Mexico estuaries as good, it also describes a hypoxic zone about the size of Massachusetts in the offshore waters of the northern Gulf (see box, “Hypoxia in the Gulf of Mexico and Long Island Sound”).



Water Clarity

Water clarity, measured as the distance light penetrates into water, is another important characteristic of estuarine and coastal habitats and of all surface waters. Reduced light penetration is often the result of rainstorms, runoff from farmland

and urban areas, eutrophic conditions, and algal blooms. Reduced clarity can impair normal algal growth and both the extent and vitality of submerged aquatic vegetation, which is a critical habitat component for many aquatic animals. EMAP data indicate that, overall, the nation's estuaries have good water clarity.

What are the extent and condition of wetlands?

Wetlands provide critical habitat, breeding grounds, resting places, and sources of food for fish, shellfish, birds, and other wildlife. They also filter pollutants, which helps protect water quality, limit flooding, and buffer coastal areas from storm damage. An estimated 95 percent of commercial fish and 85 percent of sport fish spend a portion of their lives in coastal wetlands.⁹ Shellfish—shrimp, crab, and oysters—also rely on healthy wetlands for food and habitats.

Wetland extent serves as a partial surrogate to address wetland condition. The loss of wetlands in the landscape has a negative impact on the condition of the remaining wetlands by decreasing the physical connections among aquatic resources and decreasing diversity of the landscape, which lead to diminished opportunity for biological exchange and increased habitat fragmentation.

In 1997, the conterminous U.S. had approximately 105.5 million acres of wetlands, less than half the 220 million acres that likely existed in 1600. Nearly 95 percent, or 100.2 million acres, of those wetlands are fresh water, and about 5 percent—5.3 million acres—are intertidal marine and estuarine water.¹⁰ Based on estimates made in the late 1980s, Hawaii had 51,800 acres of wetlands, and Alaska had 170 million.¹¹

Exhibit 2-5 portrays the loss of wetlands since the mid-1950s. Until the 1970s, conversion to agricultural lands was the predominant cause of wetland loss. Since then, rates of annual wetland losses have been dropping—from almost 500,000 acres to less than 100,000 acres averaged annually since 1986. The U.S. Fish and Wildlife Service National Wetlands Inventory survey estimated the annual rate of loss at 58,500 acres per year between 1986 and 1997. That represents an 80 percent reduction in the rate of loss from the previous decade.¹²

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Waters and Watersheds

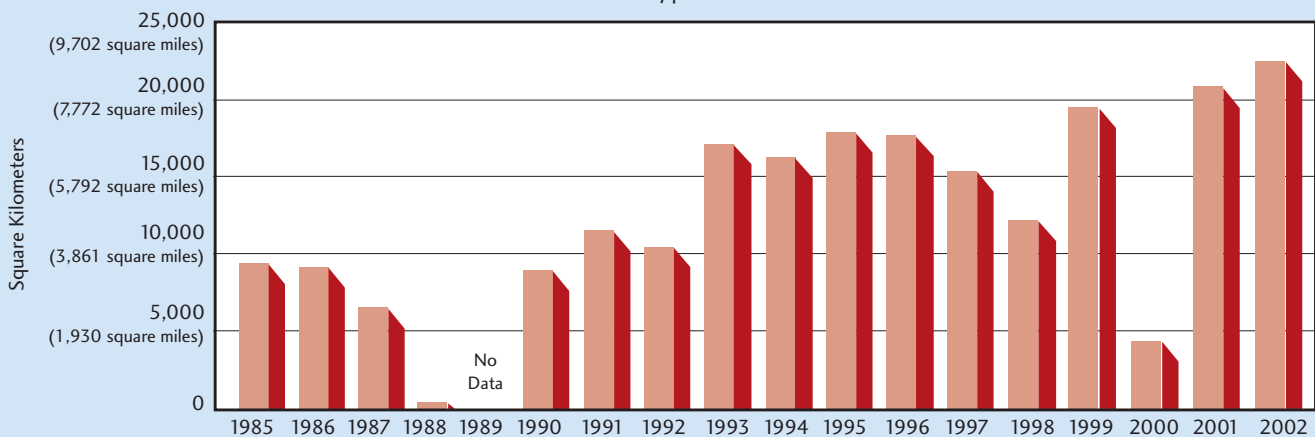
Hypoxia in the Gulf of Mexico and Long Island Sound

The area and duration of hypoxia are tracked in the Gulf of Mexico and Long Island Sound as indicators of the natural variability in those water-bodies to determine whether actions to control nutrients are having the desired effect and how local species are affected.

The largest zone of oxygen-depleted coastal waters in the U.S. is in the northern Gulf of Mexico on the Louisiana/Texas continental shelf. Hypoxic waters are most prevalent from late spring through late summer and are more widespread and persistent in some years than in others, depending on river flow, winds, and other environmental variables. Hypoxia occurs mostly in the lower water column, but can encompass as much as the lower half to two-thirds of the entire column.

The midsummer bottom areal extent of hypoxic waters in the Gulf of Mexico increased from 3,500 square miles (9,000 square kilometers) in 1985 to 8,500 square miles (22,000 square kilometers) in July 2002 (Exhibit 2-3). The primary cause of the hypoxic conditions is probably the eutrophication of those waters from nutrient enrichment delivered to the Gulf by the Mississippi River and its drainage basin.^{13,14}

Exhibit 2-3: Areal extent of midsummer hypoxia in the Gulf of Mexico, 1985-2002



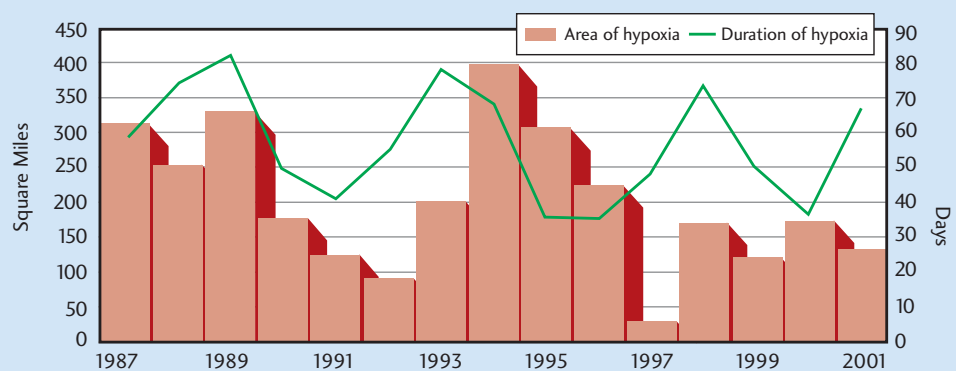
Note: Hypoxia in the Gulf is defined as less than 2.0 parts per million (ppm).

Annual midsummer cruises have been conducted systematically over the past 15 years (with the exception of 1989). Hypoxia in bottom waters covered an average of 8,000-9,000 km² in 1985-92 but increased to 16,000-20,000 km² in 1993-99.

Source: For 1985-1999 data years: Rabalais, Nancy N. et al. *Characterization of Hypoxia: Topic 1 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico*. May 1999, updated July 2000; for 2000-2002 data years: Rabalais, Nancy N., Louisiana Universities Marine Consortium. Unpublished data, personal communication. February 11, 2003.

The maximum area of hypoxia in Long Island Sound averaged 201 square miles (521 square kilometers) from 1987 through 2001. The largest area was 395 square miles (1,023 square kilometers) in 1994, and the smallest was 30 square miles (78 square kilometers) in 1997 (Exhibit 2-4). The duration of hypoxia averaged 56 days during the same period, with a low of 34 days in 1996 and a high of 82 days in 1989. Hypoxia is typically more severe in the western portions of the sound, where the nitrogen load is higher and mixing of fresh and salt water is more restricted.¹⁵

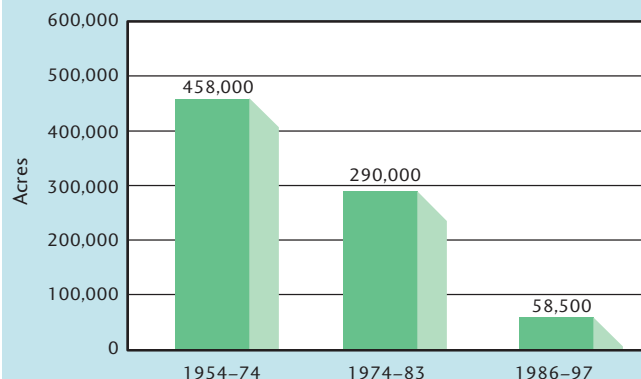
Exhibit 2-4: Maximum area and duration of hypoxia in Long Island Sound, 1987-2001



Note: Hypoxia in Long Island Sound is defined as less than 3.0 parts per million (ppm).

Source: EPA, Long Island Sound Office. *Sound Health 2001: Status and Trends in the Health of Long Island Sound*. 2001.

Exhibit 2-5: Average annual wetland loss,
1954-1974, 1974-1983, 1986-1997



Source: Frayer, W.E. et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States 1950s to 1970s*. 1983; Dahl, T.E. and C.E. Johnson. *Wetland Status and Trends in the Conterminous United States 1970's to 1980's*. 1991; Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*. 2000.

Between 1986 and 1997, 98 percent of all wetland losses in the conterminous U.S. were fresh water wetlands. Since the 1950s, fresh water emergent wetlands (marshes) have declined by nearly 24 percent, and 10.4 million acres of fresh water forested wetlands have been lost. Coastal and estuarine losses during the same time were much lower on an absolute scale—about 1.4 million acres—but that loss represents a nearly 12 percent decline in coastal and estuarine wetlands.¹⁶

Loss of land to open water is a particular problem in Louisiana, whose 3.5 million acres of coastal wetlands represent about 40 percent of all of the coastal wetlands in the continental U.S. The state has lost more than 600,000 acres of coastal vegetated wetlands and is now losing coastal wetlands at an average annual rate of 16,000 to 19,000 acres per year.¹⁷ In addition to flood controls and altered channels to facilitate navigation, rising sea level, marshland sloughing (sections breaking off) into deeper bays and sounds, and land subsidence (sinking) may have contributed to those losses.¹⁸

Additionally, major ecological effects have occurred from the conversions of one wetland type to another: clearing trees from a forested wetland or excavating a shallow marsh to create an open water pond, for example. Such conversions change habitat types and community structure in watersheds

and have an impact on the plant and animal communities that depend on them.

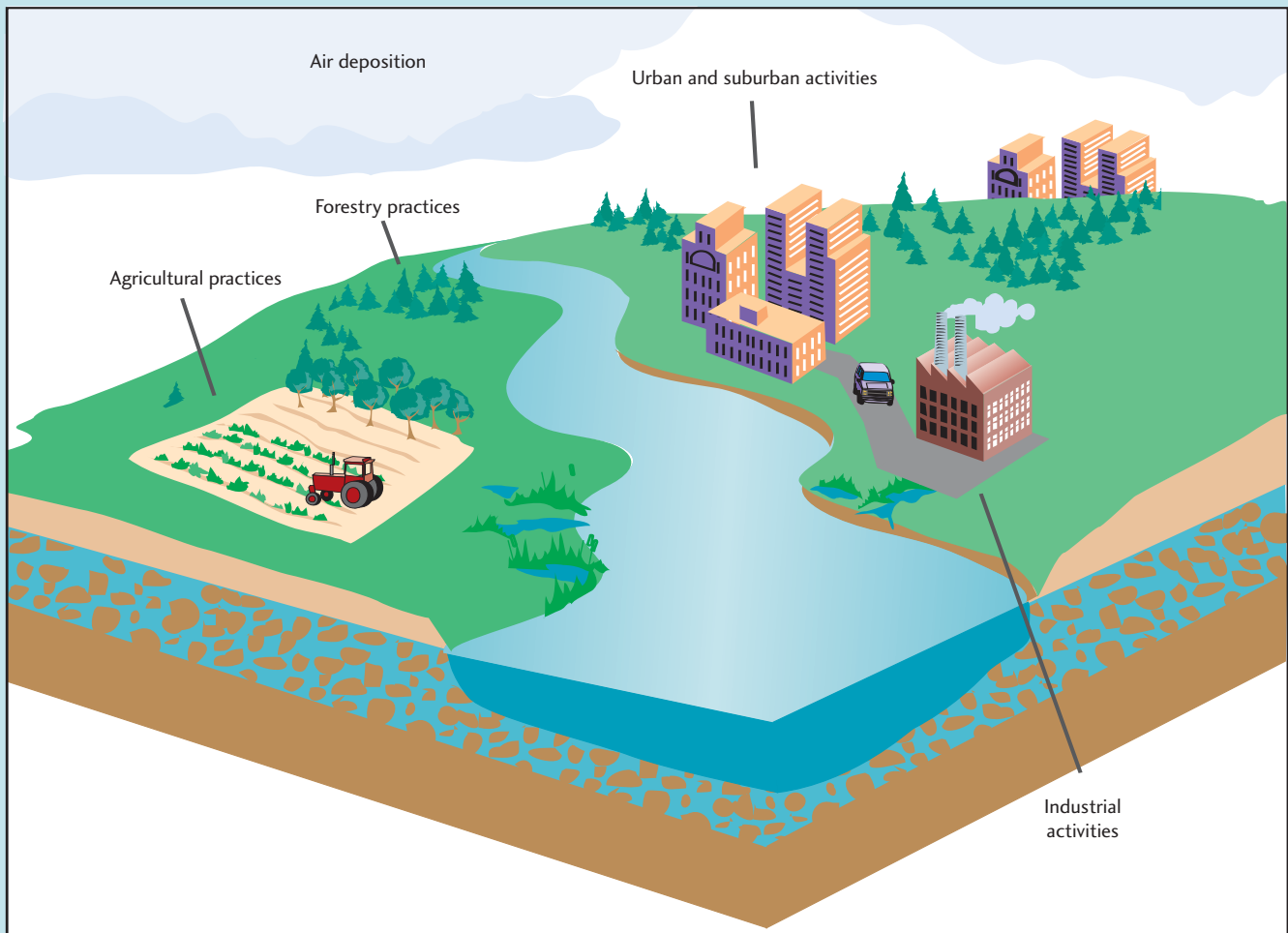
What are stressors to waters and watersheds?

Stressors affecting waters include alteration of natural water ecosystems, excess nutrients, toxic chemicals, and viruses and bacteria (pathogens, which are described in the following sections covering Drinking Water, Recreation in and on the Water, and Consumption of Fish and Shellfish). Some human activities associated with these stressors are illustrated in Exhibit 2-6. The indicators presented here to identify water stressors are drawn from national surveys or assessments. There are, however, strong indications from state-reported causes of impaired waters that stressors responsible for locally degraded water quality include sediments from non-point sources, nutrients from point and non-point sources, pathogens from point and non-point sources, and metals—largely as a result of point source discharges from years ago and atmospheric deposition.¹⁹ All these conditions and situations may harm humans and aquatic species, reduce recreational opportunities, and increase the treatment costs for drinking water.

Under the Clean Water Act, states evaluate their waters and list impaired waters for potential reductions in point and non-point sources or for habitat restoration. In 1998, more than 20,000 waterways were identified as impaired under Section 303(d) of the Clean Water Act.²⁰ States have identified the principal causes of such impairments as siltation, pathogens, metals (particularly mercury), nutrients, habitat alteration, pesticides, organic enrichment/low dissolved oxygen, thermal modifications, low or high pH, and fish consumption advisories. The major transport mechanism for mercury is atmospheric deposition, which is also a significant source of nitrogen to waters.

Losing natural areas adjacent to waterbodies—and forested areas to development and agricultural activities—raises concerns about both water quality and quantity, especially in fast-growing areas such as the southeastern U.S. When impervious surfaces—asphalt and concrete, for example—impede or accelerate natural flows, water cannot percolate through soil. As a result, rain water rushes off, picking up pollutants and overwhelming local streams. Recent trends toward low-density development leave fewer pristine natural areas and

Exhibit 2-6: Selected activities affecting water, watersheds, and drinking water resources



fewer trees and expose more land to pesticides and chemical fertilizers. (For a more detailed discussion of those stressors, see the “Land Use” section of Chapter 3 – Better Protected Land.)

Physical alteration of a waterbody—damming or cutting channels in a river, or developing along shorelines or on adjacent wetlands—can have significant effects on water and on aquatic life. Although waterbodies are usually modified to achieve some gain—flood control, easier navigation, reduced erosion, or more area for farming or development—such alterations may also reduce fish and wildlife habitat, disrupt the patterns and timing of water flows, block the movement of wildlife, and reduce or eliminate the natural filtering of sediment and pollutants.

An analysis of rivers, streams, lakes, and reservoirs (excluding very small streams where data were not collected), based on remote sensing and U.S. Geological Survey (USGS) data, found that 23 percent of the stream banks, lake shorelines, and adjacent wetlands had been altered by use as croplands or by urban development. The natural habitat and function of those waterbodies is probably altered as well.²¹ The data are not collected in a manner that allows for aggregation to provide a national perspective. At present, data for lakes and reservoirs are aggregated, even though a reservoir is a man-made structure or seriously altered habitat. Data on the degree to which streams and rivers are channelized, leveed, or dammed are not available, but these alterations result in similar impacts.

Chapter 2 - Purer Water

Waters and Watersheds

Although nitrogen and phosphorus are beneficial plant nutrients, human activities have increased their flow into waterbodies—in some cases to harmful levels. Runoff from farms and urban and suburban areas, nitrogen from power plants, emissions from vehicles and industry, and discharges from sewage treatment plants and septic systems can be sources of excess nutrients, causing excessive algae and plant growth. The resulting eutrophication harms aquatic life, fouls swimming beaches, causes odor from excess decaying algae, and may increase blooms of harmful algae such as red or brown tides.²²

Ground water in agricultural areas often has higher nitrogen concentrations than that in non-agricultural areas. For example, approximately 10 percent of streams and 20 percent of wells in farming areas exceed federal drinking water standards for nitrate.²³

Contaminated sediments can be a serious problem in certain areas and may be associated with industrial activity that predated awareness of the harmful effects of certain pollutants and the adoption of pollution control programs.²⁴ Pollutants such as dioxins, mercury, lead, polychlorinated biphenyls (PCBs), and other persistent bioaccumulative toxic chemicals in sediments can affect water quality and aquatic life. Industrial releases of metals, as reported through the Toxics Release Inventory, remain potential stressors to water quality. Some toxic sediments kill benthic organisms, reducing the food available to larger animals such as fish. Some contaminants in sediment are taken up by organisms, which are then eaten by next-level predators. In that way, contaminants can move up the food chain in increasing concentrations, affecting fish, shellfish, waterfowl, and mammals, including people.

The USGS has synthesized contaminant and nutrient data from its 1992–1998 National Water Quality Assessment (NAWQA) program on 36 study units. Some of the major findings include: detectable concentrations of pesticides are widespread in urban, agricultural, and mixed-use area streams; streams in urban areas generally have higher concentrations of insecticides than streams in agricultural areas; elevated (above background) levels of selected heavy metals are found in waters; and widespread volatile organic compounds are seen in shallow urban ground water.²⁵

What ecological effects are associated with impaired waters?

Biological communities reflect the cumulative effect of virtually all watershed stressors over time. Waters stressed by increased chemical contamination or altered habitats become impaired, which changes their structure, composition, and function. Pollution-sensitive species, along with organisms that require particular habitats, yield to more pollution-tolerant species and organisms that can adapt to a variety of habitat alterations and changes. Such changes can ultimately lead to a loss of aquatic diversity and abundance.

Several federal, regional, state, and tribal monitoring programs examine factors that affect aquatic communities. They have established direct and indirect relationships between the pressures on a community and its organisms by noting the changes in the structure, composition, and function of the animals and plants. Those “biological response signatures” help provide clues to watershed problems—including the types and sources of pressures.

The Macroinvertebrate Index of Biotic Integrity (IBI) and the Fish IBI are examples of such response signatures. They are indices that can measure incremental changes in the condition of waters and provide clues to the pressures affecting aquatic communities. IBIs have also been developed for coastal waters, wetlands, and lakes, and their use is growing at the regional, state, tribal, watershed, and local levels.²⁶ (See Chapter 5 – Ecological Condition, for further discussion of IBIs.) IBIs for benthos were assessed for the Northeast, Southeast, and Gulf Coastal areas. Assessments showed that 56 percent of the coastal waters were in good condition, 22 percent were in fair condition, and 22 percent were in poor condition. Of the 22 percent with poor benthic condition, 62 percent also had sediment contamination, 11 percent had low dissolved oxygen concentrations, 7 percent had low light penetration, and 2 percent showed sediment toxicity.²⁷



Drinking Water

What is the quality of drinking water?

In 2002, state data reported to EPA showed that approximately 251 million people were served by community water systems that met all health-based standards (i.e., reported no health-based violations). This number represents 94 percent of the total population served by community water systems, up from 79 percent in 1993 (Exhibit 2-7).²⁸ Underreporting and late reporting of violations data by states to EPA, however, affect the accuracy of these data. The water used by community water systems comes from both surface water and ground water.

The nation has some 55,000 community water systems (a subset of all public water systems), all of which must test their water and treat it as needed to remove contaminants to specified levels before distributing it to customers. In 2002, community water systems served about 268 million people. Large-scale water supply systems usually rely on surface waters; smaller water systems tend to use ground water. Non-community water systems are also required to test and treat water. There are no national treatment or monitoring requirements for private wells. (The "Ground Water" discussion, under the "Waters and Watersheds" section of this chapter, provides more detail on the use of ground water as a drinking water resource.)

National drinking water standards apply to public water

systems, which include municipally or privately owned water systems, homeowner associations, and other entities such as some schools, businesses, campgrounds, and shopping malls that draw their own water.

National health-based standards exist for about 90 regulated contaminants. These intensive technical evaluations include many factors: occurrence in the environment; human exposure and risks of harmful health effects in the general population and sensitive subpopulations; analytical methods of detection; technical feasibility; and impacts of the regulation on water systems and public health.

National drinking water standards also prescribe protocols, frequencies, and locations for monitoring. Water systems



Drinking Water Indicators

Population served by community water systems that meet all health-based standards

monitor at treatment plants and also in distribution systems for contaminants such as disinfection by-products and coliform bacteria that may form or recur there. Monitoring locations generally depend on the contaminant of interest. Annually, community drinking water suppliers report their overall water test results to their customers. Suppliers also must notify their customers of violations that pose an immediate threat to health. Non-community public water systems are not required to provide this annual report but are required to notify customers when drinking water standards are violated.

Exhibit 2-7: Population served by community water systems with no reported violations of health-based standards, 1993-2002

Fiscal Year	Population served by CWSs that had no reported violations	Percent of CWS-served population that was served by systems with no reported violations
2002	250,596,287	94
2001	239,927,650	91
2000	239,299,701	91
1999	229,805,285	91
1998	224,808,251	89
1997	215,351,842	87
1996	213,109,672	86
1995	208,700,100	84
1994	202,626,433	83
1993	196,229,162	79

Source: EPA, Office of Water. *Safe Drinking Water Information Systems/Federal version (SDWIS/FED)*. 2003.

What are sources of drinking water contamination?

Microbiological, chemical, and radiological contaminants can enter water supplies as a result of human activity and release from natural sources. For instance, chemicals can migrate from disposal sites or underground storage systems and contaminate sources of drinking water. Animal wastes, pesticides, and fertilizers may be carried to lakes and streams by rainfall runoff or snow melt. Nitrates from fertilizers also can be carried by runoff and percolate through soil to contaminate ground water (see Chapter 3 – Better Protected Land, for more discussion of nitrates). Arsenic and radon are examples of naturally occurring contaminants that may be released into ground water as it travels through rock and soil.

Human wastes from poorly managed or maintained septic and sewage systems as well as wastes from animal feedlots and wildlife carrying microbial pathogens (e.g., *Giardia*, *Cryptosporidium*, and *E. coli*) may get into waters ultimately used for drinking. All drinking water supply systems in the U.S. that use surface water or ground water with close hydrological connections to surface water must disinfect water and most must also filter it to remove pathogens. Disinfecting drinking water is a key element of treatment because it provides a barrier against harmful microbes. Disinfectants such as chlorine, however, react with naturally occurring organic matter in source water and in distribution systems to form chemical by-products such as trihalomethane and haloacetic acid compounds. Generally, the older a system's infrastructure, the greater the risk for breaches or infiltrations in the distribution system, which increase the risk of contamination.

What human health effects are associated with drinking contaminated water?

The potential health effects of consuming contaminated drinking water range from minor to fatal. Drinking inadequately treated water could result in nervous system or organ damage, developmental or reproductive effects, or cancer.²⁹

The Safe Drinking Water Act

The Safe Drinking Water Act, as amended in 1996, mandates that EPA, states, and water systems implement multiple barriers to protect consumers from the risks of unsafe drinking water. Key activities include protection of source water, development and implementation of regulations based on sound science and risk assessments, improvements to drinking water infrastructure, certification of water system operators, technical assistance to water systems, and improving consumer awareness.

Consuming water with nitrates at sufficiently high levels can result in potentially fatal alterations in the hemoglobin (the iron-containing pigment in red blood cells) of infants and very young children, called “blue baby syndrome.”³⁰ National standards for public water systems are designed to provide levels of treatment that are protective against adverse health effects.

The consequences of consuming water contaminated with pathogens can include gastrointestinal illnesses that cause stomach pain, diarrhea, headache, vomiting, and fever (see box, “Waterborne Disease Outbreaks Associated with Drinking Water 1971–2000,” and discussions on “Waterborne Diseases” and “Gastrointestinal Illnesses” in Chapter 4 – Human Health). A microbial outbreak of *Cryptosporidium* in Milwaukee in 1993 sickened about 400,000 people and killed more than 50, most of whom had seriously weakened immune systems.³¹

Disinfection of drinking water is one of the major public health advances of the 20th century and has been a critical factor in reducing the incidence of waterborne diseases, including typhoid, cholera, hepatitis, and gastrointestinal illness in the U.S.³² By-products of disinfection have also been associated with potential cancer, developmental, and reproductive risks, although the extent of risk posed is still uncertain. Limiting concentrations of disinfection by-products in drinking water, while ensuring that microbes are kept in check, will have a positive effect on public health.

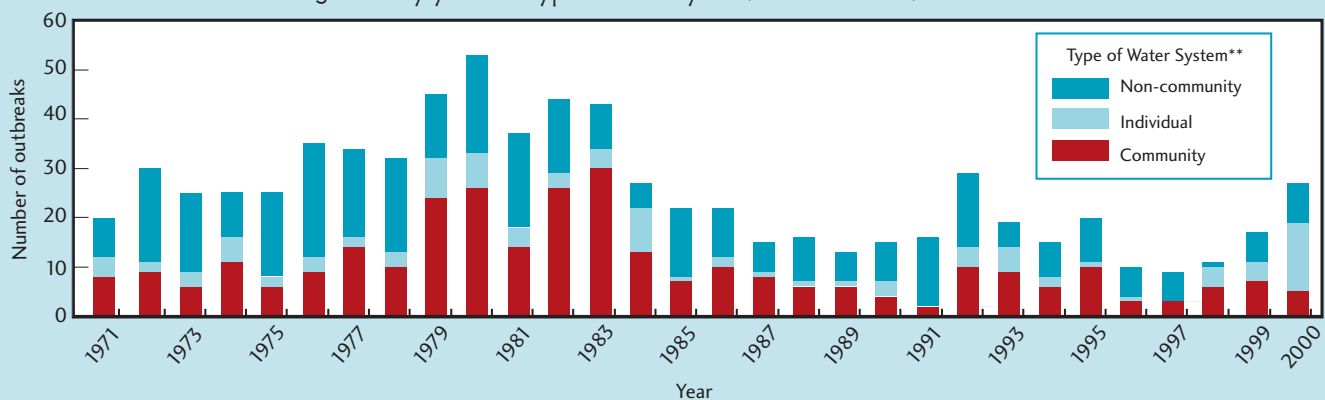
Waterborne Disease Outbreaks Associated with Drinking Water 1971-2000

Since 1971, the Centers for Disease Control and Prevention (CDC), EPA, and the Council of State and Territorial Epidemiologists have maintained a collaborative surveillance system for the occurrences and causes of waterborne disease outbreaks (WBDO). These data are only a small part of the larger body of information related to drinking water quality in the U.S. State, territorial, and local public health agencies are primarily responsible for detecting and investigating WBDOs and voluntarily reporting them to CDC. These data are used to identify types of water systems, their deficiencies, the etiologic agents (e.g., microorganisms and chemicals) associated with outbreaks, and to evaluate current technologies for providing safe drinking water and safe recreational waters. This system reports outbreaks and estimated numbers of people who become ill. It does not provide information on non-outbreak related or endemic levels of waterborne illness. Moreover, the focus is on acute illness. The system does not address chronic illnesses such as cancer, reproductive, or developmental effects. CDC and EPA are collaborating on a series of epidemiology studies to assess the magnitude of non-outbreak waterborne illness associated with consumption of municipal drinking water.

Between 1971 and 2000, there were 751 reported waterborne disease outbreaks associated with drinking water from individual, non-community systems, and community water systems (Exhibit 2-8). During 1999-2000, a total of 44 outbreaks (18 from private wells, 14 from non-community systems, and 12 from community systems) associated with drinking water were reported by 25 states.³³

However, these data should be interpreted with caution. Many factors can influence whether a WBDO is recognized and investigated by local, territorial, and state public health agencies. For example, the size of the outbreak, severity of the disease caused by the outbreak, public awareness of the outbreak, whether people seek medical care or report to a local health authority, reporting requirements, routine laboratory testing for organisms, and resources for investigation can all influence the identification and investigation of a WBDO. This system underreports the true number of outbreaks because of the multiple steps required before an outbreak is identified and investigated. Thus, an increase in the number of outbreaks reported could either reflect an actual increase or improved surveillance and reporting at the local and state level.

Exhibit 2-8: Number of reported waterborne disease outbreaks* associated with drinking water by year and type of water system, United States, 1971-2000 (n=751)



*A WBDO is defined as an event in which (1) more than two persons have experienced an illness after either the ingestion of drinking water or exposure to water encountered in recreational or occupational settings, and (2) epidemiologic evidence implicates water as the probable source of illness.

**Non-community water systems are systems that either (1) regularly supply water to at least 25 of the same people at least 6 months per year, but not year round (e.g., schools, factories, office buildings, and hospitals that have their own water systems), or (2) provide water in a place where people do not remain for long periods of time (e.g., a gas station or campground).

Individual water systems are not regulated by the Safe Drinking Water Act and serve fewer than 25 persons or 15 service connections, including many private wells.

Community water systems provide water to at least 25 of the same people or service connections year round.

Source: Based on data presented in Craun, G.F. and R.L. Calderon. *Waterborne Outbreaks in the United States, 1971-2000*. 2003.



Recreation in and on the Water

Federal, state, and local governments monitor the water quality at many beaches, and issue advisories or close beaches when the water is contaminated and may pose health risks.

What is the condition of waters supporting recreational use?

EPA collects information from 237 agencies on beach closings and advisories through its National Health Protection Survey of Beaches, which is one way to measure the condition of recreational waters. Between 1997 and 2001, the percentage of beaches affected by advisories or closings rose from 23 to 27 percent. During the same period, the number of local, state, and federal agencies participating in the survey increased from 159 in 1997 to 237 in 2001. Survey respondents (primarily for coastal and Great Lakes beaches) reported that beaches were closed or under advisory on more than 19,000 beach days, or about 6 percent of total beach days, during the 2001 swimming season.³⁴ (The increase in the

percentage of beaches affected is likely a reflection of more consistent monitoring and reporting.)

Because reporting under the survey is voluntary and data are drawn primarily from coastal and Great Lakes beaches rather than inland beaches, the survey's reliability as a national indicator is unknown. Furthermore, monitoring and reporting vary by state, with some states having very aggressive programs.³⁵

California, for example, has one of the most highly developed beach monitoring and notification programs in the nation. State law requires frequent monitoring at high-use beaches and establishes well-defined thresholds for issuing beach advisories. A committee made up of state, federal, and local agency officials, as well as representatives from the environmental community and the Beach Water Quality Workgroup helps coordinate the efforts.

California beaches are monitored at least once a week, with some in Southern California monitored 5 to 7 days each week. Other states generally monitor once a week, although some monitor twice a month or less. The monitoring involves testing for several indicators including total coliform bacteria, fecal coliform, and the EPA-recommended indicator *Enterococcus*. If a standard is exceeded, local health departments use various methods to notify the public promptly.

Recreational Water Indicators

Number of beach days that beaches are closed or under advisory



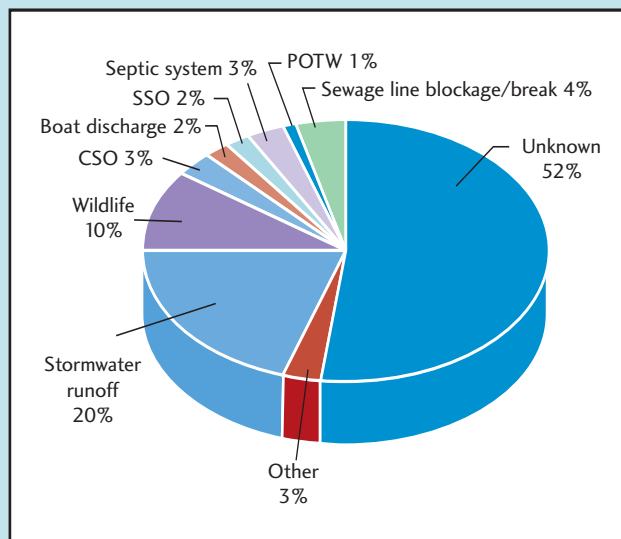
What are sources of recreational water pollution?

EPA asks survey respondents to identify the sources of pollution that cause advisories or closings. Without precise information, respondents use their best judgment to identify sources. In more than half the cases, the source is unknown (Exhibit 2-9). The most frequently identified source is storm water runoff that contains harmful contaminants such as bacteria from livestock or pet waste, inadequate sewage treatment, or poorly designed or operated septic systems.³⁶

What human health effects are associated with recreation in contaminated waters?

The health effects of swimming in contaminated waters are usually minor and temporary—sore throats, ear infections, and diarrhea—but can be more serious, even fatal. Waterborne microbes can cause meningitis, encephalitis, and severe gastroenteritis.³⁷ However, data on the effects and number of occurrences are limited. The number of occurrences may be underreported because people may not link common symptoms with exposure to contaminated recreational waters and, unless symptoms are debilitating, do not seek medical attention. Additional research and information are needed to improve understanding of the types and extent of health effects associated with swimming in contaminated waters (For additional information see the discussions on “Waterborne Diseases” and “Gastrointestinal Illnesses” in Chapter 4 – Human Health).

Exhibit 2-9: Reported sources of pollution that resulted in beach closings or advisories, 2001



CSO - Combined Sewer Overflow
 SSO - Sanitary Sewer Overflow
 POTW - Publicly Owned Treatment Works

Source: EPA, Office of Water. EPA's BEACH Watch Program: 2001 Swimming Season. May 2002.



Consumption of Fish and Shellfish

Fish and shellfish are important and desirable sources of nutrition for many people. However, chemical and biological (bacteria, pathogens) contaminants can accumulate in fish and shellfish, making it unhealthy to consume them, especially in large quantities.

What is the condition of waters that support consumption of fish and shellfish?

Most states sample fish in their waters and then issue fish consumption advisories as a way of informing the public of risks associated with eating certain types and sizes of fish from certain waterbodies. Advisories are based on fish tissue monitoring data collected by states and tribes and are largely focused on areas of known or suspected contamination.

In the U.S., 14 percent of the river miles, 28 percent of lake acreage, and 100 percent of the Great Lakes and their con-

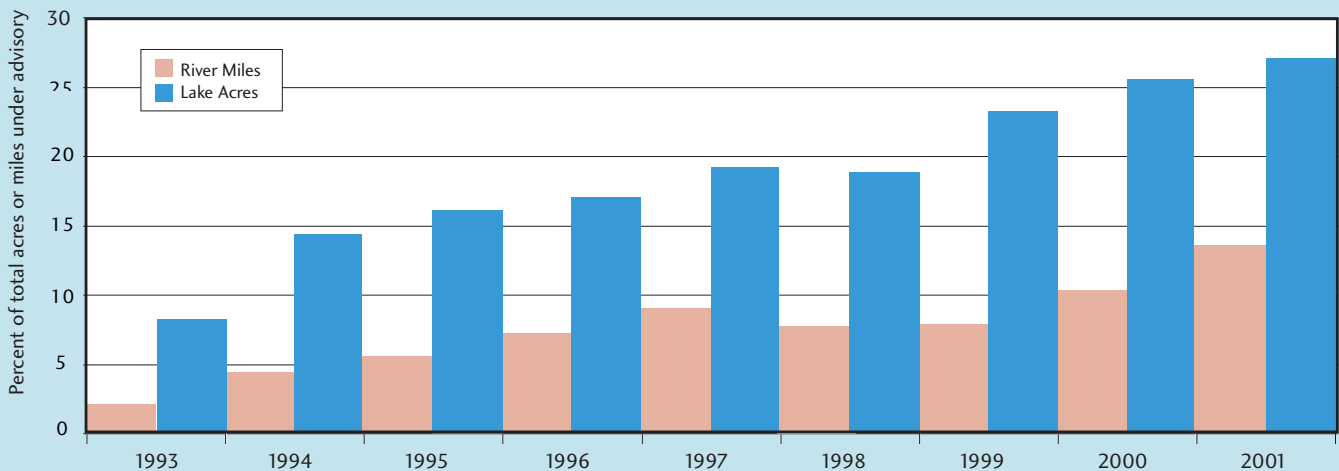
necting waters are under fish consumption advisories.³⁸ Those percentages have increased in recent years (Exhibit 2-10). The increases are most likely the result of more consistent monitoring and reporting and decreases in concentration criteria, and are not necessarily an indication that conditions are getting worse.

Fish advisories that limit or restrict consumption, especially of top-level predators (e.g., walleye and lake trout), are widespread across the U.S. Advisories are issued for various contaminants—mercury, dioxin, and PCBs are responsible for many of the advisories throughout the U.S. In January 2001, EPA and the U.S. Food and Drug Administration issued a nationwide advisory for women who are pregnant or may

Consumption of Fish and Shellfish Indicators

- Percent of river miles and lake acres under fish consumption advisory
- Contaminants in fresh water fish
- Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue

Exhibit 2-10: Trends in percentage of river miles and lake acres under fish consumption advisory, 1993-2001



Source: EPA, Office of Water. Update: National Listing of Fish and Wildlife Advisories. May 2002.

become pregnant, nursing mothers, and young children to limit the consumption of certain species of fish that may contain mercury to one meal per week. The jointly issued nationwide advisory applies to fresh water fish and fish bought from stores and restaurants (i.e., commercially caught fish, including ocean and coastal fish).

Criteria used to issue advisories vary among states. Some have more stringent criteria and more robust advisory programs than others. Fish advisory data presented in Exhibit 2-10 are intended to show total number of miles and acres under advisory—rather than the number of advisories—to clearly represent the amount of area covered and to track trends.

Coastal states also identify, survey, and classify waters where shellfish grow and then prohibit the harvesting of shellfish if the water quality does not meet certain federal standards. Data indicate improvements since testing began in 1966. The percentage of prohibited waters decreased from a high of 26 percent in 1974 to 13 percent in 1995.³⁹ Because the survey has not been repeated since 1995, information on more recent conditions is not available.

What are contaminants in fish and shellfish, and where do they originate?

Most advisories about fish consumption involve one or more of five primary contaminants: DDT, PCBs, chlordane, dioxins, and mercury.⁴⁰ Mercury is a naturally occurring element that is present throughout the environment and in plants and animals. Human activity can release some of that mercury, increasing the amount available to accumulate in humans and other animals. Mercury, which is detectable in most U.S. waters, comes from a number of sources (e.g., from burning fossil fuels and from wastes that create mercury emissions that settle on land and water). In some areas, mercury contamination is the result of activities and practices that have ceased. In soils and sediments, bacteria convert mercury to

highly toxic methylmercury, which is absorbed by fish and accumulates in their tissue.

Some synthetic toxic substances such as DDT and PCBs are common in fresh and coastal waters. Although manufacture and use of PCBs and DDT have been banned in the U.S. for many years, sediments deposited years ago, and residual amounts in soil, continue to contaminate U.S. watersheds (Although production ceased in 1997, PCBs can be found in some products manufactured prior to the ban (e.g., electrical transformers).⁴¹ PCBs, DDT, and mercury can contaminate fish and shellfish and be carried up the food chain to larger fish, such as large-mouth bass, tuna, swordfish, and some sharks. Such concerns led to the nationwide mercury advisory.

Officials in the Great Lakes region are using a multimedia approach to focus on persistent toxic chemicals in air, sediments, and fish tissue (see box, “Bioaccumulative Toxics in the Great Lakes: A Multimedia Look”). Threats to shellfish also include bacterial contamination from human and animal wastes and naturally occurring toxins that shellfish accumulate from consuming certain algae.⁴² Although closings of shellfish beds generally result from excessive coliform concentrations, other pathogens are not always measured and could be a concern. In addition, state and local agencies use different procedures to determine what factors (e.g., presence of chemical contaminants) should be used to dictate closings.

What human health effects are associated with consuming contaminated fish and shellfish?

The effects of eating contaminated fish or shellfish vary greatly. The greatest risks come from consuming contaminated fish and shellfish regularly over a period of time. Assessments show a measurable risk of cancer from some chemical contaminants that are sometimes found in fish tissues (e.g., DDT, PCBs). Mercury is toxic in sufficient quantities, especially to the nervous system. Shellfish contaminated



Bioaccumulative Toxics in the Great Lakes: A Multimedia Look

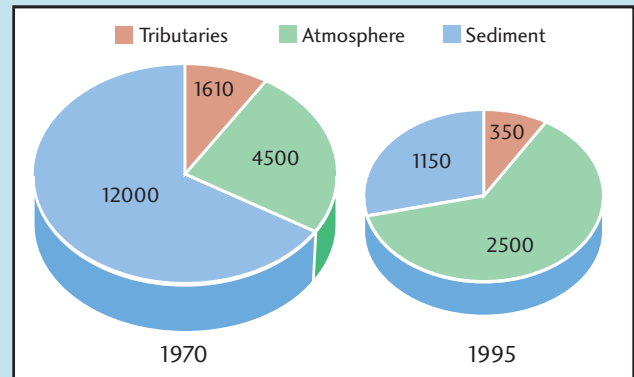
Toxic chemicals enter the water of the Great Lakes (and therefore fish) from the atmosphere, tributaries, and sediments. These chemicals can be retained by plants and animals and increase in concentration through the food chain, a process called "bioaccumulation." Environmental data and modeling were used to estimate the relative contributions from each pathway to Lake Michigan. Total contaminant loads have decreased since the 1970s, and atmospheric deposition has increased in importance over time because of decreases in direct discharges to the lake and levels in sediments (Exhibit 2-11).

The Integrated Atmospheric Deposition Network (IADN) and the Great Lakes Fish Monitoring Program (GLFMP) monitor persistent bioaccumulative toxic (PBT) pollutants in the air and fish, respectively, of the Great Lakes. Both programs show decreases in PBTs over time (Exhibits 2-12 and 2-13). In spite of these downward trends, levels of PCBs and other PBTs in certain types of fish still exceed health protection levels in all five lakes. Air data from Chicago showing elevated PCB levels suggest that cities still contain significant sources of PCBs.

GLFMP samples are also being used to identify the presence of "new" bioaccumulating pollutants in the Great Lakes, such as certain brominated flame retardants.

Exhibit 2-11: Lake Michigan polychlorinated biphenyls (PCBs) sources, 1970 and 1995

Values in kilograms per year

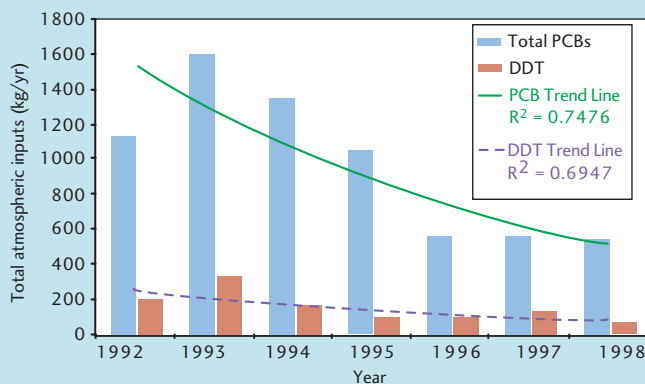


Note: This graphic was created for this report by the EPA Great Lakes National Program Office and the EPA, Office of Research and Development's Large Lakes Research Station using MICHTOX, a mass balance and bioaccumulation model, and air, water, and sediment data drawn from the Great Lakes Environmental Monitoring Database (GLEND). The 1970 model run was based on available data and extrapolations. The 1995 model run was based on data collected during the Lake Michigan Mass Balance Study that collected over 25,000 samples at 200 locations in 1994-1995.

Source: EPA, Great Lakes National Program Office. *Great Lakes Environmental Monitoring Database (GLEND)*. 2002.

Exhibit 2-12: Atmospheric deposition of PCBs and DDT in the Great Lakes, 1992-1998

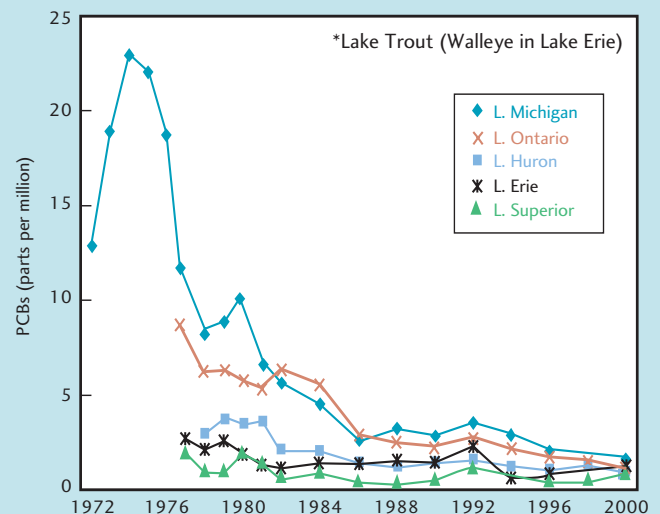
Total Atmospheric Inputs (Wet + Dry + Gaseous Absorption)



Note: Note: R^2 is the coefficient of determination. It gives a measure of the strength of the correlation.

Source: Buehler, S., et al. *Atmospheric Deposition of Toxic Substances to the Great Lakes: IADN Results through 1998*. 2001.

Exhibit 2-13: Polychlorinated biphenyls (PCBs) trends in Great Lakes fish tissue, *1972-2000



Source: EPA, Great Lakes Fish Monitoring Program. *Toxics in Top Predator Fish*. February 24, 2003 (April 4, 2003); <http://www.epa.gov/glnpo/glindicators/fishtoxics/topfishb.html>.



Minnesota Chippewa Tribe: Fish Consumption

The Minnesota Chippewa are a federally recognized tribal confederation with approximately 40,000 members. The tribe's six reservations occupy approximately 1.8 million acres in the northern portion of Minnesota, including 667 lakes covering approximately 700,000 acres, 702 miles of streams, and 250,000 acres of wetlands. Because water is an abundant natural resource for the tribe, its members rely heavily on fish caught in those waters as a source of food.

The major, widespread contaminants in Minnesota Chippewa tribal waters are mercury, DDT, PCBs, and dioxin and furans. Fish consumption is the primary route of human exposure to these contaminants. Thus, the tribe chose as a primary environmental indicator the quantity of fish from its waters that can be consumed safely by its most at-risk members: women of childbearing age, nursing mothers, and children.

The tribally designated, treaty-protected quantity of preferred fish consumption is 224 grams (about 8 ounces) per day. The quantity of preferred fish that may be consumed safely by the most at-risk citizens is limited to 5 percent (about 0.4 ounces) or less of that 8 ounces.

Lake-specific guides for fish consumption are prepared for members of the tribe. The guides offer recommendations on the pounds per month of several fish species that it is safe to consume.⁴³

with pathogens associated with human or animal wastes can cause gastrointestinal illness—even death in people with compromised immune systems (see Chapter 4 – Human Health). Mollusks, mussels, and whelks are the main shellfish that can carry biotoxins causing common symptoms, such as irritation of the eyes, nose, and throat as well as tingling lips and tongue.⁴⁴

Contaminated fish and shellfish are a particular concern to people in either of two high-risk categories: those with conditions that put them more at risk (e.g., pregnant women, nursing mothers, children, or people with compromised immune systems); and people who consume fish as a primary food source (e.g., some tribes and ethnic groups). Because of their higher consumption rates, some communities have developed their own guidance to identify specific types of fish of concern (see box, “Minnesota Chippewa Tribe: Fish Consumption”).



Limitations of Water Indicators

Many sources of data support indicators that help to answer questions about the condition of water and watersheds, the quality of drinking water, the quality of water supporting recreation in and on the water, and consumption of fish and shellfish—as well as the potential stressors and effects associated with these. Other indicators show potential stressors and associated effects, but the data have limited ability to fully answer the questions.



Water and Watersheds

It is difficult to use existing data to give a complete and accurate picture of the state of U.S. surface waters to support aquatic life for several reasons:

- Only a portion of waters is sampled to assess the condition of the whole; many have targeted their monitoring programs to known problem areas.
- States and tribes do not use a consistent set of monitoring procedures for water quality.
- Monitoring designs are not structured across agencies to assess the condition of all U.S. waters. Sampling techniques, sampling locations, and even data analysis procedures are inconsistent.
- States define “quality” in different ways. The standards of each state accommodate both the state’s policies and the important physical and ecological differences that can exist between waters.

The situation is similar for watersheds. Given existing data and differing monitoring approaches, a comprehensive nationwide assessment of watershed condition has not been achieved. More comprehensive and consistent monitoring is needed, particularly when the changing face of the American landscape is considered. Building dams and channels, withdrawing water for irrigation, and expanding development are changing the shape and flow of streams, but there are insufficient data on the effects of those activities on aquatic habitats. There are, however, some very strong state and regional programs that collect data on pollution loads and their effects on aquatic habitats. The Chesapeake Bay Program’s suite of indicators is an excellent example (see box, “Chesapeake Bay Program Suite of Indicators”).



Human Uses of Water Resources

Similar problems occur in gathering information on other water-related issues. For example, underreporting and late reporting of community water system violations data by states to EPA continue to affect the ability to report accurately on the quality of the nation’s drinking water. Of the 49 states that issue fish advisories, six do not use a risk-based approach. An EPA study of 268 contaminants in freshwater fish tissue is in the first of four seasons of monitoring, but cannot yet contribute to an understanding of the national scope of this issue. The data on beach closings and advisories include most coastal and Great Lakes beaches but few inland beaches. Reporting is voluntary, and not all states report consistently. Similarly, data on the effects of contamination on animals and plants are lacking. Monitoring designs are not yet structured across agencies to assess the condition of the entire country.

Chesapeake Bay Program Suite of Indicators

EPA's Chesapeake Bay Program uses indicators extensively for making decisions, informing the public about conditions and trends, and measuring progress toward specific environmental goals. The indicators presented below were selected from more than 90 existing environmental management measures.

Maryland, Pennsylvania, Virginia, the District of Columbia, the Chesapeake Bay Commission, EPA (representing 21 federal agencies), participating citizen groups, local governments, and scientific advisory groups are all involved in the development, peer review, and approval of the indicators and goals.

Trends in Blue Crab: Mature Females

The number of mature female crabs is well below the long-term average and has declined since the early 1990s.

Acres of Bay Grasses

Acres of bay grasses increased to more than 85,000 acres in 2001 from a low point of 38,000 acres in 1984.

Water Clarity

As of 2001, most of the mainstem bay, larger embayments, and lower regions of large tributaries meet the minimum light requirement for submerged aquatic vegetation; upper regions of large tributaries and many minor tributaries do not.

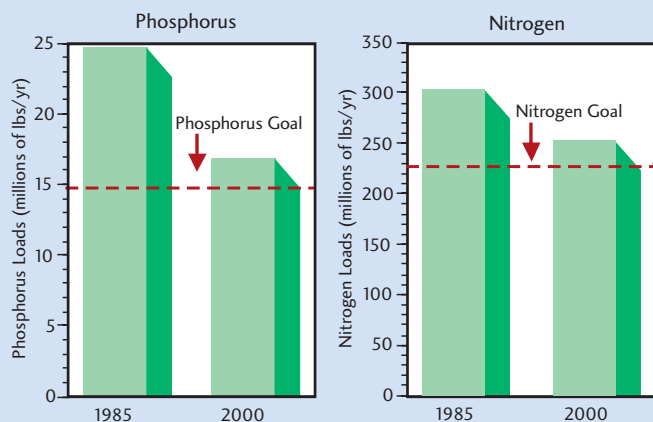
Nutrient Loads Delivered to the Bay

Between 1985 and 2000, nutrient loads to the bay decreased significantly: annual phosphorus loads decreased by 8 million pounds per year; and annual nitrogen loads decreased by 51 million pounds per year (Exhibit 2-14).

Riparian Forest Buffer— Conservation and Restoration

Between 1996 and August 2002, 2,283 miles of riparian forest were restored (Exhibit 2-15).

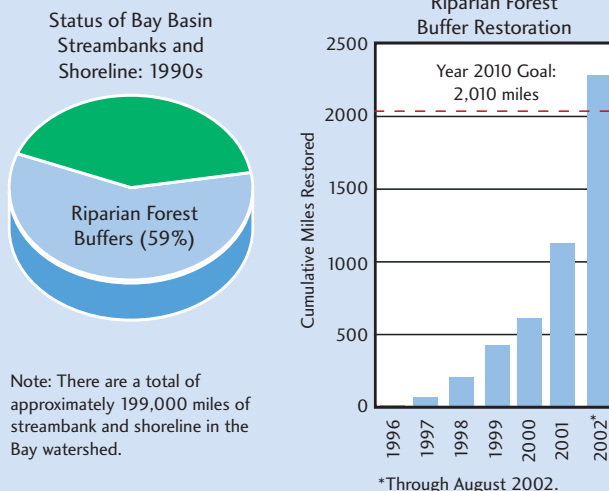
Exhibit 2-14: Total nutrient loads delivered to the Chesapeake Bay from MD, PA, VA, and DC, 1985 and 2000



Note: Data include total nitrogen and phosphorus loads delivered to the Bay from point and nonpoint sources, from Chesapeake Bay Agreement jurisdictions: MD, PA, VA, and DC.

Source: EPA, Chesapeake Bay Program. Phase 4.3 Watershed Model. Last updated July 2002.

Exhibit 2-15: Riparian forest buffer conservation and restoration, 1996-2002



Note: There are a total of approximately 199,000 miles of streambank and shoreline in the Bay watershed.

Source: EPA, Chesapeake Bay Program. Chesapeake Bay Riparian Forest Buffer Inventory. September 1996; EPA Chesapeake Bay Program. Chesapeake Bay Program Office Data Center. June 1998; EPA Chesapeake Bay Program Office Forestry Workgroup. Riparian Forest Buffer Conservation and Restoration. January 2, 2003. (April 7, 2003; <http://www.chesapeakebay.net/status/cfm?sid=83>).

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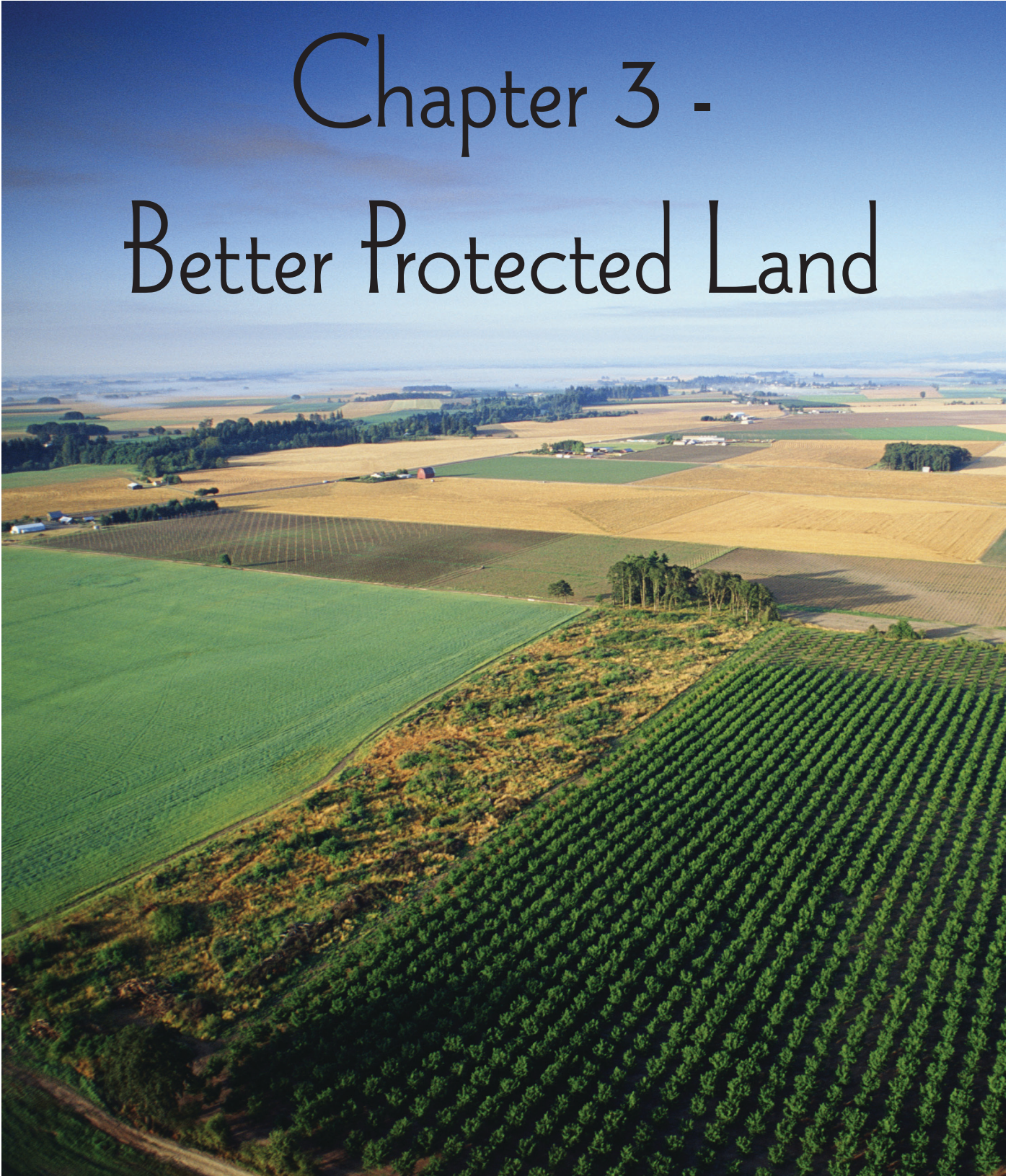
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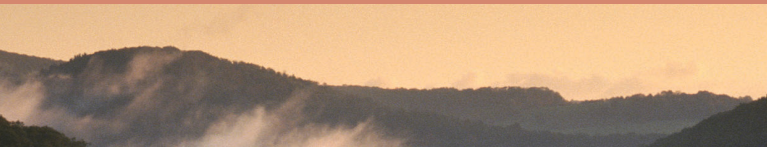
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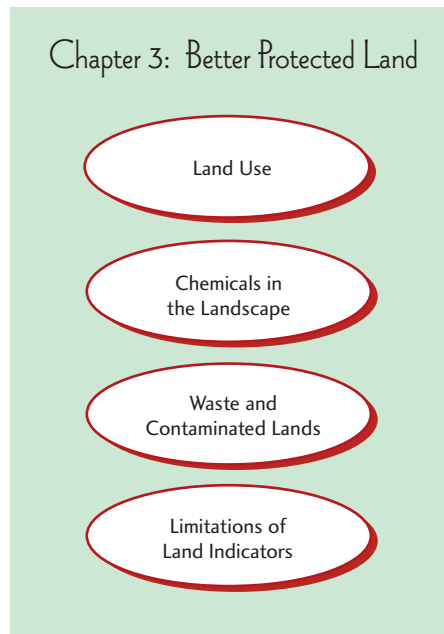
Introduction

The United States is a nation rich in land resources. The land provides the foundation on which communities are built, and from which food, shelter, and other essentials are obtained. Vast acreages not only provide habitat for hundreds of thousands of species, but also support agricultural activities, timber production, and mineral and energy extraction. In addition, diverse landscapes provide numerous opportunities for recreation and aesthetic enjoyment, including hiking, bird watching, gardening, camping, and skiing.

Much like air and water, land is a resource that must be carefully managed and protected. What happens on the land can affect not only land itself, but air and water as well, with potential consequences for human and ecological health. Protecting land resources means ensuring that lands meet current needs and support healthy communities and ecosystems. To this end, EPA's land protection activities focus on the prevention, management, control, and cleanup of various substances that are released to or used on land, such as

toxic chemicals, pesticides, fertilizers, and wastes. Other government agencies, notably the U.S. Department of the Interior and the U.S. Department of Agriculture (USDA) at the federal level, manage land for natural resource and conservation purposes. Additionally, cities and counties adopt and implement land use laws and regulations, overseen in some cases by the states.

This chapter examines critical questions about aspects of land use, chemical and waste applications, and land contamination: How much land is being used for various purposes? How has this use changed over time? How much waste is generated, how has this changed, and how is the waste managed or disposed of? What is the extent of land contamination? The answers help to set a baseline against which to measure the effects of land practices on the condition of human health and ecosystems. The chapter presents available national-level data on these questions, and identifies gaps where the data are limited.



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Land Use

The U.S. landscape has changed over the past 400 years through extensive use in meeting human needs for food and shelter, economic and energy development, and recreation. Before European settlers came to this country, the more than 2 billion acres of landscape consisted of forests, grasslands, deserts, shrublands, and wetlands. Today, 98 million acres are considered developed lands supporting residential, commercial, industrial, and transportation uses; 377 million acres are used specifically to produce crops; and 832 million acres are considered grazing lands.^{1,2}

The federal government manages nearly 28 percent of the nation's lands, or 630 million acres, mostly in the western U.S. and Alaska.³ Federal management responsibilities are distributed among several agencies, including the USDA Forest Service, the Bureau of Land Management, the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Department of Defense. State and local governments manage another 198 million acres.^{4,5} The more than 828 million acres of publicly managed lands support various public purposes, such as recreational uses, the production of specific commodities, grazing for cattle and sheep, mineral exploration and development, and timber harvesting.^{6,7,8} In many parts of the country, public land provides highly valued open space.



Land Use Indicators

Extent of developed lands

Extent of urban and suburban lands

Extent of agricultural land uses

Extent of grasslands and shrublands

Extent of forest area, ownership, and management

More than 4 percent of the nation is designated as wilderness, and millions of other acres are protected in national parks, state parks, wildlife refuges, or other classifications of reserved land. Of the 106 million acres of land now designated as federal wilderness, more than half are in Alaska.⁹ Such protected lands provide recreational opportunities, open space, wildlife habitat, and watershed protection.

More than 1.4 billion acres of private and tribal land are managed in the interests of their owners, with various land use constraints imposed by zoning and other regulations.^{10,11} Although both private and public landowners may use their lands for similar purposes, such as harvesting timber and raising livestock, private lands are more likely to be developed and used for crop production than those under public ownership. Many levels of government regulate land use, with widely varying practices, creating challenges in understanding national patterns of land use.

Another important land use, but one for which it is not possible to identify how much land is used, is land managed for energy production and other forms of mining. There are almost 1,900 producing coal mines, the majority of them surface mines in western states and underground mines in Appalachia. There are also nearly 2,000 other mines and 534,000 oil wells across the country. The extent of land that those activities affect is not known, but some of the results of mining are described in the chemicals and waste discussions in this chapter.¹²

The following questions focus primarily on the extent of various land uses. Extent is important because it affects habitat availability for all species, including humans. Extent of land cover and land use represent two different concepts and both are discussed. Land cover is essentially what can be seen on the land—the vegetation or other physical characteristics—while land use describes how a piece of land is being managed by humans. In some cases, land uses can be determined by cover types (e.g., the presence of housing indicates residential land use), but often more information is needed for those uses that are not visible (e.g., lands leased for mining, “reserved” forest land, “grazing rights” on shrublands). Extent of uses and cover types is additionally complicated because there are numerous varying estimates of actual amounts due to different terminology, definitions, and approaches to estimation. Within the discussion of each question, those variations are explored. The importance of extent is discussed in more detail in Chapter 5 – Ecological Condition.

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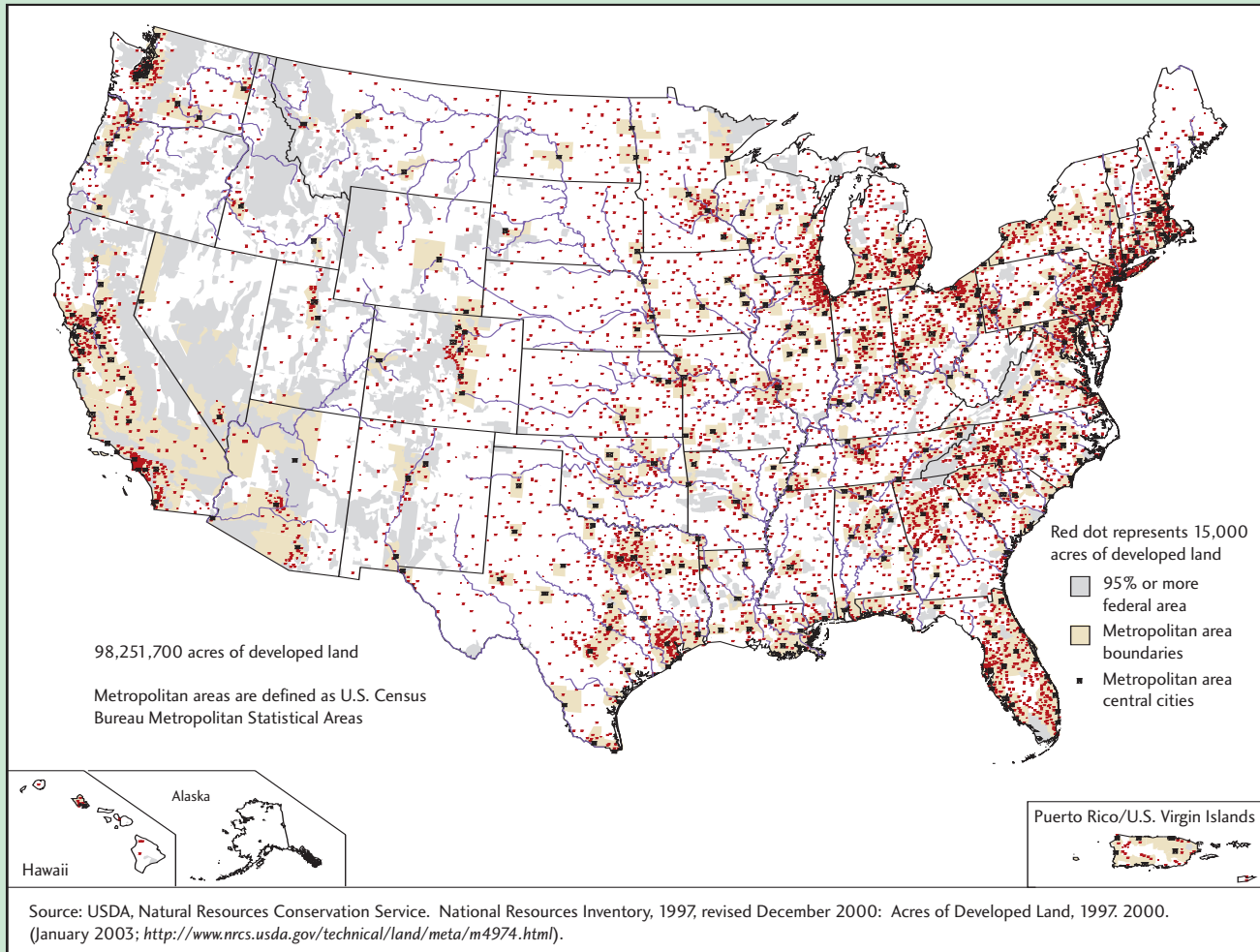
What is the extent of developed lands?

The majority of Americans live in areas or transport themselves on lands that are considered to be “developed land.” Estimates of the actual amount of developed land vary depending on definitions of “developed” and differing assessment techniques.¹³ The USDA Natural Resources Conservation Service’s National Resources Inventory (NRI) estimated that there were approximately 98 million acres of developed land in the United States in 1997



(Exhibit 3-1).¹⁴ That represents 4.3 percent of the nation’s total land area, up from 3.2 percent in 1982.¹⁵ Between 1982 and 1997, approximately 25 million acres of land, primarily forest and cropland, were converted to developed uses. The pace of land development in the 1990s was more than 1.5 times that of the 1980s.¹⁶ Since the middle of the last century, the number of Americans living in U.S. Census Bureau-defined urban areas increased from 64 percent to 79 percent of the total population.¹⁷ Urban and suburban ecosystems represent a subset of developed lands and include highly urbanized areas and surrounding suburbs, and developed outlying areas greater than 270 acres in size. Estimates are that there were approximately 32 million acres of urban and suburban lands in 1992.¹⁸

Exhibit 3-1: Extent of non-federal developed land, 1997



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What is the extent of farmlands?

Farmlands are lands used for growing crops and producing forage, as well as the lands that contribute to those uses, such as forested windbreaks or farmsteads. Currently, there are no accurate estimates of the extent of farmland. Different components of farmland can be identified, including approximately 377 million acres of non-federal lands that are used to grow crops and 120 million acres of pastureland managed to produce forage for livestock.¹⁹ Most of these croplands and pasturelands are privately owned. Another 712 million acres of both private and public lands may support grazing for livestock production, but these lands are not specifically seeded or fertilized and are normally not considered part of farmlands.^{20,21} Lands used for agricultural production show constant shifts in the uses among crop, pasture, range, and forest to meet production needs, implement rotations of land in and out of cultivation, and maintain and sustain soil resources. Within those shifts, however, trends indicate that the amount of cropland, rangeland, and pastureland in the U.S. has gradually decreased because of lower U.S. exports of grain, improvements in agricultural productivity and efficiency, and conversion of agricultural lands to development near growing population centers.²² Between 1982 and 1997, cropland acreage decreased by 10.4 percent (44 million acre decrease)

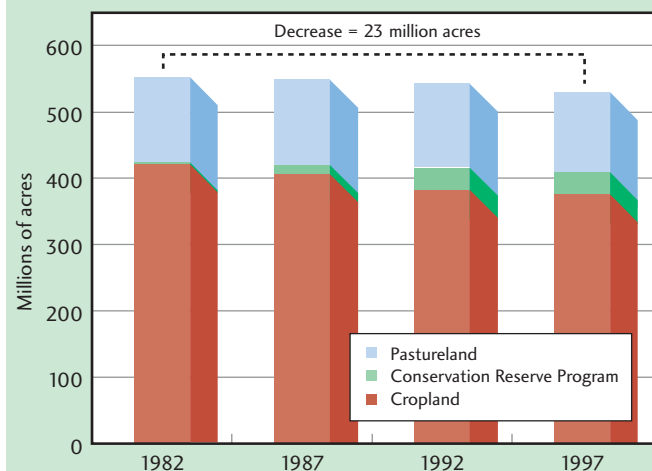
and pastureland acreage by 9.1 percent (12 million acre decrease) (Exhibit 3-2).²³ In that same timeframe, however, 32.7 million acres consisting primarily of croplands were enrolled in the Conservation Reserve Program (CRP), a voluntary program that encourages farmers to set aside agricultural lands for conservation purposes.²⁴

What is the extent of grasslands and shrublands?

As of 1992, the ecosystem of grasslands and shrublands occupied about 861 million acres in the lower 48 states and 205 million acres in Alaska, for a total of 1.066 billion acres (excluding Hawaii), or about 47 percent of the U.S.²⁵ That area includes not only the grasslands and shrublands of the West but coastal meadows, grasslands and shrubs in Florida, mountain meadows, hot and cold deserts, and tundra. It also includes more-managed grasslands and agricultural lands that are often classified as rangelands and pasturelands. One of the challenges in determining the extent of this ecosystem is that grasslands and shrublands can be used for grazing and are often counted as agricultural lands.

The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States concludes that no consistent, nationwide data are available on the change in acreage of grasslands and shrublands. Researchers have estimated that there were between 900 million and 1 billion acres of grasslands and shrublands in the lower 48 states before European settlement. On the basis of that estimate, between 40 million and 140 million acres had been converted to other uses by 1992.²⁶

Exhibit 3-2: Change in cropland, CRP land, and pastureland acreage, 1982-1997



Source: USDA, National Resources Conservation Service. *Summary Report 1997 National Resources Inventory* (revised December 2000). 2000.

What is the extent of forest lands?

In 2001, forests covered about one-third of the national land area, approximately 749 million acres.^{27,28} It is estimated that in 1630, 1.045 billion acres of forest land existed in what was to become the land area of the U.S. Nearly 25 percent of these lands were cleared by the early 1900s, leaving 759 million acres of forest land in 1907. Since that time the total amount of forest land nationwide,



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while changing regionally has remained relatively stable, with an increase of 2 million acres between 1997 and 1999.²⁹

Most forested lands are managed for a combination of uses, including recreation, timber production, grazing, and mining. Approximately 10 percent of the nation's forests is "reserved" through designations such as national parks or wilderness areas, and 9 percent supports private industrial (major timber management companies) timber production.³⁰ In 2001, the USDA Forest Service considered more than 503 million acres of both private and public forests "timberlands," or available for harvest. From 1976 to 2001, public land harvest nationwide dropped nearly 47 percent to less than 2 billion cubic feet annually. In the same timeframe, private land harvest increased by almost 29 percent to 14 billion cubic feet annually (Exhibit 3-3).³¹ Private forests are being converted to developed land uses faster than any other land type.³² (Chapter 5 – Ecological Condition contains a more detailed discussion of forest land condition.)

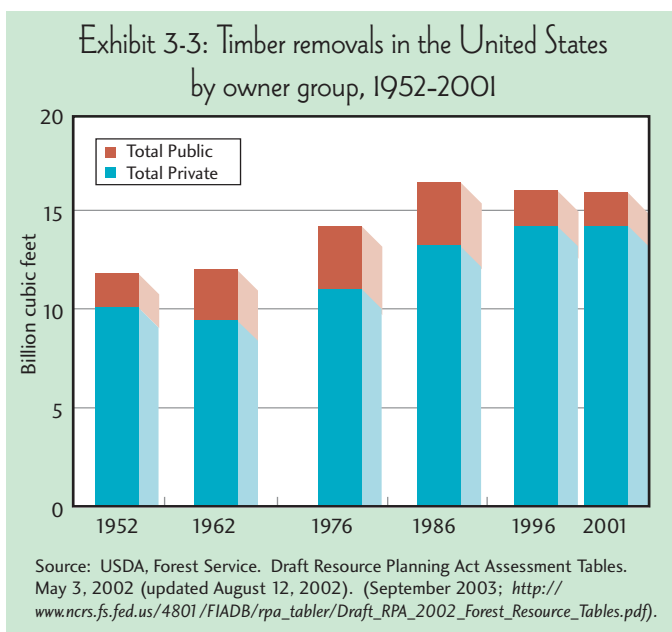
Increased storm water runoff from impervious surfaces can increase the flow of polluted runoff into surrounding waterbodies that residents may rely on for drinking and recreation. Development patterns can affect quality of life by limiting recreational opportunities, decreasing open space and wildlife habitat, and increasing vehicle miles traveled and the amount of time spent on roads. And, as discussed later in this chapter, agricultural land uses may expose humans to dust and various chemicals.

What ecological effects are associated with land use?

Land use and land management practices change the landscape in many ways that can have direct and indirect—as well as positive and negative—ecological effects. One direct effect is the conversion of one type of use to a more human-oriented land use, such as developed land or agriculture. Examples of indirect effects may include changes in runoff patterns or soil erosion.

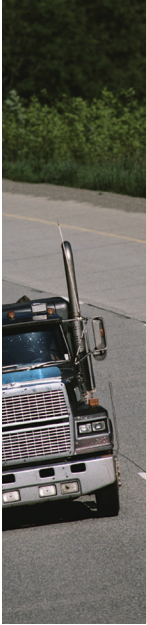
Land development affects water quality and quantity by creating hard surfaces such as roads, structures, and parking lots. Such impervious surfaces limit the natural soil filtering process, change runoff patterns, contribute to floods, and potentially contribute to the effects of droughts due to lower water tables. Land development also creates "heat islands," domes of warmer air over urban and suburban areas caused by the loss of the cooling effects of trees and shrubs and the absorption of more heat by pavement, buildings, and other sources. Some agricultural practices can degrade ecological condition, such as livestock grazing, which can damage streamside vegetation and contribute nutrients to ecosystems that then enter waterbodies. Forest practices can affect water quality when trees are removed along streams or on steep slopes, causing erosion, stream sedimentation, increased water temperatures (from loss of shade), and loss of fish habitat. Tree planting can have positive ecological effects by lowering stream temperatures and improving fish habitat. Other chapters contain further discussion of the effects of land development and agricultural and forest uses on ecosystems and water quality (see Chapter 2 – Purer Water; and Chapter 5 – Ecological Condition).

Land use can also have indirect effects on air quality. Patterns of dispersed land development increase the number of miles



What human health effects are associated with land use?

Land development patterns have direct effects on air and water quality, which can then affect human health. The increased concentration of air pollutants in developed areas can exacerbate human health problems such as asthma.



Measuring Impervious Surfaces

One effect of land development is the creation of impervious surfaces—areas, for example, with pavement or buildings, which restrict or prevent the infiltration of water into underlying soil. Research has shown that increasing the amount of impervious surfaces within watersheds can degrade streams and affect the health of aquatic ecosystems. Some aquatic species may be affected when impervious surfaces constitute as little as 2 percent of a watershed's area; others may be affected when impervious surface area is 10 to 12 percent. By preventing the processing of pollutants through soils, impervious surfaces help channel pollutants directly into waterways. Estimates of impervious areas have been developed based on many approaches, including the use of remotely sensed satellite imagery such as the National Land Cover Dataset (NLCD), assessments of population and road density, and zoning delineations. Over the last several years, EPA researchers analyzed 1,624 watersheds in Georgia using two different approaches. In the first approach, three different data sets (population density from census block-level data, commercial/industrial and quarrying/mining land cover categories from the NLCD, and major highway and interstate digital data coverage) were integrated for analysis. The second approach applied assumptions about percentage of imperviousness to various classes of NLCD data. The NLCD-only approach showed that 69 of the Georgia watersheds had greater than 10 percent total impervious area, while the integrated analysis identified 80. The NLCD-only approach identified 76 watersheds in the 5 to 10 percent impervious range, whereas the integrated analysis showed 117 watersheds. The results indicate that the NLCD-only approach provides a rapid-assessment tool for identifying currently urbanized and impaired watersheds (more than 10 percent imperviousness), but it underestimates potentially vulnerable watersheds that may suffer impairment in the near future (currently 5 to 10 percent imperviousness).^{33,34}

driven by commuters. Agricultural land uses contribute to wind erosion and dust in many areas of the country.

Certain land uses and practices, such as land conversion, overgrazing, excess fertilization, and use of agricultural chemicals, can enhance the growth of invasive plants.³⁵ Additionally, failure to manage invasive species can lead to major threats to native ecosystems.³⁶

Land practices related to development, timber harvest, and agriculture can affect soil quality both positively and negatively. Some agricultural practices such as organic farming, creation of buffer strips in riparian areas, and precision pesticide and fertilizer application technologies can improve land conditions. Other practices may negatively affect soil quality by promoting soil compaction and erosion. Soil erosion can have several major effects on ecosystems. Sediment is the greatest pollutant in aquatic ecosystems, by both mass and volume, and soil erosion and transport are the source.³⁷ Although rates of erosion declined between 1982 and 1997 by about 1.4 tons per acre, more than one-quarter of all croplands still suffer excessive water and wind erosion.^{38,39} (Excessive is defined as exceeding "tolerable" rates as defined by USDA Natural Resources Conservation Service models).⁴⁰

Land conversion and land management practices also have significant effects on sensitive areas, such as wetlands, coastal



areas, and the banks of streams, rivers, and lakes. According to USDA estimates, most wetland conversion over the past 15 years, particularly in the southern and eastern parts of the country, has been due to land development.⁴¹ (See Chapter 2 – Purer Water for an in-depth discussion of wetlands, their significance, and loss.)

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Chemicals in the Landscape

The nation's commerce depends greatly upon the development and use of chemical products, and over the past 50 years, the use of such chemicals has increased significantly. The Toxic Substances Control Act chemical inventory now identifies more than 76,000 chemicals currently or recently used in the country. Nearly 10,000 of those, excluding inorganic polymers, microorganisms, naturally occurring substances, and non-isolated intermediaries, are produced or imported in quantities greater than 10,000 pounds per year; for about 3,100 chemicals, the quantities exceed 1 million pounds per year. Associated annual production and import volumes increased by 570 billion pounds (9.3 percent) to 6.7 trillion pounds between 1990 and 1998.⁴² Commercial and industrial processes such as mining, manufacturing, and electrical generation all use and release chemicals. Pesticides are used in homes, yards, factories, and office buildings and, most frequently, to support agricultural production, where they have contributed to an increase in agricultural productivity levels over the past 50 years. Fertilizers, used to supplement soils for enhanced plant growth, have also contributed to those productivity increases.



Chemicals in the Landscape Indicators

Quantity and type of toxic substances released and managed

Agricultural pesticide use

Fertilizer use

Pesticide residues in food

Potential pesticide runoff from farm fields

Risk of nitrogen export

Risk of phosphorous export

The use and release to the environment of chemicals have created a range of challenges for protecting human health and the environment. Toxic chemicals, including some pesticides, can lead to a variety of acute or chronic health problems, and excess fertilizers carried in runoff may contribute nutrients to aquatic ecosystems that harm water quality and aquatic life.

How much and what types of toxic substances are released into the environment?



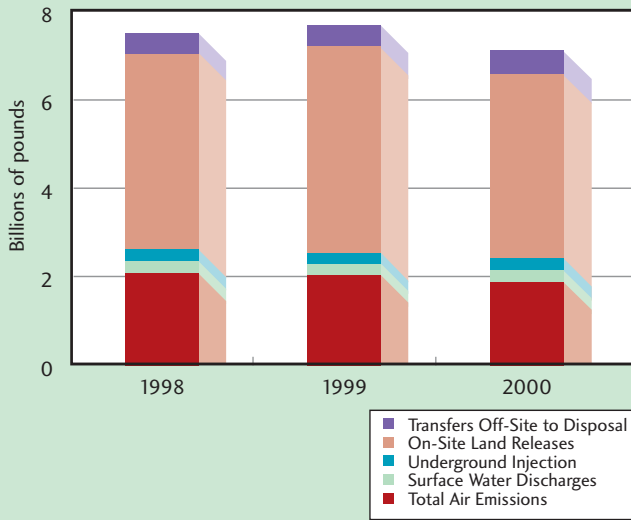
Many industries release toxic substances into the air, soil, and water through their manufacturing and production activities. Under the

Emergency Planning and Community Right-to-Know Act of 1986 and the Pollution Prevention Act of 1990, facilities are required to calculate and report to EPA and states their releases of more than 650 toxic chemicals and chemical compounds. EPA makes these toxics release data available to the public through the Toxics Release Inventory (TRI). In 2000, total TRI releases reached 7 billion pounds. Of these releases, 58 percent were to land, 27 percent were to air, 4 percent each were to water and underground injection at the generating facility, and 7 percent were chemicals disposed of off-site to land or underground injection. Between 1998 and 2000, toxic releases decreased overall by about 409 million pounds, or 5.5 percent. Of that total, releases to land decreased by approximately 276 million pounds (Exhibit 3-4).⁴³ Of the original set of chemicals from industries that have reported consistently since 1988, total on- and off-site releases decreased 48 percent between 1988 and 2000, a reduction of 1.55 billion pounds.⁴⁴

Some of the releases reported in the TRI include chemicals that are managed under EPA regulations. For example, the above figures for total releases in the TRI include chemicals in waste disposed of in hazardous waste disposal units regulated under Subtitle C of the Resource Conservation and Recovery Act (RCRA), whether at the generating facility or after being transferred to another facility. Approximately 206 million pounds of toxic chemicals in waste were disposed of in RCRA Subtitle C facilities in 2000, which corresponds to approximately 2.9 percent of total TRI releases in 2000.⁴⁵ In addi-

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Exhibit 3-4: Total Toxics Release Inventory (TRI) releases across industry, 1998–2000



Source: EPA, Office of Environmental Information. 2000 Toxics Release Inventory (TRI) Public Data Release Report. May 2002.

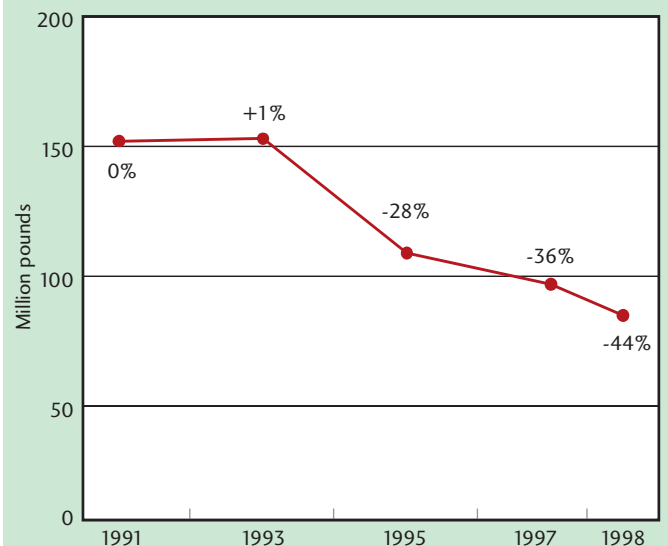
tion to the 7 billion pounds of toxic chemicals released in 2000, 31 billion pounds of toxic chemicals were managed and transferred for treatment (50 percent), recycling (39 percent), and burning for energy recovery (11 percent). The total amount of toxic chemicals managed and transferred between 1998 and 2000 increased by almost 29 percent, a net increase of 8.4 billion pounds.⁴⁶ For the past few years, EPA has tracked three metals—lead, mercury, and cadmium—and 27 organic chemicals, which were identified as the highest priorities for waste minimization. The Agency uses those waste minimization priority chemicals (WMPC) to measure the total weight of particularly toxic chemicals going to disposal. Trend data are available for 17 of the 30 WMPCs and show that releases of those 17 have been steadily declining since 1993 (Exhibit 3-5). Overall, between 1991 and 1998, there was a 44 percent reduction in WMPC quantities generated in industrial and hazardous waste.⁴⁷

Persistent bioaccumulative toxic (PBT) chemicals, including dioxins, lead, mercury, and PCBs, are tracked because they persist and accumulate in the environment. In 2000, PBTs represented 12.1 million pounds (less than 1 percent) of the released chemicals that TRI tracks.⁴⁸ Although they constitute a fraction of overall toxic releases, PBTs are significant even in small quantities, given the chronic risks they pose to ecosystems and humans through bioaccumulation.

What are the volume, distribution, and extent of pesticide and fertilizer use?

Pesticides are substances or mixtures used to destroy or repel various pests, including insects, animals, plants, and microorganisms. EPA's most recent *Pesticide Industry Sales and Usage* report shows that annual use of pesticides for all purposes

Exhibit 3-5: Trends in Toxics Release Inventory (TRI) waste minimization priority chemicals (WMPC), 1991-1998



Source: EPA, Office of Solid Waste and Emergency Response. *Waste Minimization Trends Report (1991 - 1998)*. September 2002.

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Chemicals in the Landscape

declined by about 15 percent between 1980 and 1999.⁴⁹ This decline has not been steady, with pesticide use higher in 1999 than it was in the early 1990s. Excluding chlorine used for disinfection, the largest use of pesticides is in agricultural production, and that use fluctuates, depending on a number of factors such as weather or type of crop. According to the National Center for Food and Agricultural Policy (NCFAP), a private, non-profit research organization, use of agricultural pesticides increased between 1992 and 1997 from 892 million to 985 million pounds.⁵⁰ The recent EPA report shows a similar increase in use of all pesticides in this same timeframe, with a leveling of use between 1997 and 1999.⁵¹

Approximately half of those pesticides are herbicides used to control weeds that limit or inhibit the growth of a desired crop. Pesticides are also used in smaller quantities in rights-of-way, businesses, and home lawns and gardens. Based on EPA's national pesticide sales estimates, industrial, commercial, and governmental pesticide applications—many of which occur in urban environments—totaled 148 million pounds in 1999. Home and garden pesticide use was estimated to be 140 million pounds.⁵²

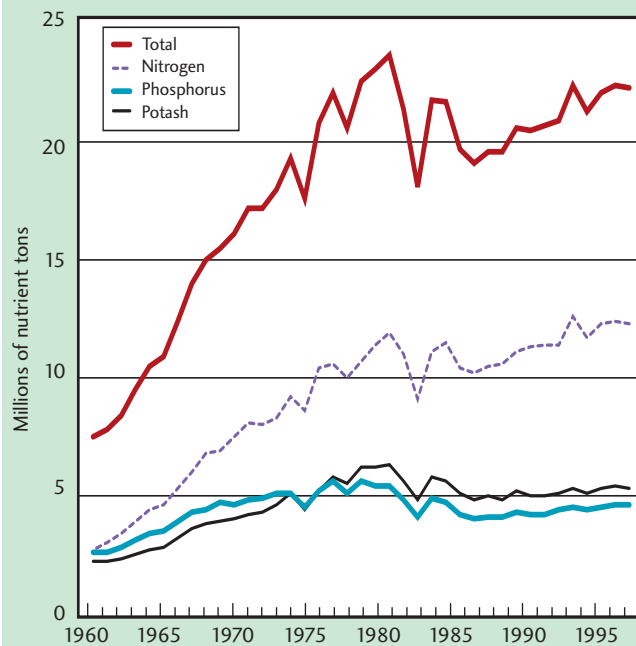
The use of insecticides, which as a class tend to be the pesticides most acutely toxic to humans and wildlife, significantly declined between 1997 and 2001. The number of individual chemical treatments per acre (acre-treatments) for insecticides labeled “danger for humans” decreased by 43 percent. In that same period, acre-treatments for insecticides labeled “extremely or highly toxic to birds” declined by 50 percent, and acre-treatments of those labeled “extremely or highly toxic to aquatic organisms” dropped by 23 percent.⁵³



The use of nitrogen, phosphorus, and potash, the most prevalent fertilizer supplements in commercial farming, rose from 7.5 million nutrient

tons (tons of a chemical nutrient in a fertilizer mixture) in 1961 to nearly 24 million nutrient tons in 1981. Exhibit 3-6 displays trends in the use of fertilizer over the past 40 years. Although aggregate use dipped in 1983, it increased most recently between 1996 and 1998 to more than 22 million nutrient tons.⁵⁴ Use of most major fertilizers is concentrated on croplands in the Midwest.⁵⁵ (Chapter 2 – Purer Water discusses some of the effects of fertilizer use on water quality.)

Exhibit 3-6: Use of fertilizer, 1960-1998



Source: Daberkow, S. et al. *Agricultural Resources and Environmental Indicators: Nutrient Use and Management*. February 2003.

What is the potential disposition of chemicals from land?

Chemicals and nutrients can move from their location of use or origin to a place in the environment where humans and other organisms can become exposed to them. People are exposed to chemicals in all aspects of their daily lives, through their clothing, use of everyday products, housing, automobiles, and buildings.

Pesticide residues on food are one way people can be exposed to pesticides. The U.S. Department of Agriculture's Pesticide Data Program (PDP) measures pesticide residue levels in fruits, vegetables, grains, meat, and dairy products from across the country, sampling different combinations of commodities each year. In 2000, PDP collected and analyzed a total of 10,907 samples: 8,912 fruits and vegetables, 178 rice, 716 peanut butter, and 1,101 poultry which originated from 38 States and 21 foreign countries. Approximately 80

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percent of all samples were domestic, 19 percent were imported, and less than 1 percent was of unknown origin.⁵⁶

The simple presence of detectable pesticide residues in foods should not be considered indicative of a potential health concern. The PDP uses analytical methods that are very sensitive and are capable of detecting extremely small (or “trace”) quantities of pesticides that are orders of magnitude lower than those raising potential health concerns. Overall, approximately 42 percent of all samples contained no detectable pesticide residues, 22 percent contained a detectable residue of a single pesticide, and 35 percent contained detectable amounts of two or more pesticides. Testing found that no more than 1.4 percent of samples exceeded regulatory limits (also known as “tolerance levels”). Residues exceeding the pesticide tolerance level established by EPA for that food were detected in only 0.2 percent of all composite samples. Residues of other pesticides for which no tolerance level had been set by EPA for that food were found in 1.2 percent of all samples. These residues were generally at low concentrations and may be due to spray drift, crop rotations, or cross contamination at packing facilities. USDA reports all such exceedances to the Food and Drug Administration for further investigation and any needed follow-up.⁵⁷

Pesticide and fertilizer runoff into surface and ground water can also expose humans and the environment to the effects of chemicals. Models that use data from the USDA NRI, the NCFAP, and other sources show that the highest potential for pesticide runoff is predominantly associated with the upper and lower Mississippi and Ohio River valleys.⁵⁸ Similarly, EPA has developed models based on land cover characteristics to assess the risk of nitrogen and phosphorus runoff into watersheds. Those studies also show that the areas with the highest risk for nitrogen and phosphorus runoff are concentrated in the midwestern states and other agricultural areas.⁵⁹ (See Chapter 5 – Ecological Condition for additional discussion of how nutrient runoff can affect the chemical characteristics of ecosystems.)



In addition to runoff, chemicals can enter land through pesticide “spray drift,” the physical movement of a pesticide through air at the time of application, or soon thereafter, to any site other than that intended for application. Both modeling and incident reports indicate that spray drift is a route of disposition.⁶⁰

What human health effects are associated with pesticides, fertilizers, and toxic substances?

Because they are designed to kill or harm living organisms, many pesticides pose some risk to humans, animals, and the environment. The risk of adverse health effects depends on how, where, how much, and how frequently pesticides are used; what happens after use; who is exposed; and how they are exposed. Human exposures to harmful levels of chemicals, such as organophosphates or organochlorine pesticides, can cause adverse neurological, developmental, and reproductive effects. A significant challenge lies, however, in correlating the existence of chemicals in the environment, either singly or in combination, with the health effects observed in a given population.

There are no nationwide pesticide surveillance systems to track exposure consistently, but several state and national pesticide surveillance systems do collect information on pesticide-related injuries and illness. Although those systems are not nationally comprehensive, their information provides a starting point for examining the health effects of pesticides.

Fertilizers are often applied in greater quantities than crops can absorb and end up in surface or ground water. Although fertilizers may not be inherently harmful, they can be linked to human health problems when excess nutrients cause algal blooms and eutrophication in waterbodies. Drinking ground water contaminated with runoff

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Chemicals in the Landscape

from some fertilizers can have severe or even fatal health effects, especially in infants and children (e.g., blue baby syndrome).⁶¹

The Toxic Exposure Surveillance System (TESS) contains information from poison control centers that report occurrences of pesticide-related injury and illness. One finding from TESS data is that organophosphates are much more likely to cause post application symptoms than are other types of pesticides. In addition, the data show that in 2001, more than 100,000 people were sufficiently concerned about their actual exposure to pesticides to call their local poison control center. Estimates are that approximately 19 percent of the people who called developed symptoms as a result of their pesticide exposure. These symptoms included abdominal pain, diarrhea, vomiting, rash, blurred vision, irritation to eyes or skin, headache, dizziness, coughing, and difficulty breathing. In addition, of the approximately 20,000 cases that were followed to determine medical outcome: 83 percent had a minor outcome, 15 percent had a moderate outcome (usually require treatment), and 1.5 percent had a major outcome (life-threatening symptoms or residual disability).⁶² Other studies of treated poisonings, not just from pesticides, have found that the poison control center data may capture only about 25 percent of all poisoning incidents.⁶³

Health effects from exposure to toxic chemicals range from short-term acute effects to long-term chronic effects such as cancer or asbestosis. For example, as discussed in Chapter 4 – Human Health, despite major success in reducing exposure to lead, many children remain at risk of neurological damage through lead poisoning—primarily from contact with lead-based paint chips and lead-containing dust in their homes. In addition, EPA, along with other state and federal agencies that are responsible for protecting public health, pays special attention to PBTs and persistent organic pollutants, which do not easily break down and thus tend to accumulate in humans

and other organisms. Such accumulation can lead to serious chronic health issues.⁶⁴

What ecological effects are associated with pesticides, fertilizers, and toxic substances?

A number of ecological effects of direct chemical exposure on individual species have been identified. Reproductive failure in birds, for example, has been linked to organochlorine insecticides such as DDT, which are still present in the environment from past applications in the United States, as well as from current use in other parts of the world. Many pesticides are toxic to a variety of fish, bird, plant, and insect species. As a result, use—and especially misuse—of pesticides can, where exposures are of sufficient magnitude, cause significant loss of non-target species. Eliminating or limiting those exposures may have a beneficial effect. For example, the resurgence of the bald eagle population is thought to be the result, at least in part, of bans on various chemicals.⁶⁵

Indirect environmental effects of pesticides and other chemicals on ecosystems are more complex and difficult to understand. As previously discussed, pesticides and nutrients run off from their point of application and are deposited in aquatic systems and sediments, where they may accumulate to levels that exceed water quality standards for specific chemicals. (The effects of runoff on the condition of aquatic systems are discussed in more detail in Chapter 2 – Purer Water.)

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Contaminant Levels and Bald Eagles in Michigan

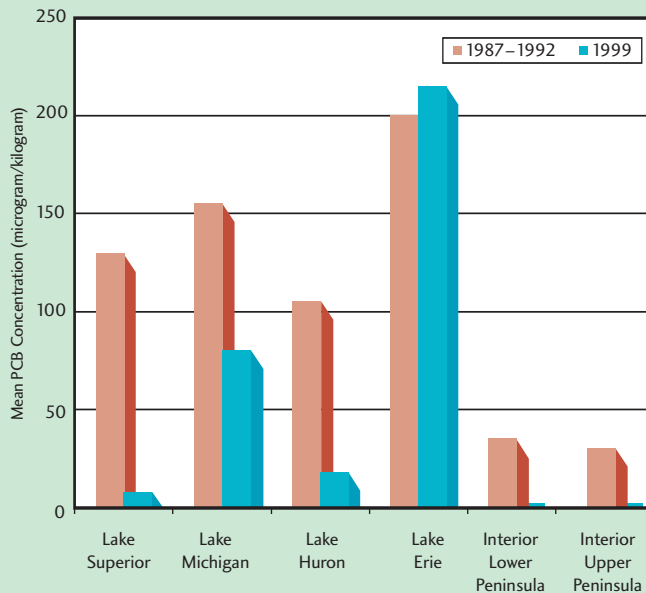
Bald eagles were significantly affected by contaminants in the environment in the early 1960s and 1970s. Now monitoring them can provide a gross indication of general contaminant levels in the environment. In 1999, a consortium of the Michigan Department of Environmental Quality, the U.S. Fish and Wildlife Service, and researchers from Michigan State University and Clemson University initiated a bald eagle contaminant-monitoring project. Ninety samples of blood and feathers were collected by non-lethal procedures from permanent inland nests, from nests in additional inland watersheds being assessed as part of the Michigan department's 5-year watershed assessment cycle, and from Great Lakes and connecting channel nests.

Exhibits 3-7 and 3-8 show changes in mean PCB levels and mean mercury levels, respectively, in bald eagles between the late 1980s and early 1990s, and in 1999. Specifically, PCB levels in the blood of bald eagles were dramatically lower in 1999 for inland nests and those in Lakes Superior, Michigan, and Huron. (Although Lake Erie did not show the same result, only one eagle was sampled there in 1999.) Similarly, mean mercury levels in bald eagle feathers declined in all geographic areas examined.

The Michigan Department of National Resources has also conducted an annual census of bald eagle nests in Michigan since 1961. The nests increased from 50 in 1961 to 366 in 2000. During that same time period, bald eagle productivity, as measured by the number of young fledged per nest, increased more than 50 percent.

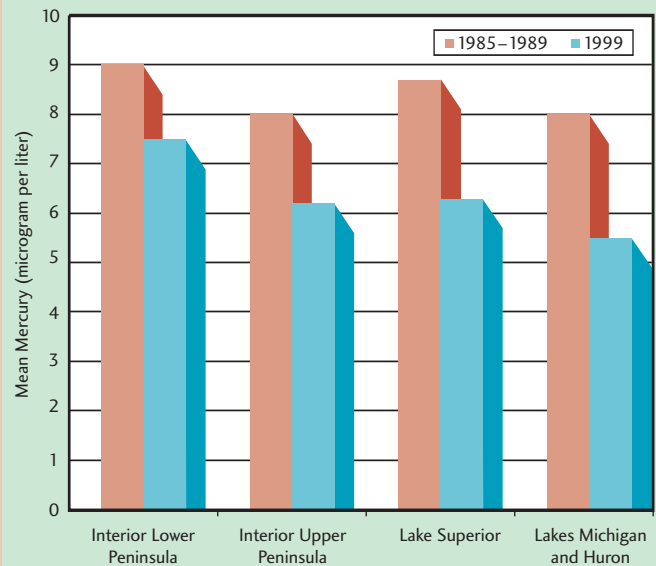
The contaminant and population measures demonstrate that levels of key environmental contaminants in bald eagles within the Great Lakes Region have declined through the 1990s, and that populations and productivity are increasing.⁶⁶

Exhibit 3-7: Mean polychlorinated biphenyls (PCB) concentrations in nesting bald eagle feathers, 1987-1992 and 1999



Source: Michigan Department of Environmental Quality, Office of Special Environmental Projects. *State of Michigan's Environment 2001: First Biennial Report*. 2001.

Exhibit 3-8: Mean mercury levels in nesting bald eagle feathers, 1985-1989 and 1999



Source: Michigan Department of Environmental Quality, Office of Special Environmental Projects. *State of Michigan's Environment 2001: First Biennial Report*. 2001.

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Waste and Contaminated Lands

“Waste” is broadly defined as unwanted material left over from manufacturing processes or refuse from places of human or animal habitation.

Within that category are many types of waste, including municipal solid waste, hazardous waste, and radioactive waste, which have properties that may make them dangerous or capable of having a harmful effect on human health and the environment.⁶⁷ Waste and contaminated lands are particularly important to environmental health because they may expose land and living organisms to harmful material if they are not properly managed.

There have been major improvements in managing the nation's waste and in cleaning up contaminated sites. National, state, tribal, and local waste programs and policies aim to prevent pollution by reducing the generation of wastes at their source and by emphasizing prevention over manage-

ment and subsequent disposal. Preventing pollution before it is generated and poses harm is often less costly than cleanup and remediation. Source reduction and recycling programs often can increase resource and energy efficiencies and thereby reduce pressures on the environment. When wastes are generated, EPA, state environmental programs, and local municipalities work to reduce the risk of exposures. If land is contaminated, cleanup programs address the sites to prevent human exposure and ground water contamination.

Increased recycling protects land resources and extends the life span of disposal facilities.

How much and what types of waste are generated and managed?

The types of waste generated range from yard clippings to highly concentrated hazardous waste. Only three types of waste—municipal solid waste (MSW), hazardous waste (as defined by the Resource Conservation and Recovery Act [RCRA]), and radioactive waste—are tracked with any consistency on a national basis. Other types of waste, for which no or very limited national data exist, are listed in the box, “Other Types of Waste,” and are described in detail in Appendix B.

MSW, commonly known as trash or garbage, is one of the nation's most prevalent waste types. In 2000, the U.S. generated approximately 232 million tons of MSW, primarily in homes and workplaces—an increase of nearly 160 percent since 1960.⁶⁸ During that time, the population increased 56 percent, and gross domestic product increased nearly 300 percent.⁶⁹ In 2000, each person generated approximately 4.5 pounds of waste per day—or about 0.8 tons for the year—a per-capita generation increase from 2.7 pounds per day in 1960.⁷⁰ For the last decade, per capita generation has remained relatively constant, and the amount of MSW recovered (recycled or composted) increased more than 1,100 percent, from 5.6 million to 69.9 million tons in total (Exhibit 3-9).⁷¹ Combustion (incineration) is also used to reduce the volume of waste before disposal. Approximately 33.7 million tons (14.5 percent) of MSW were combusted in 2000.⁷² Of that amount, approximately 2.3 million tons were combusted for energy recovery—a process where energy is produced from waste combustion and made available for other uses.⁷³



Waste and Contaminated Lands Indicators

Quantity of municipal solid waste (MSW) generated and managed

Quantity of RCRA hazardous waste generated and managed

Quantity of radioactive waste generated and in inventory

Number and location of municipal solid waste (MSW) landfills

Number of RCRA hazardous waste management facilities

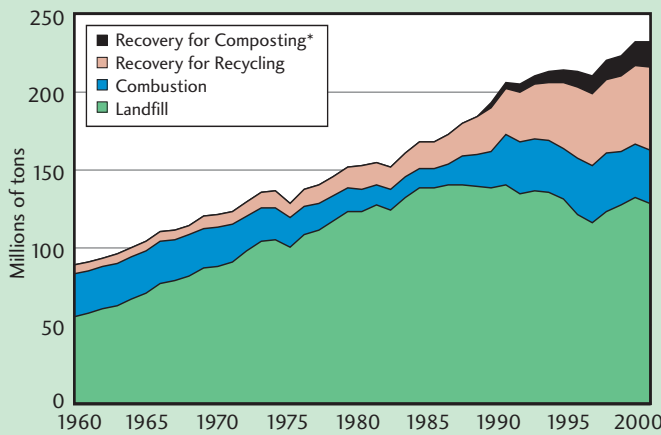
Number and location of Superfund national priority list sites

Number and location of RCRA corrective action sites

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Waste and Contaminated Lands

Exhibit 3-9: Municipal solid waste management, 1960-2000
(2000 total = 232 million tons)



*Composting of yard trimmings and food wastes. Does not include mixed MSW composting or backyard composting.

Source: EPA, Office of Solid Waste and Emergency Response. *Municipal Solid Waste in the United States: 2000 Facts and Figures*. June 2002.

The term “RCRA hazardous waste” applies to hazardous waste (waste that is ignitable, corrosive, reactive, or toxic) that is regulated under the RCRA. In 1999, EPA estimated that 20,000 businesses generating large quantities—more than 2,200 pounds each per month—of hazardous waste collectively generated 40 million tons of RCRA hazardous waste.⁷⁴ Comparisons of annual trends in hazardous waste generation are difficult because of changes in the types of data collected (e.g., exclusion of wastewater) over the past several years. But the amount of a specific set of priority toxic chemicals found in hazardous waste and tracked in the Toxics Release Inventory is declining, as previously discussed under “Chemicals in the Landscape.” In 1999, approximately 69 percent of the RCRA hazardous waste was dis-

Other Types of Waste

- Extraction wastes
- Industrial non-hazardous waste
- Household hazardous waste
- Agricultural waste
- Construction and demolition waste
- Medical waste
- Oil and gas waste
- Sludge

posed of on land by one of four disposal methods: deep well/underground injection, landfill disposal, surface impoundment, or land treatment/application/farming.⁷⁵

In 2000, approximately 600,000 cubic meters of different types of radioactive waste were generated, and approximately 700,000 cubic meters were in storage awaiting disposal.⁷⁶ By volume, the most prevalent types of radioactive waste are contaminated environmental media (i.e., soil, sediment, water, and sludge requiring cleanup or further assessment) and low-level waste. Both of these waste types typically have the lowest levels of radioactivity when measured by volume. Additional radioactive wastes in the form of spent nuclear fuel (2,467 metric tons of heavy metal) and high-level waste “glass logs” (1,201 canisters of vitrified high-level waste) are in storage awaiting long-term disposal.⁷⁷ Very small amounts of those wastes are still being generated. For example, less than 1 cubic meter of spent nuclear fuel was generated in 2000. The total amount of radioactive waste being generated is expected to drop over the next few decades as cleanup operations are completed.⁷⁸

As previously mentioned, other types of waste for which national data are not available or are not current are listed below and described in Appendix B. These other types of waste contribute a substantial amount to the total waste “universe,” although the exact percentage of the total that they represent is unknown.

What is the extent of land used for waste management?

Between 1989 and 2000, the number of municipal landfills in the U.S. decreased substantially—from 8,000 to 2,216.⁷⁹ The combined capacity of all landfills, however,

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remained relatively constant because newer landfills typically have larger capacities. In 2000, municipal landfills received approximately 128 million pounds of MSW, or about 55 percent of what was generated.⁸⁰ In addition to municipal landfills, the nation had 18,000 surface impoundments—ponds used to treat, store, or dispose of liquid waste—for non-hazardous industrial waste in 2000.⁸¹

Excluding wastewater, nearly 70 percent of the RCRA hazardous waste generated in 1999 was disposed of at one of the nation's RCRA treatment, storage, and land disposal facilities. Of the 1,575 RCRA facilities, 1,049 are storage-only facilities. The remaining facilities perform one or more of several common management methods (e.g., deepwell/underground injection, metals recovery, incineration, landfill disposal).⁸²

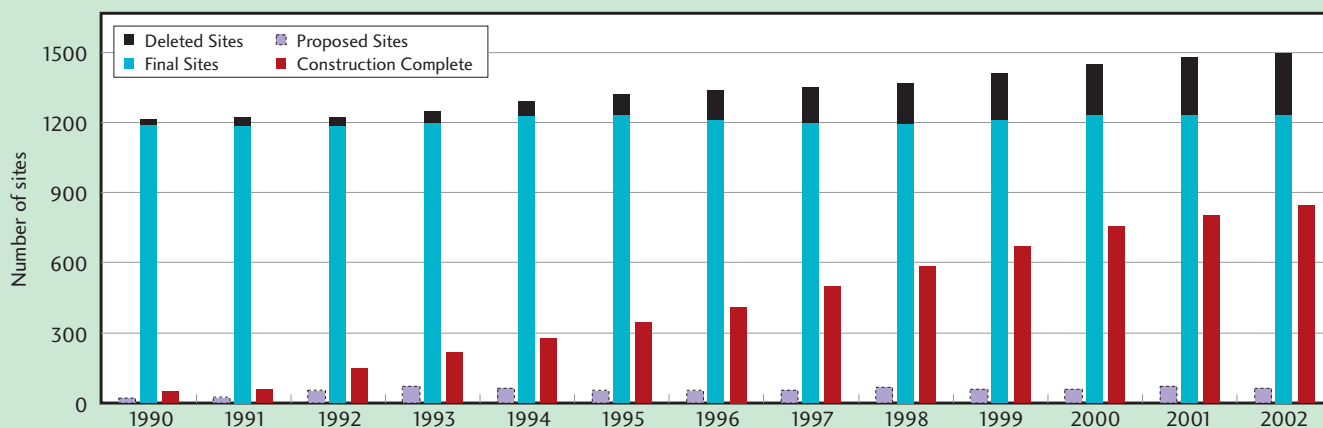
The nation also uses other sites for waste management and disposal, but there are no comprehensive data sets that assess those additional sites or the extent of land now used nationally for waste management in general. Before the 1970s, waste was not subjected to today's legal requirements to reduce toxicity before disposal and was typically disposed

of in open pits. Early land disposal units that still pose threats to human health and the environment are considered to be contaminated lands and are subject to federal or state cleanup efforts.

What is the extent of contaminated lands?

Many of the contaminated sites that must be managed and cleaned up today are the result of historical contamination. Located throughout the country, contaminated sites vary tremendously. Some sites involve small, non-toxic spills or single leaking tanks, whereas others involve large acreages of potential contamination such as abandoned mine sites. To address the contamination, federal and state programs use a variety of laws and regulations to initiate, implement, and enforce cleanup. The contaminated sites are generally classified according to applicable program authorities, such as RCRA Corrective Action, Superfund, and state cleanup programs.

Exhibit 3-10. Superfund National Priorities List (NPL) site totals by status and milestone, 1990-2002



Note: "Construction Complete" sites include most "Deleted" sites and some "Final" sites.

Source: EPA, Office of Solid Waste and Emergency Response. National Priorities List Site Totals by Status and Milestone. March 26, 2003. (April 3, 2003; <http://www.epa.gov/superfund/sites/query/queryhtm/npltotal.htm>) and Number of NPL Site Actions and Milestones by Fiscal Year. March 26, 2003. (April 3, 2003; <http://www.epa.gov/superfund/sites/query/queryhtm/nply/htm>).

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Although many states have data about contaminated sites within their boundaries, the total extent of contaminated land in the U.S. is unknown because few data are aggregated for the nation as a whole and acreage estimates are generally not available. A nationally accurate assessment would require both more detailed information on specific sites—such as the area of each site—and consistent aggregation of those data nationally. To assess the full nature of “extent” would require data on specific contaminants, as well as an assessment of risks, hazards, and potential for exposure to those contaminants.

Other Types of Contaminated Lands

- Leaking underground storage tanks
- Accidental spill sites
- Land contaminated with radioactive and other hazardous materials
- Brownfields
- Some military bases
- Waste management sites that were poorly designed or poorly managed
- Illegal dumping sites
- Abandoned mine lands

targeted for immediate action by federal, state, and local agencies.⁸⁵

Other types of contaminated lands, for which data are very limited, include areas contaminated by leaking underground storage tanks and brownfields. Brownfields are lands on which hazardous substances, pollutants, or contaminants may be or have been present. Brownfields are often found in and around economically depressed neighborhoods. Cleaning up and redeveloping these lands can benefit surrounding communities by reducing health and environmental risks, creating more functional space, and improving economic conditions.

The most toxic abandoned waste sites in the nation are listed on the Superfund National Priorities List (NPL) (Exhibit 3-10). Thus, examining the NPL data—along with data on RCRA corrective action sites—provides an indication of the extent of the most significantly contaminated sites. NPL sites are located in every state and several territories. As of October 2002, there were 1,498 final or deleted NPL sites.⁸³ An additional 62 sites were proposed to the NPL.⁸⁴ (When a “proposed” site meets the qualifications to be cleaned up under the Superfund Program, it becomes a final NPL site. Sites are considered for “deletion” from the NPL list when cleanup is complete.) Of the 1,498 sites, 846 sites are “construction completion sites,” which are former toxic waste sites where physical construction for all cleanup actions are complete, all immediate threats have been addressed, and all long-term threats are under control. This is up from 149 construction completes in 1992.

The other types of contaminated lands are listed here (see box) and described in more detail in Appendix B.

What human health effects are associated with waste management and contaminated lands?

People who live, work, or are otherwise near contaminated lands and waste management areas are more vulnerable than

EPA also estimates that approximately 3,700 hazardous waste management sites may be subject to RCRA corrective action, which would provide for investigation and cleanup and remediation of releases of hazardous waste and constituents. Contamination at the sites ranges from small spills that require soil cleanup to extensive contamination of soil, sediment, and ground water. In addition, 1,714 of these 3,700 potential corrective action sites are high-priority sites that are



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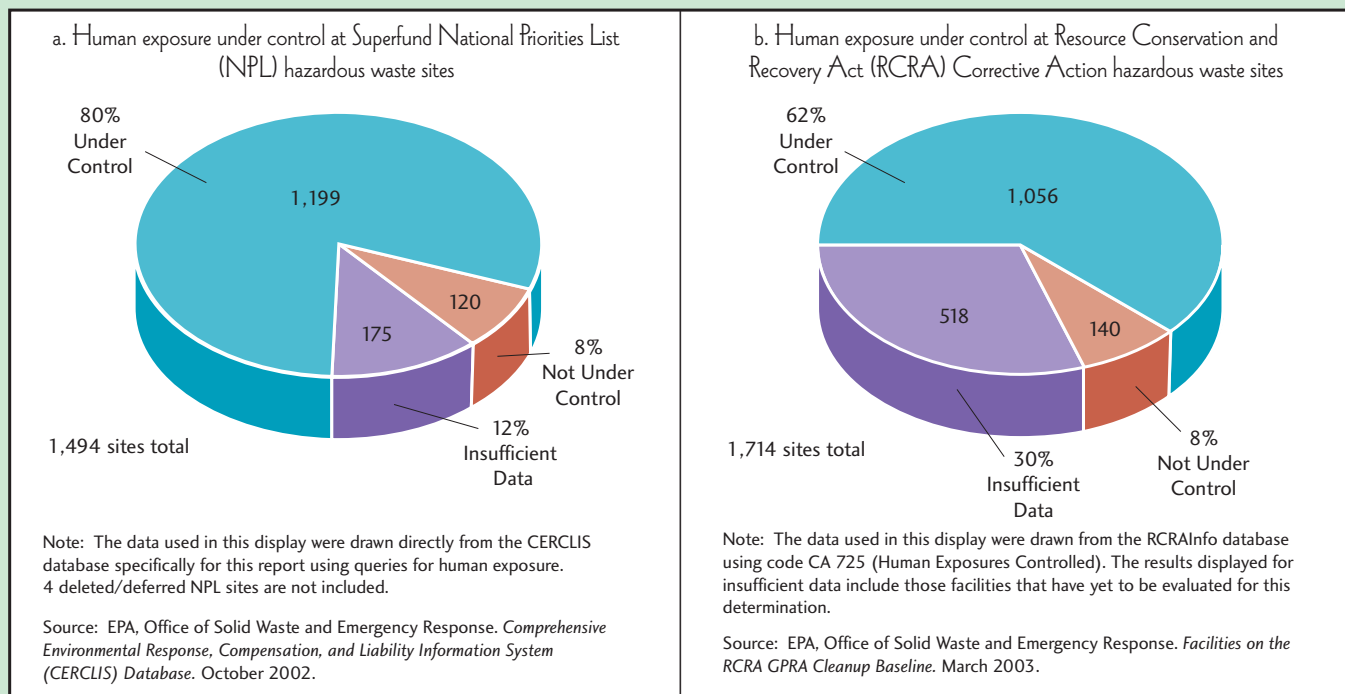
Human Exposures Under Control at Identified Contaminated Sites

Progress is being made to control the pathways by which humans are potentially exposed, under current conditions, to unacceptable levels of contaminants at Superfund and priority RCRA Corrective Action sites. In October 2002, 1,199 Superfund sites out of 1,494 Superfund sites were found to have human exposures under control (Exhibit 3-11 a).⁸⁶ As of March 2003, 1,056 of 1,714 RCRA Corrective Action sites were similarly found to have human exposures under control (Exhibit 3-11 b).⁸⁷ "Under control" indicates that EPA or state officials have determined that there are no unacceptable human exposures to contamination (present above appropriate risk-based levels) that can be reasonably expected under current land- and water-use conditions. Examples of risk-based levels used in these determinations include EPA- and/or varying state-promulgated standards, as well as other appropriate standards, guidelines, guidance, or criteria.

Government officials base a "Current Human Exposures Under Control" determination on site-specific characterization information, including chemical analyses of relevant environmental media (ground water, surface water, indoor and outdoor air, and soil), and on the potential ways people could be exposed to that contamination including inhalation, direct contact, or ingestion of the contaminated media or food impacted by contaminated media. In addition, examples of exposure control actions taken that could lead to an "under control" determination include implementing cleanups such as removing contaminated media, providing alternative water supplies, and implementing access and other land use controls and restrictions. These site-specific evaluations result in an EPA or state official determining that human exposures are either under control, not under control, or that there is insufficient information to make the determination.

It is important to note that the environmental measurements, human activity patterns, and actions taken to prevent exposure are the basis of these human exposures determinations. Biomonitoring or personal monitoring (see Chapter 4 – Human Health) is not typically used to make these determinations. Furthermore, EPA uses "Current Human Exposures Under Control" as a means to measure short-term protectiveness; additional cleanup actions (i.e., beyond those on which the "Current Human Exposures Under Control" is based) may be necessary as part of a final remedy designed to ensure long-term protection from reasonably expected future exposures.

Exhibit 3-II: Human exposure under control at identified hazardous waste sites



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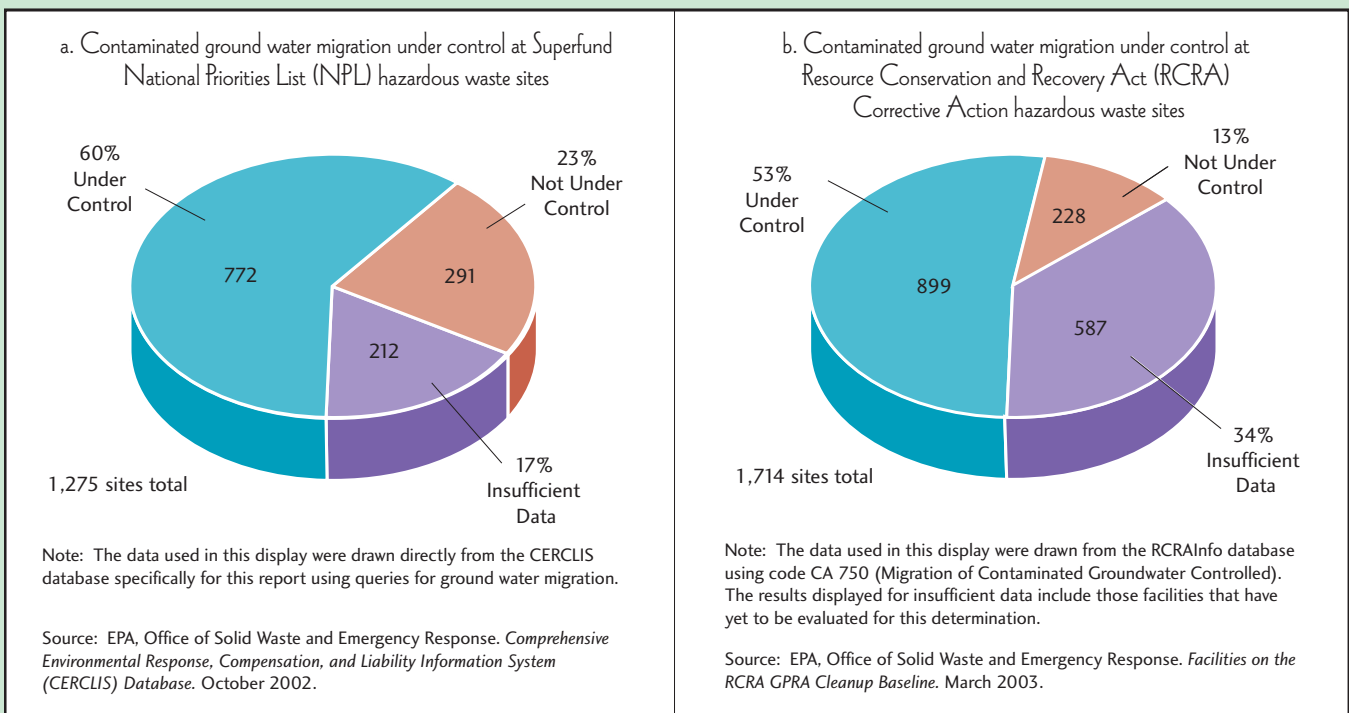
Migration of Contaminated Ground Water Under Control at Identified Contaminated Sites

Progress is being made to control the spread of contamination in ground water at Superfund and priority RCRA Corrective Action sites. As of October 2002, 772 out of 1,275 Superfund sites had ground water contamination under control (Exhibit 3-12a).⁸⁸ Similarly, as of March 2003, 899 of the 1,714 RCRA Corrective Action sites were under control (Exhibit 3-12b).⁸⁹ "Under control" means a plume of contaminated ground water is not spreading above appropriate risk-based levels, or is not adversely affecting surface water bodies into which contaminated ground water is discharging. Examples of risk-based levels used in these determinations include EPA- and/or varying state-promulgated standards, as well as other appropriate standards, guidelines, guidance, or criteria.

Government officials base a "Migration of Contaminated Ground Water Under Control" determination on site-specific characterization information and monitoring data pertaining to relevant environmental media (e.g., ground water and surface water where warranted). In addition, examples of actions taken that could lead to an "under control" determination include documenting the lack of plume growth in response to an engineered "pump and treat" or subsurface barrier system, or in response to natural attenuation processes (both of which would include ongoing monitoring). These site-specific evaluations result in an EPA or state official determining that the migration of contaminated ground water is under control, not under control, or that there is insufficient information to make the determination.

EPA is using the "Migration of Contaminated Ground Water Under Control" determination as a means of protecting ground water and surface water resources. As such, actual or potential human exposures to contaminants in ground water would be addressed in the "Current Human Exposures Under Control" determination. Furthermore, "Migration of Contaminated Ground Water Under Control" is a short-term cleanup goal; additional cleanup actions (i.e., beyond those on which this measure is based) may be necessary as part of a final remedy designed to ensure long-term protection of ground water resources.

Exhibit 3-12: Contaminated ground water migration under control at identified hazardous waste sites



others to the threats such areas might pose in the event of accident or unintended exposure to hazardous materials. Depending on factors such as management practices, the sources of contamination, and potential exposure, some waste, contaminated lands, and lands used for waste management pose a much greater risk to human health than others. Some areas, such as properly designed and managed waste management facilities, pose minimal risks.

Determining the relationship between types of sites and human health is usually extremely complicated. For many types of cancer, understanding is limited by science and the fact that people usually are exposed to many possible cancer-causing substances throughout their lives. Isolating the contributions of exposure to contaminants to incidence of respiratory illness, cancer, and birth defects is extremely difficult—impossible in many cases. Nonetheless, it is important to gain a more concrete understanding of how the hazardous materials associated with waste and contaminated lands affect human populations.

Although some types of potential contaminants and waste are not generally hazardous to humans, other types can pose dangers to health if people are exposed. The number of substances that exist that can or do affect human health is unknown; however, the TRI program requires reporting of more than 650 chemicals and chemical categories that are known to be toxic to humans.

EPA's Superfund Program has identified several sources of common contaminants, including commercial solvents, dry-cleaning agents, and chemicals. With chronic exposure, commercial solvents such as benzene may suppress bone marrow function, causing blood changes. Dry-cleaning agents and

degreasers contain trichloroethane and trichloroethylene, which can cause fatigue, depression of the central nervous system, kidney changes (e.g., swelling, anemia), and liver changes (e.g., enlargement).⁹⁰ Chemicals used in commercial and industrial manufacturing processes, such as arsenic, beryllium, cadmium, chromium, lead, and mercury, may cause various health problems. Long-term exposure to lead may cause permanent kidney and brain damage. Cadmium can cause kidney and lung disease. Chromium, beryllium, arsenic, and cadmium have been implicated as human carcinogens.⁹¹

What ecological effects are associated with waste management and contaminated lands?

Hazardous substances, whether present in waste, on lands used for waste management, or on contaminated land, can harm wildlife (e.g., cause major reproductive complications), destroy vegetation, contaminate air and water, and limit the ability of an ecosystem to survive. For example, if not properly managed, toxic residues left from mining operations can be blown into nearby areas, affecting resident bird populations and the water on which they depend. Certain hazardous substances also have the potential to explode or cause fires, threatening both wildlife and human populations.⁹²

The negative effects of land contamination and occasionally of waste management on ecosystems occur after contaminants have been released on land (soil/sediment) or into the air or water. For example, mining activities have affected aquatic life in Colorado's Eagle River, as described in box, "Cleanup of the Eagle Mine Superfund Site."

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Waste and Contaminated Lands



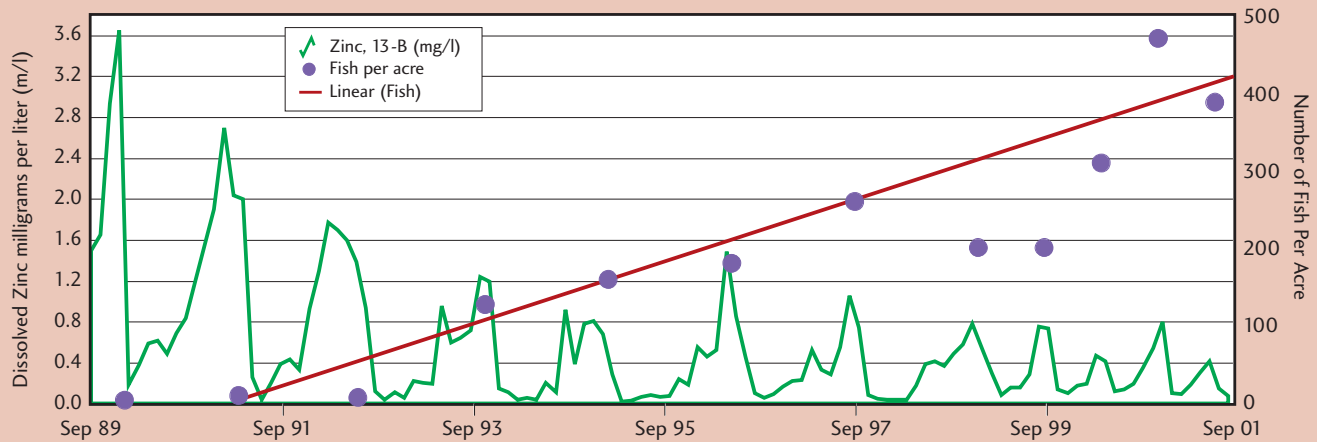
Cleanup of the Eagle Mine Superfund Site

The Eagle Mine, southwest of Vail, Colorado, was used to mine gold, silver, lead, zinc, and copper between 1870 and 1984. After the mine closed, several contaminants, including lead, zinc, cadmium, arsenic, and manganese, were left behind, and they spread into nearby ground water, the Eagle River, and the air, posing a risk to people and wildlife.

Colorado filed notice and claim in 1985 against the former mine owners for natural resource damages under Superfund. In June 1986, the site was placed on the National Priority List, and shortly thereafter the state and the previous owners agreed to a plan of action. Cleanup operations included constructing a water treatment plant to collect mine seepage and other contaminated water sources; relocating all processed mine wastes and contaminated soils to one main, on-site tailings pile; capping that pile with a multilayer clean soil cap; and revegetating all disturbed areas with native plant species.

The water quality in the Eagle River began to show improvements in 1991; as zinc concentrations in the river dropped, the resident brown trout population grew (Exhibit 3-13). An October 2000 site review concluded that public health risks had been removed and that significant progress had been made in restoring the Eagle River. Today, biological monitoring is undertaken to sample the Eagle River's water quality, aquatic insects, and fish populations.⁹³

Exhibit 3-13: Eagle mine zinc concentrations and brown trout populations downstream of the consolidated tailings pile



Note: Zinc concentrations fluctuate during the seasons according to water levels.

Source: Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division. Eagle Mine. February 5, 2003. (April 7, 2003; <http://www.cdph.state.co.us/hm/rpeagle.asp#SiteSummary>).

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Limitations of Land Indicators

Many sources of data support indicators that help to answer questions about the trends and effects of land use, chemicals in the landscape, and waste and contaminated land. But there are limitations in using the indicators to fully answer the questions.



Land Use

There are a number of gaps in information about land use and cover. Significantly varying estimates of developed land result from varying definitions and approaches to land use assessments. Statistical sampling and satellite remote sensing techniques vary in total estimates—and represent different sources of error. Data on some cover types and land uses are sparse or nonexistent, and inventories are seldom done on lands in Alaska. Numerous federal agencies conduct national inventories, but because they cover different land areas with different classifications and varying statistical sampling, integrating those data is challenging. Remotely sensed data are being used increasingly to estimate land cover but will probably need to be combined with other data sets to produce an accurate estimate of land uses. Additionally, remote sensing data from multiple years are not readily available for analysis of trends. Soil erosion information is collected by the NRI for croplands but does not exist nationally for forests or rangelands, particularly those under federal ownership.



Chemicals in the Landscape

No pesticide reporting system currently provides information on the volume, distribution, and extent of pesticide use nationwide across all sectors. Data used in this report are only estimates based on available information that includes crop profiles, pesticide sales, expert surveys, and sampling of stream and ground water. While no national reporting system exists, California has developed an

advanced system for full pesticide use reporting. Reports about the specifics of pesticide applications are filed by farmers, commercial applicators, structural pest control companies, and commercial landscaping firms.⁹⁴

The TRI program does not cover all releases of chemicals from all industrial facilities. For example, facilities that do not meet the TRI reporting requirements (those that have fewer than 10 full-time employees or do not meet TRI chemical-specific threshold amounts for reporting) are not required to report their releases. Some facilities conduct and report on actual monitoring data; others use estimation approaches, which are not consistent nationwide. New chemicals are being produced constantly, which poses challenges to EPA's efforts to monitor their potential interaction and effects.

Better information is needed on the chemistry, quantities, and longevity of various substances; on the cumulative effects of various chemicals on the environment and humans; and on the pathways and effects of exposure. More monitoring is required, along with more effective means to link ambient exposures to health and ecological effects. A more comprehensive and cohesive intergovernmental—federal, state, and local—reporting system that helps to link environmental and health data would be of great assistance.



Waste and Contaminated Lands

The data available nationally on total waste generated are not comprehensive; they exist as independent data sets maintained by different agencies and organizations. The data are gathered in various units (e.g., MSW in weight by pounds or tons, radioactive waste in volume by canisters). No easy method exists to convert weight to volume for understanding “extent.”

Some data are available on sites used for various types of waste management, but there is no broad assessment or

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national database of contaminated lands. National-level statistics on the total acreage of those lands, actual concentrations found in soils or waters around the sites, or health or ecological effects around the sites do not exist. Lack of those data creates challenges for addressing cleanup or redevelopment opportunities.

In lieu of national-level environmental indicators, activity measures of prevention, reduction of toxicity, and cleanup are used as indicators. Those measures take into account health and ecological outcomes. At this time, they are the best available indicators of environmental status and effects.



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Chapter 4 - Human Health





Introduction

Protecting the health of Americans from environmental pollutants has always been a key goal of EPA policies and programs. EPA has taken a number of actions to fulfill this goal, including establishing standards for pollutants in the environment, requiring sources to limit their pollution, and educating members of the public about actions they can take to protect their health. The indicators presented in Chapters 1 through 3 provide a measure of the progress that has been made in reducing environmental pollution in air, water, and land.

EPA is moving, where possible, to supplement the measures described in the earlier chapters with outcome indicators that could provide a clearer understanding of how environmental factors contribute to public health outcomes such as disease trends. Information on whether particular death and disease rates are going up or down, along with information on the various environmental and other factors that influence these trends, would strengthen environmental decision-making and evaluation. For example, this type of information could help EPA evaluate not only whether air quality has improved, but also whether rates of respiratory problems associated with air pollution have improved, and if not, why.

Developing these types of outcome measures is challenging for many reasons:

- Although numerous health problems have suspected links to environmental pollution, many factors in addition to the environment influence whether a person who comes in contact with a pollutant will ever show symptoms of exposure or develop disease. Those factors include the quantity and type of pollutant, the number of contacts with it, and a person's age, health, genetic make-up, and lifestyle.

- A pollutant's impact may range along a continuum from no effect to mild symptoms to serious acute or chronic impacts. Different people have different vulnerabilities, so some may experience effects at ambient pollutant levels while others may not.



- Researchers have had success elucidating the linkage between individual pollutants and health. In reality, however, people are more typically exposed to a number of pollutants. How pollutants interact, and how exposure to multiple pollutants affects health, is not well understood at present.

EPA is working to lay the foundation for developing effective measures for tracking progress in protecting human health from environmental pollution. These include measures of outcomes, such as diseases, as well as biomonitoring measures that can tell us, for example, how much of a certain pollutant has penetrated into and resides within our blood and tissue.

This chapter describes key elements that begin to establish a basis for developing and using environmental public health indicators:

- The chapter begins with an overview of the major trends and indicators for health and disease in the U.S.
- Next, the chapter examines the role of the environment in disease. Understanding the linkage between exposure and health effects is a critical foundation for the development and use of environmental public health indicators.

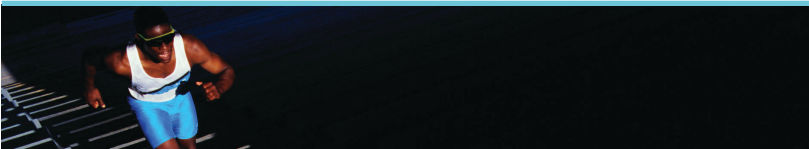


Chapter 4 - Human Health

Introduction

- Examples are presented that demonstrate this linkage and illustrate how environmental health indicators can strengthen environmental management decision-making and evaluation.
- Then, the chapter describes the approaches to measuring exposure to environmental pollution. A number of these approaches may provide the basis for environmental public health indicators in the future.
- Finally, the chapter concludes with a section on the scientific and data-gathering challenges that lie ahead in developing and using environmental public health indicators.

Changes in the health of a nation's people, both improvements and declines, can take years to detect, and EPA cannot develop this national overview alone. For example, nearly all of the health and exposure information currently available is collected by other federal and state agencies, such as the Centers for Disease Control and Prevention (CDC). Development and use of environmental public health indicators will require continued effective coordination and collaboration among federal and state agencies.



Health Status of the United States

There are several ways to assess the health of a specific group of people or an entire country's population that are used consistently across the world as indicators of health status. They include how long people can expect to live (life expectancy), how many infants die before their first birthday (infant mortality), the major causes of death, and the amount of illness in a national population. Among the most common measurements is the number of deaths caused by disease. The national death rate for a disease—especially if the numbers of early deaths (deaths before the average life expectancy) are high—can be a warning of health problems. This section presents an overview of health and major disease trends in the U.S. Some important diseases are presented that have a major impact on the health of Americans. It is important to note that environmental factors may not play a role in all diseases or causes of death presented in this section.

What are the trends and indicators for health and disease in the United States?

The overall health status of the U.S. today is generally good and improving. Over the past century, the nation has basically

conquered many infectious diseases that once sickened or killed thousands of people: childhood diseases such as measles and mumps, and waterborne ailments such as typhoid and cholera. Significant progress in improving sanitation and drinking water means that Americans are now relatively safe from the diarrheal diseases that imperil much of the world. Accidents are now the leading threat to children in the U.S., and most adults die from chronic illnesses rather than from infectious diseases (Exhibit 4-1). At the turn of the century, many people died from infectious diseases such as tuberculosis and influenza. Today more than 60 percent of all U.S. deaths are attrib-



Health Status of the United States: Selected Indicators

Life expectancy

Cancer mortality

Cancer incidence

Cardiovascular disease mortality

Cardiovascular disease prevalence

Chronic obstructive pulmonary disease mortality

Asthma mortality

Asthma prevalence

Cholera prevalence

Cryptosporidiosis prevalence

E. coli O157:H7 prevalence

Hepatitis A prevalence

Salmonellosis prevalence

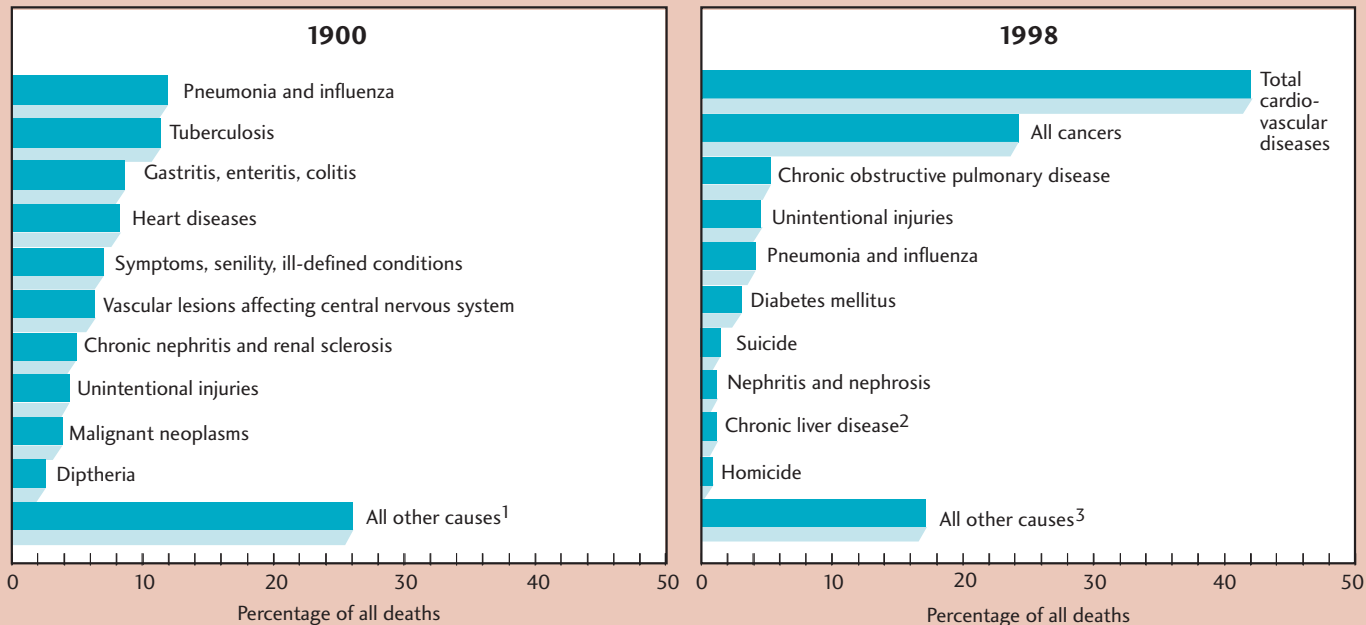
Typhoid fever prevalence

Shigellosis prevalence

Chapter 4 - Human Health

Health Status of the United States

Exhibit 4-1: Causes of death, United States, 1900 and 1998



¹Other causes may include typhoid fever, measles, homicide, suicide, syphilis, and diabetes.
²Includes cirrhosis.
³Other causes may include motor vehicle accidents, AIDS/HIV, septicemia, Alzheimer's disease, and Parkinson's disease.

Source: CDC, National Center for Chronic Disease Prevention and Health Promotion. *Unrealized Prevention Opportunities: Reducing the Health and Economic Burden of Chronic Disease*. November 2000. Data for 1990 from U. S. Bureau of the Census; data for 1998 from National Center for Health Statistics.

uted to cardiovascular diseases—those involving the heart and blood vessels—and cancer.¹

Infant mortality (death) and life expectancy are two key indicators of any nation's overall health (Exhibit 4-2). Infant mortality has dropped to the lowest level ever recorded in the U.S.,² but U.S. rates are still higher than those of other developed countries. In 1998, the U.S. ranked 28th out of 38 countries with available statistics for infant mortality.³

American life expectancy continues to improve. In the last century, life expectancy at birth increased from 51 to 79.4 years for women and from 48 to 73.9 years for men.⁴ However, Americans still have a somewhat lower life expectancy than those of other developed countries.⁵ In 1997, the U.S. ranked 19th for both males and females in life expectancy, compared with 30 other countries or geographic areas of at least 1 million people. (The U.S. numbers are within 2 years of the life expectancy of 13 and 14 other countries for females and males, respectively.)⁶

Because many infectious diseases are controlled and Americans are living longer, it is not surprising that chronic health problems, which are often associated with aging (e.g., heart disease, cancer, stroke, and lung disease), are among the leading causes of illness and death. Some conditions are wholly or partly the result of individual choices about smoking, diet, or exercise, but other health problems may also be associated with exposure to environmental pollutants.

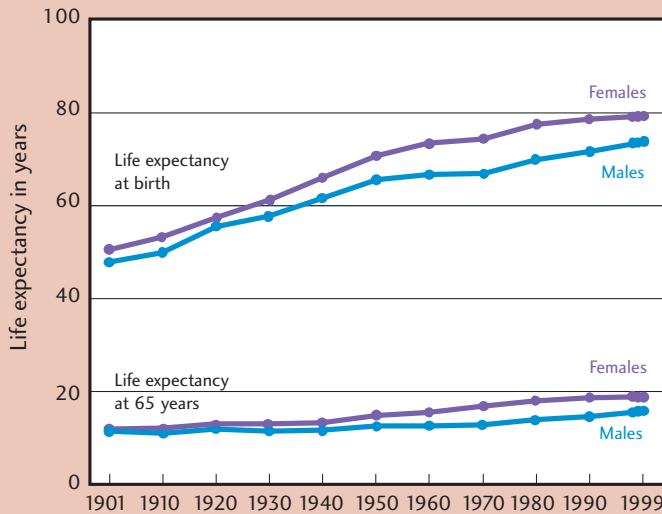
The trend data for the diseases presented in this section provide a valuable national overview of the U.S. population. Exhibit 4-3 summarizes the national trends for death rate (number of people dying per year), and incidence rate (number of people developing the disease per year) or prevalence (part of the population affected by a condition or disease). Exhibit 4-4 shows trends in death rates for people age 65 and older.

Chapter 4 - Human Health

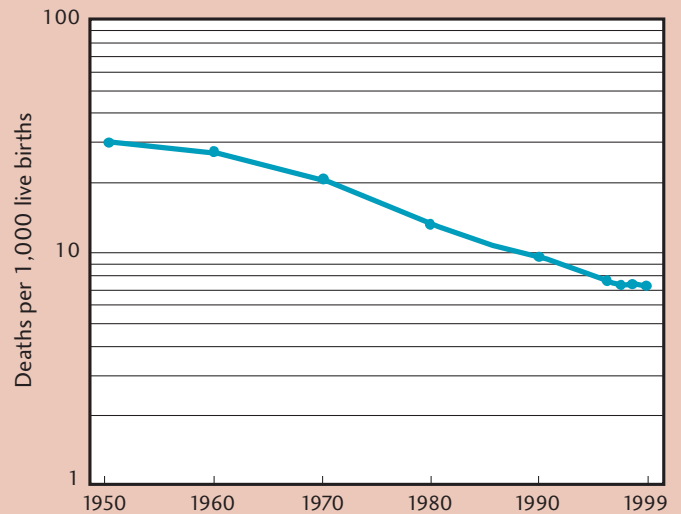
Health Status of the United States

Exhibit 4-2: Life expectancy and infant mortality in the United States

a. Life expectancy at birth and at 65 years of age by sex: United States, 1901-1999



b. Infant mortality rates: United States, 1950-1999



Note: Infant is defined as under 1 year of age.

Source: Pastor, R.N., et al. *Chartbook on Trends in the Health of Americans. Health, United States, 2002.* 2002.

Cancer

National cancer death rates declined overall during the 1990s,⁷ but cancer is still the second-leading cause of death in the U.S., and the number of people who develop cancer each year has actually increased since 1973.⁸ Although the overall death rates have dropped for some types—leukemia and breast, cervical, colorectal, stomach, and uterine cancers—the death rates for lung cancer and skin cancer, the most common type of cancer in the country, have increased.⁹ The number of people developing cancer shows the same mixed results for different subsets of the U.S. population. For example, lung cancer rates have declined for men but increased for women since 1973, and leukemia rates have declined among adults but not among children.¹⁰

Cardiovascular Disease

Cardiovascular diseases (CVD) are any that involve the heart and blood vessels. Examples are high blood pressure and hardening of the arteries, which can lead to heart attacks, strokes, and disability. Until age 65, more men than women

Health Data: Disease Mortality Versus Disease Morbidity

Disease mortality (death). This is an easy and reliable outcome to measure; reporting deaths is a legal requirement supported by a national collection system. A sudden increase in deaths due to identical causes in one geographic region can alert health officials to an environmental problem, such as a waterborne disease outbreak. But in completing death certificates, officials may not always be aware of underlying factors such as environmental exposure or genetic factors as potential causes of birth defects or death.

Disease morbidity (illness). Morbidity data—the number of people who have a particular illness—can be useful in linking current health conditions to possible environmental factors, in analyzing disease trends, and/or identifying factors that cause specific diseases or trends. For example, the decline in lung cancer in men has been related to the decline in smoking. But such data are not always available and are frequently reported without causal association. State and federal agencies may ask hospitals and clinics to report admitted cases of asthma, heart attacks, cancer, or other diseases, but such requests lack the force of law in many states. Full reporting in one geographic area may create the false impression of a hot spot for a certain disease, whereas poor or underreporting masks the incidence of disease nationwide.

Exhibit 4-3: Select disease trends

Disease	National Trend	
	Death Rate	Incidence*
Cancer (overall)	Decreasing (children ¹ and adults ²)**	Increasing (children ¹ and adults ³)*
Lung Cancer	Increasing ³	Increasing (F ³) Decreasing (M ³)
Skin Cancer (Melanoma)	Increasing ³	Increasing ³
Blood Cancer (Leukemia)	Decreasing (adults ³)	Increasing (children ¹) Decreasing (adults ³)
Cardiovascular Diseases (CVD) (Heart Disease)	Decreasing ⁴	Not reported
Respiratory/Lung Diseases Chronic Obstructive Pulmonary Disease (COPD), including chronic bronchitis and emphysema	Increasing ⁵	Not reported
Disease	Death Rate	Prevalence***
Asthma	Increasing ⁶ (children and adults)	Prevalence Increasing ⁶ (children) Prevalence Decreasing ⁷ (adults)

¹ 1975-1998 ² 1990-1998 ³ 1973-1998 ⁴ 1950-1998 ⁵ 1980-1998
⁶ 1980-2001 ⁷ 1997-1999

F=Females; M=Males

*Incidence trend is reported, unless specified otherwise. Incidence is the number of new cases of a disease in a given time period.

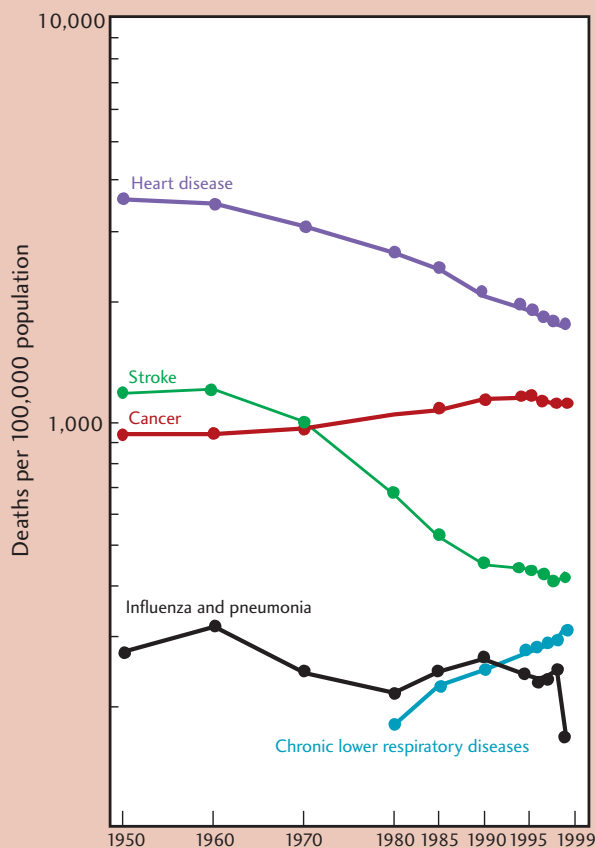
**Rates for specific cancers may vary from these trends.

***Prevalence is the part of the total population affected by a condition or disease.

Note: Environmental pollutants may be only one small contributor to health effect trends.

Sources: NIH, National Cancer Institute, Surveillance, Epidemiology, and End Results (SEER) Program, 1973-1998; CDC, National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS), 1950-1998; CDC, NCHS National Health and Interview Surveys, 1980-2001.

Exhibit 4-4: U. S. death rates due to leading causes of death among persons 65 years of age and over, 1950-1999



Note: Causes of death shown are the five leading causes of death among persons 65 years of age and over in 1999. Data are plotted on the log scale.

Source: Pastor, R.N., et al. *Chartbook on Trends in the Health of Americans. Health, United States, 2002.* 2002.

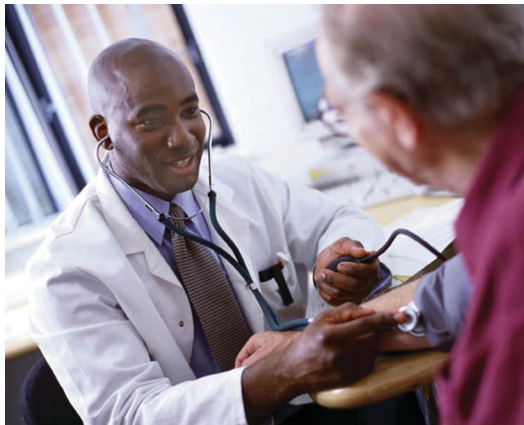
Chapter 4 - Human Health

Health Status of the United States

have CVD, but after that age, the percentages are the same for women and men. After age 74, a higher percentage of women than men have CVD. The overall mortality trend for CVD has declined dramatically since the 1950s (Exhibit 4-4). Advances in the prevention and treatment of heart disease and stroke rank among the major public health achievements of the 20th century.¹¹ Heart disease remains the leading cause of death in the U.S., and stroke is third.

Respiratory and Lung Diseases

Chronic obstructive pulmonary disease (COPD) encompasses a group of health conditions such as obstructed airflow and breathing-related symptoms. Chronic bronchitis and emphysema, for example, are classified as COPD. In 1999, COPD was the fourth-leading cause of death in the U.S.¹² Between 1980 and 1998, death rates for COPD increased for all racial and ethnic groups in the nation, reflecting in large part the effects of cigarette smoke.^{13,14} Death rates for males began to decline slightly between 1993 and 1998; by contrast, death rates for females have steadily increased since 1980.¹⁵ Mortality data may not give a complete picture of the environmental impact of the disease, because many people with COPD have progressive disability, not immediate death.



Asthma

Asthma is a disorder of the respiratory system characterized by labored breathing, wheezing, cough, and pain or tightness in the chest. It is a common chronic disease in children, and in adults it is more common in females and African Americans. Although the number of adults with asthma has declined slightly since 1997, childhood asthma is on the rise.¹⁶ Asthma death rates for adults have also increased since 1980. The groups that have the highest incidence, women and African Americans, also have the highest death rates.¹⁷ The prevalence of asthma shows regional differences; it is highest in the Northeast and lowest in the South. In addition, in a 1996 survey, people who lived in a central city reported a higher percentage of asthma cases than those who lived elsewhere.¹⁸

Asthma is believed to have a genetic component, but airborne allergens and irritants in the home, workplace, and community can aggravate the disease and trigger attacks.

Gastrointestinal Illnesses

The gastrointestinal tract includes the mouth, esophagus, stomach, small intestine, and the large intestine. Gastrointestinal infections and illnesses are caused by several types of microorganisms (bacteria, viruses, and parasites). The Notifiable Disease Program has recommended seven gastrointestinal illnesses caused by microorganisms for reporting: cholera, cryptosporidiosis, *E. coli* O157: H7, hepatitis A, salmonellosis, shigellosis, and typhoid fever. These seven illnesses are indicators of gastrointestinal illness prevalence. They can cause vomiting, diarrhea, fever, and dehydration, and they

are transmitted primarily by water or food contaminated with feces or by personal contact with an infected person or animal. Untreated human sewage and runoff, especially when it contains animal wastes, are sources of contamination. Cholera and typhoid fever rarely occur in the U.S. but are included because they can be severe illnesses and because a sudden increase in reported cases could flag a public health problem. The number of deaths attributed to microorganism-

induced gastrointestinal illnesses recently increased in the U.S., after decades of relatively stable death rates.¹⁹ The increases were particularly dramatic in young children (less than 6 years of age) and older Americans (more than 65 years of age). Many cases of gastrointestinal illnesses go unreported or are not diagnosed, making it difficult to estimate the number of people affected every year.^{20,21} Often, depending on the severity of symptoms, an infected person may not visit a doctor or hospital, which further contributes to the underestimation of gastrointestinal illness.

What are the trends for children's environmental health issues?

Important environmental health issues for children include infant mortality, low birth weight, childhood cancer, childhood asthma, and birth defects. Since 1950, infant mortality has steadily declined in the United States. Disorders related to premature birth or low birthweight are the second-leading cause of infant death, after birth defects. The number of low birthweight infants born each year increased between 1991 and 2000, with the greatest increase for white infants.²² Despite that increase, rates of infant mortality and low birthweight for African American infants are more than twice those for white infants.²³

Death rates for childhood cancer have declined since 1975, largely because of improved treatment.²⁴ During the same period, however, the number of children who develop cancer each year has risen. Leukemia, lymphoma, and central nervous system cancers are the most prevalent types of childhood cancer.²⁵ In 1999, cancers were the second-leading cause of death for children between 5 and 9 years of age and the



Why Children May Be Especially Vulnerable to Some Environmental Pollutants

- Children's nervous, immune, digestive, and other systems are still developing, which may reduce their natural protection and ability to process or inactivate some pollutants.
- Children eat more food, drink more fluids, and breathe more air in proportion to their body weight than adults, and they have a more rapid metabolism, which can increase their exposure to some pollutants, but can also reduce exposure to other pollutants.
- Children's behaviors, such as crawling and placing their hands and objects in their mouths, may allow more pollutants to enter their bodies.

third-leading cause of death for children between 1 and 4 years of age.²⁶

Identified asthma prevalence in children has increased since 1980, especially for children age 4 and younger and for African American children (Exhibit 4-5).²⁷ In 2001, approximately 6 million—or 9 percent—of U.S. children less than 18 years old had asthma, compared to approximately 3.6 percent of children in 1980.²⁸ The number of children ever diagnosed with asthma by a health professional—

referred to as asthma lifetime diagnosis—has also increased slightly since 1999. However, the number of children having asthma attacks seems to have leveled off since 1997.²⁹

Researchers do not understand completely why children develop asthma or why asthma prevalence has increased in the past two decades. The tendency to develop asthma can be inherited, and several factors may trigger acute asthma attacks, such as dander from dogs and cats, house dust mites (microscopic animals living in indoor house dust), cockroach allergens, and pollen.^{30,31} Researchers also believe that air pollutants such as environmental tobacco smoke (ETS), particulate matter, and ozone may increase the severity or frequency of asthma attacks in children who have the disease.^{32,33,34}

It is important to note that air quality has generally improved during the time that asthma prevalence in children has increased. For example, over the past 20 years, levels of criteria pollutants (including ozone and particulate matter) have decreased. Also, children's exposure to ETS has declined since the 1980s, as evidenced by a national decline in children's blood cotinine levels, an indicator that measures exposure to ETS. While on the surface, this appears to suggest



Children's Environmental Health: Selected Indicators

Infant mortality

Low birthweight incidence

Childhood cancer mortality

Childhood cancer incidence

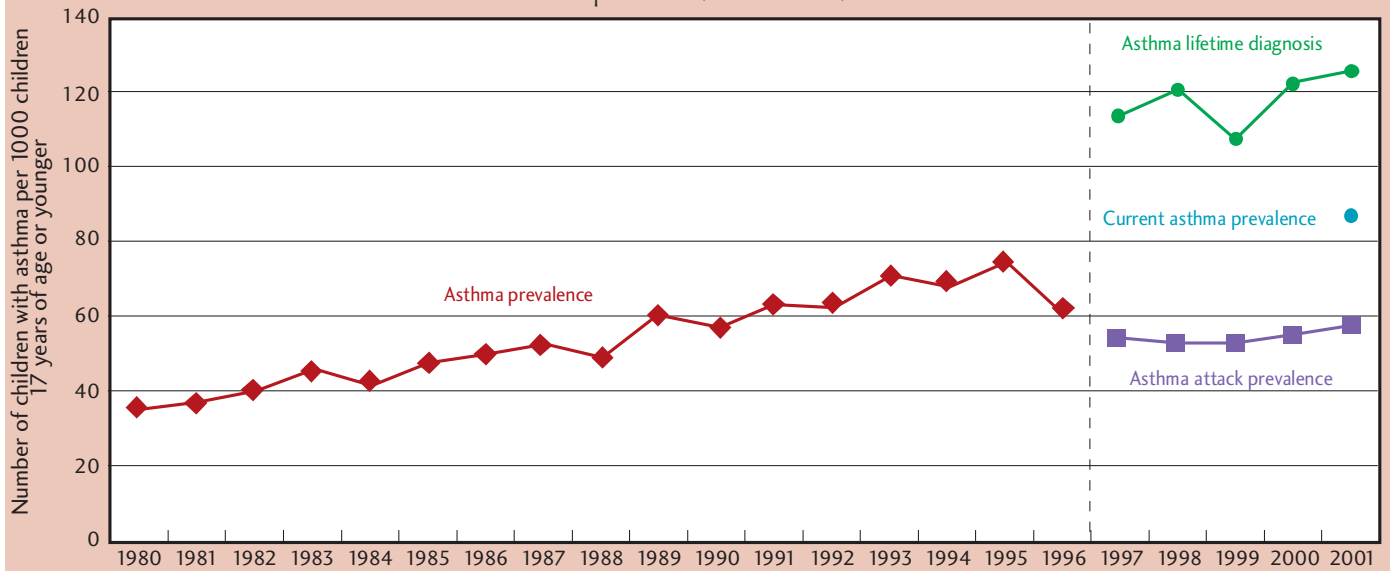
Childhood asthma mortality

Childhood asthma prevalence

Deaths due to birth defects

Birth defect incidence

Exhibit 4-5: Asthma prevalence, 1980-1996, asthma lifetime diagnosis, current asthma, and asthma attack prevalence, 1997-2001, in children



Note: The survey questions for asthma changed in 1997; data before 1997 cannot be directly compared to data in 1997 and later.

Source: Based on and updated from Akinbami, L.J. and K.C. Schoendorf. *Trends in Childhood Asthma: Prevalence, Health Care Utilization and Mortality*. 2002. Data from CDC, National Center for Health Statistics, National Health Interview Surveys, 1980-2001.

that air pollution is not related to the incidence or prevalence of asthma, there are too many complexities and uncertainties to draw this conclusion. For example, although air quality has improved at a national level, areas such as inner cities, where there is a higher prevalence of asthma, continue to experience intermittent exposure to poorer air quality, which may contribute to asthma prevalence. It is also possible that other environmental factors may make children more sensitive to air pollution; increased sensitivity could cause asthma rates to rise even as ambient air quality improves. For example, indoor air pollutants that are not monitored at a national level may trigger asthma attacks (in addition to tobacco smoke, which is monitored, as discussed previously).



Birth defects are the leading cause of infant mortality, accounting for almost 20 percent of all such deaths in 1999.³⁵ Defects that occur most often are those that affect the heart and lungs. A large number of birth defects may be due to genetic factors. It is unclear at this time what role environmental pollutants have in developing birth defects, but some studies suggest possible environmental links. Because some birth defects are not recognized immediately, they are underreported on birth and death certificates, and the overall problem may be underestimated.^{36,37} Also, many serious birth defects are not evident until later in life—an additional factor in underreporting.



Environmental Pollution and Disease

Many studies in people have demonstrated an association between environmental exposure and certain diseases or other health problems. Examples include radon and lung cancer; arsenic and cancer in several organs; lead and nervous system disorders; disease-causing bacteria such as *E. coli* O157: H7 (e.g., in contaminated meat and water) and gastrointestinal illness and death; and particulate matter and aggravation of heart and respiratory diseases.

To understand the relationship between health and the environment, scientists study a series of events that begins with the release of a pollutant into the environment and may end with the development of disease in a person or a population. Exhibit 4-6 broadly illustrates these events: (1) release of pollution into the environment (air, water, food, soil, and dust), (2) exposure through a variety of activities (inhalation, skin contact, and ingestion of contaminated media), and (3) the development of disease or other health problems.



What is the role of the environment in disease?

Decades of research have provided the scientific foundation for understanding the role of the environment in disease. For many pollutants, scientists know with some certainty that exposure to these pollutants, at sufficiently high concentrations, can cause a variety of health effects. For other pollutants, where scientific evidence is less conclusive, scientists can only establish an “association” between exposure and health problems.

Some effects on health may be short-term and reversible, such as irritated eyes from smog. Other effects, such as emphysema, heart disease, and cancer are chronic or even fatal. Some effects may appear shortly after exposure. Others, such as cancer, may require a long lead time before the disease appears.

Elucidating the linkage between environmental pollution and disease is challenging. We understand this linkage fairly well for some pollutants, such as those listed above, but poorly for others. This section describes some of the challenges to elucidating those linkages, and uses examples to highlight the role that indicators can play in strengthening our understanding of that linkage and in supporting environmental management efforts.

Environmental Pollution and Disease: Selected Indicators

- Blood lead level*
- Cardiovascular disease mortality*
- Chronic obstructive pulmonary disease mortality*
- Cholera prevalence*
- Typhoid fever prevalence*

In many cases, pollution likely is just one of several factors—including diet, exercise, alcohol consumption, and genetic make-up—that influence whether an exposed person will ever become sick. Although exposure to ETS is associated with lung cancer, whether a person will develop cancer from that exposure depends on the amount, frequency, and length of exposure, exposure to other contaminants, and personal characteristics (genes) and behavior (diet and other lifestyle choices).³⁸ All these factors can be important in illness and premature death, but they are poorly understood, difficult to quantify, and not routinely tracked or reported. Because of these complexities, it is very difficult to establish causal relationships, and few diseases are known to be exclusively the result of exposure to an environmental pollutant. In many cases, only a small portion of the national incidence of a particular disease is likely to be attributed to a specific environmental factor.

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Environmental Pollution and Disease

Exhibit 4-6: Pathway from pollution to exposure to potential health effects



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Environmental Pollution and Disease

Further complicating the picture is the fact that several segments of the population may be at higher risk for damage or disease from environmental pollutants. Potentially sensitive groups include children; older Americans; people with existing health problems such as diabetes, respiratory disease, or heart disease; and persons with compromised immune systems, including those who have HIV/AIDS or are undergoing cancer chemotherapy. Poor or other disadvantaged populations may live in more polluted environments that expose them to higher concentrations of pollutants. Understanding the impacts of pollutants on such sensitive groups is important for those people directly, as well as for the development of protective national health standards and policies.

Children may be more vulnerable to some environmental pollutants than adults for a number of reasons related to their size, growth, and behaviors. Further, children may become ill from exposures that would not affect adults.

Older Americans may also be especially vulnerable to harmful health effects associated with environmental pollutants, in part because some health problems take many years to develop. A long life span may provide the time needed for occupational or cumulative environmental exposures to induce illness or disease. Also, because of medical advances, many older Americans may be living with health conditions that previously shortened life spans. And, older Americans may have pre-existing conditions—such as heart ailments, diabetes, or respiratory disease—that reduce their tolerance to pollutants. Even relatively healthy older people may, merely as a result of age, have a diminished capacity to fight infections, pollution, or other causes of stress to their systems that might have posed little risk when they were younger. Harmful substances may be processed and eliminated from the body more slowly in older people, which can prolong exposure to those substances and increase susceptibility to associated health problems. Older people are also more likely to become dehydrated and experience other serious consequences of gastrointestinal disease.

Sorting out the role of all these risk factors—including the environment—and their interactions is a major challenge of scientific research. In addition to the tools already available for elucidating the linkage between environmental exposure and disease, EPA is exploring the use of indicators to complement the traditional tools—exposure assessment, toxicology, and human studies—that are used to evaluate the potential

impacts of environmental exposures. Three examples are presented below that illustrate how indicators can play a role in elucidating linkages between environmental pollution and health problems. In two of these examples (lead and water-borne diseases), indicators also play a key role in focusing the environmental protection decision and in evaluating the success of those decisions.

Health Effects of Exposure to Lead

Lead, a naturally occurring metal, has been used to produce gasoline, ceramic products, paints, and solder. In homes built before 1978, lead-based paint and lead-contaminated dust from paint are the primary sources of exposure to lead. Major initiatives have been implemented to reduce lead exposure by phasing lead out of gasoline, paint, solder, and plumbing fixtures.

Health problems from lead exposure are a major environmental health problem because exposure to lead is widespread and can cause health effects at relatively low levels. Substantial data are available to link lead exposure with health effects. Lead adversely affects the nervous system, can lower intelligence, and has been associated with behavioral and attention problems. It also affects the kidney and blood-forming organs.³⁹ Children and the developing fetus are more vulnerable to the effects of lead than adults.

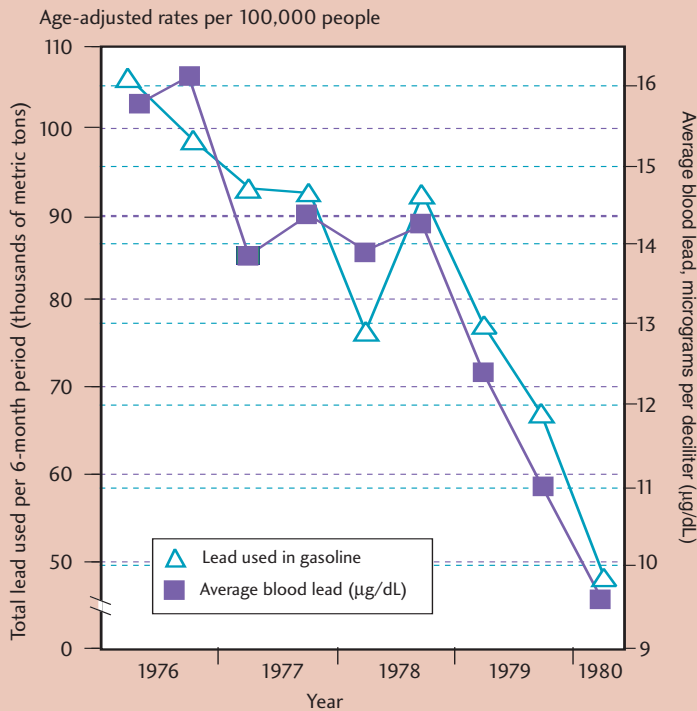
The level of lead in blood has long been used as an indicator of exposure to lead. And, because the linkage between lead exposure and health effects is so strong, blood lead is also used as an indicator of adverse effects on the nervous system.

In the 1970s, lead poisoning occurred increasingly in children who did not live in dwellings with lead-based paint, suggesting that another source or sources of lead exposure were of even greater concern than lead paint. Research found that combustion of leaded gasoline was the primary source of lead in the environment. In the 1970s, EPA promulgated regulations to ban lead in gasoline. Since that time, concentrations of lead in blood samples and in ambient air have declined significantly (Exhibit 4-7). In young children, the median concentration of lead in blood decreased by 85 percent from 1976 to 1999–2000 based on nationwide surveys (Exhibit 4-8).⁴⁰

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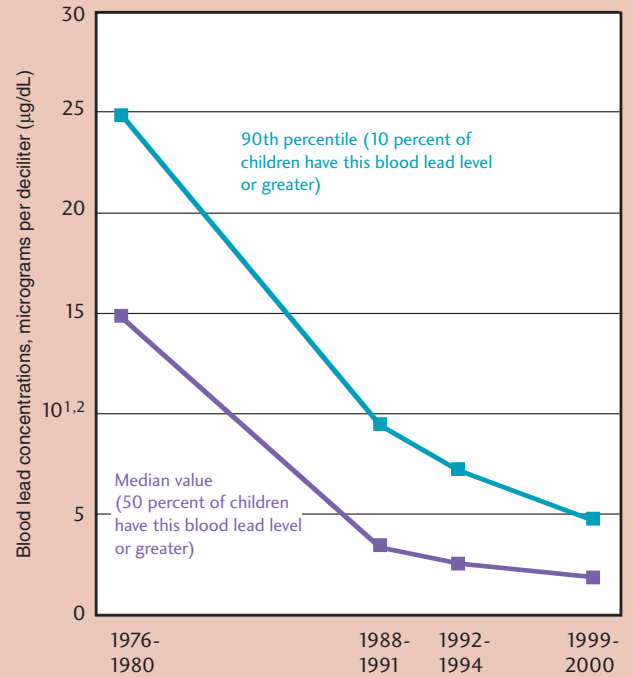
Environmental Pollution and Disease

Exhibit 4-7: Lead used in gasoline production and National Health and Nutrition Examination Survey (NHANES) blood lead averages, 1976-1980



Source: National Research Council. *Measuring Lead Exposures in Infants, Children and Other Sensitive Subpopulations*. 1993.

Exhibit 4-8: Concentration of lead in blood of children age 5 and under, 1976-1980, 1988-1991, 1992-1994, 1999-2000



¹ 10 µg/dL of blood lead has been identified by CDC as elevated, which indicates the need for intervention. (CDC. *Preventing Lead Poisoning in Young Children*. 1991.)

² Recent research suggests that blood levels less than 10 µg/dL may still produce subtle, subclinical health effects in children. (Schmidt, C.W. *Poisoning Young Minds*. 1999.)

Source: EPA. *America's Children and the Environment-Measures of Contaminants, Body Burdens, and Illnesses, Second Edition*. February 2003. Data from CDC, National Center for Health Statistics, National Health and Nutrition Examination Survey, 1976-2000.

But national averages of blood levels tell only part of the story. Between 1999 and 2000, approximately 430,000 children ages 1 to 5 (about 2 percent) had elevated blood lead levels (10 µg/dL or greater) from eating paint chips or inhaling lead-containing dust in older homes, primarily in urban areas.⁴¹ Even today, lead poisoning is considered to be a serious environmental hazard in young children in the U.S.⁴² Several major metropolitan areas, including Chicago, Detroit, Milwaukee, Palo Alto, and St. Louis, are evaluating blood lead levels of young children, focusing on areas at high risk (i.e., older housing and poorer neighborhoods), to study and address potential problems (see box, "Children's Lead Levels Remain a Concern in Urban Hot Spots"). These blood lead

screening programs, however, do not report in a systematic fashion to a central location where the data can be evaluated.

Health Effects of Air Pollution

Several outdoor air pollutants are associated with harmful health effects. These include the six "criteria" pollutants—particulate matter, ground-level ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead—for which EPA has established standards to protect human health, including the health of sensitive populations such as asthmatics, children, and the elderly. The burning of fossil fuels is the principal

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source of these pollutants. Air pollutants can be transported long distances, so they can potentially have effects distant from their source. (See Chapter 1 – Cleaner Air, for further discussion of the health effects related to air pollutants.)

Air pollution has been associated with several health problems, including reported symptoms (nose and throat irritation), acute onset or exacerbation of existing disease (e.g., asthma, hospitalizations due to cardiovascular disease), and premature deaths. The impact of air pollution on health was underscored in December 1952 when a slow-moving area of high pressure came to a halt over the city of London. Fog developed over the city, and particulate and sulfur pollution began accumulating in the stagnating air mass. Smoke and sulfur dioxide concentrations built up over 3 days. Mortality records showed that deaths increased in a pattern very similar to that of the pollution measurements. An estimated 4,000

extra deaths occurred over a 3- to 4-day period. This represents the first quantitative air pollution exposure data with a link to health.

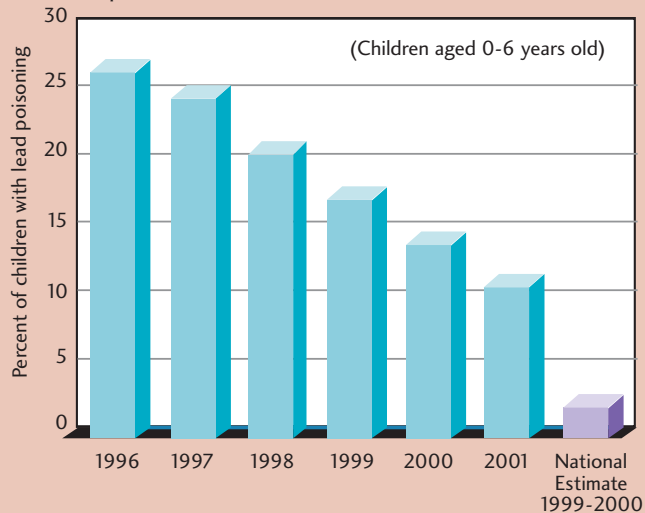
While the London episode highlighted the hazard of extreme air pollution episodes, it was unclear whether health effects were associated with lower concentrations. By the 1970s, the association between respiratory disease and particulate and/or sulfur oxide air pollution had been well established.⁴³ Improvements in the measurement of air pollution and health endpoints, plus advances in analytical techniques, have made it possible to quantitatively evaluate air pollution and health. For example, research has shown that many air pollutants may contribute to the onset or aggravation of heart disease, especially carbon monoxide and fine particulate matter (PM_{2.5}).^{44, 45, 46}

Children's Lead Levels Remain a Concern in Urban Hot Spots

Because lead in outdoor air has been reduced to very low levels, the lead dangers to children today are primarily from ingesting and inhaling lead-containing paint dust or eating paint chips in older homes, most of which are in urban areas. Several metropolitan health departments are addressing the problem by using geographic information systems and maps depicting areas of housing with potential lead hazards, as well as areas where children's blood lead levels are high (based on testing of the general population), to identify high-risk areas and promote compliance with lead hazard regulations. In Chicago, for example, EPA Region 5, the U.S. Department of Housing and Urban Development, and the city have taken enforcement action against property managers and landlords who did not disclose potential lead hazards to tenants. The city is also providing outreach and education materials to these high-risk areas. The percentage of Chicago children with elevated blood lead levels above 10 µg/dL has declined substantially since 1996, although many still have blood lead levels above the national average (Exhibit 4-9).



Exhibit 4-9: Percent of screened children in Chicago having elevated blood lead levels greater than 10 micrograms per deciliter (> 10 µg/dL), 1996–2001



Note: 10 µg/dL of blood lead has been identified by CDC as elevated, which indicates the need for intervention. (CDC. *Preventing Lead Poisoning in Young Children*. 1991.)

Source: Graphic developed for this report by Chicago Department of Public Health, Childhood Lead Poisoning Prevention Program. For 1996-2001, source is annual Illinois Department of Public Health, Childhood Lead Poisoning Surveillance Reports. For 1999-2000, source is CDC, *Second National Report on Human Exposure to Environmental Chemicals*. 2003. Data from CDC, National Health and Nutrition Examination Survey (NHANES).

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Particulate Matter

Particulate air pollution is associated with increased daily mortality in many U.S. communities and other countries. The elderly and those with preexisting diseases are particularly vulnerable.⁴⁷ Exposure to ambient particulate matter has also been associated with an increased number of hospital admissions and visits to doctors due to cardiovascular problems and respiratory disease.⁴⁸ Some studies show that exposure to particulate matter exacerbates asthma. Long-term exposure to particulate matter has been associated with increased deaths from heart and lung diseases, increased respiratory disease and bronchitis and with decreased lung function in children.⁴⁹

Ozone

Repeated short-term exposures to ozone may damage children's developing lungs, which may lead to permanent reductions in lung function.⁵⁰ Controlled studies in healthy adults have demonstrated ozone-induced lung inflammation, decrements in lung function, and associated respiratory symptoms, such as cough and pain on deep inspiration.⁵¹ Ozone exposures have also been associated with an increased number of hospital admissions and visits to doctors.⁵²

Indicators

As noted in Chapter 1 – Cleaner Air, national average criteria pollutant levels, including particulate matter and ozone levels, have decreased over the past 20 years. As discussed earlier, however, there are limitations in using these national air pollution data to evaluate rates of asthma attacks occurring during acute exposure episodes. Possible future health indicators for air pollution include death due to respiratory and cardiovascular disease, increased hospital admissions for respiratory and cardiovascular disease, and subtle changes in the cardiovascular system that can increase people's risk of heart attacks and

other cardiovascular effects. Use of these indicators is still challenged by limits in our understanding of how much air pollution contributes to the risk of cardiovascular and respiratory disease.

Waterborne Diseases

In the early 20th century, waterborne diseases such as cholera and typhoid fever were major health threats across the U.S. Deaths due to diarrhea-like illnesses, including typhoid, cholera, and dysentery, were the third largest cause of death in the nation. For instance, more than 150 in every 100,000 people died from typhoid fever each year.

Around that time, scientists began to understand the cause of these diseases. They had identified the bacteria responsible for most diarrheal deaths (typhoid, cholera, and dysentery) and elucidated how these bacteria were transmitted to and among humans. Infected and diseased individuals shed large quantities of microbes in their feces, which flowed into and contaminated major water supplies. This contaminated water was then distributed untreated to communities, which used the water for drinking and other purposes. This created a continuous transmission cycle.

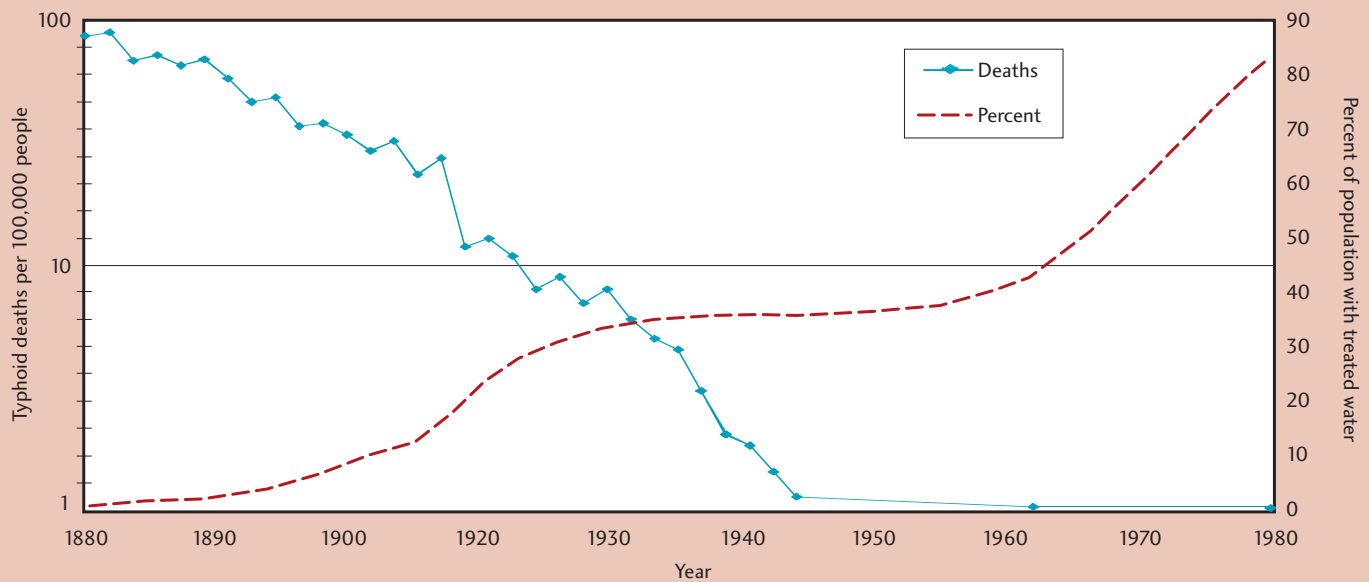


Once treatment (filtration and chlorination) of drinking water was initiated to remove pathogens, the number of deaths due to diarrheal diseases dropped dramatically in communities with treated water. Deaths due to typhoid fever were tracked throughout the early 20th century, as drinking water treatment was implemented across the country, providing an indicator of the success of this environmental management strategy (Exhibit 4-10).

Drinking water treatment is one of the great public health success stories of the 20th century. Not only did it dramatically and significantly reduce death rates from waterborne disease, it also increased life expectancy and reduced infant mor-

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Exhibit 4-10: Percent of population with treated water versus typhoid deaths in the United States, 1880-1980



Source: Craun, C.G. *Waterborne Diseases in the United States*. 1986; Whipple, G.C. *Typhoid Fever - Its Causation, Transmission and Prevention*. 1908; Fox, K. National Risk Management Research Laboratory, personal communication, 2003.

tality. Today, public health is protected against new and emerging waterborne microbial contaminants by continual improvements to the drinking water treatment process.

This example illustrates how a link was made between gastrointestinal disease (an outcome indicator) and exposure to pathogens in drinking water. Based on this connection, officials were able to take effective action to protect public health. They also were able to use an outcome measure (deaths due to typhoid) to monitor the success of these protective actions.

Today, deaths due to typhoid, cholera, and dysentery are so rare in the U.S. that they cannot serve as indicators to evaluate drinking water management decisions. The actual number of cases of typhoid, cholera, and dysentery are tracked to some extent; however, the reporting of these cases is not federally required. The waterborne disease outbreak surveillance system is a passive system in that it relies on state health departments to voluntarily report their outbreaks to CDC. (For further information on waterborne diseases, see Chapter 2 – Purer Water.)

Chapter 4 - Human Health



Measuring Exposure to Environmental Pollution

How can exposure data advance understanding of the role of the environment in disease?

“Exposure” refers to direct human contact with a pollutant (e.g., through breathing contaminated air, drinking contaminated water, or eating contaminated food). Measurements of such exposures can help identify which pollutants may cause health problems and at what levels. They can also provide the basis for determining appropriate actions to limit exposure and associated harmful health effects. For example, these data can enable health officials to respond to a health threat in a specific community (e.g., issue code red alerts when air pollution is a concern). This section describes the three key approaches—environmental monitoring, personal monitoring, and biomonitoring—that scientists use to measure how much pollution we are exposed to and how exposure data contribute to understanding the role of the environment in disease. No approach is best suited to all pollutants. Different approaches are appropriate to different types of pollutants, and each approach has strengths and weaknesses.

Environmental Monitoring

Historically, human exposure has often been estimated through environmental measurements of ambient pollutant concentrations (e.g., particulate matter in air, bacteria in water or food). However, the presence of a pollutant in the environment does not necessarily mean that anyone is exposed. For example, people must actually breathe contaminated air or ingest bacteria-laden food and water for exposure to occur.

Monitoring ambient pollutant levels is critical to measuring exposure for several pollutants, including air pollution (e.g., particulate matter, ozone, nitrogen oxides, and sulfur dioxide), radiation, biological pollutants (e.g., molds, pollen, infectious agents), and disinfection by-products, which are formed when chlorine is used to treat drinking water. For instance, measure-

ments of concentrations of pollutants in outdoor or indoor air can be coupled with human activity patterns (e.g., time spent working, exercising outdoors, sleeping) to estimate human exposures. This approach was used to establish national air and water quality standards for many pollutants that protect the U.S. population from harmful health effects.

Personal Monitoring

With personal monitoring, the monitoring device is worn by individuals as they proceed through their normal activities. This approach is most common in workplaces. The radioactivity sensors worn by nuclear power plant workers are one example. Personal monitoring has been used to estimate total human exposures, including exposures from the air people breathe, the water they drink, and the food they eat.⁵³ One advantage of personal monitoring is that the data provide valuable insights into the sources of the pollutants to which people are actually exposed. A challenge with personal monitoring is ensuring that sufficient sampling is done to be representative of the population being studied.

Biomonitoring

Several environmental pollutants, notably heavy metals and some pesticides, can accumulate in the body over time, often with increasing risk of harm. These pollutants or their breakdown products (i.e., metabolites formed when a pollutant is broken down in the body) leave residues in the body that can be measured, usually in the blood or urine. These residues reflect the amount of the pollutant in the environment that actu-



Measuring Exposure to Environmental Pollution: Selected Indicators

Blood lead level

Blood mercury level

Blood cotinine level

Urine organophosphate level to indicate pesticides

Chapter 4 - Human Health

ally gets into the body. The approach of measuring pollutant levels in tissue or fluid samples from individual people is called “biomonitoring.”

National-scale biomonitoring data can be useful as indicators of the distribution of exposure across the entire population to a variety of pollutants. Also, such data provide an important bridge to understanding the relationships between ambient pollutant concentrations (e.g., in air, water), exposures to these pollutants, and health problems. Biomonitoring data provide exposure information that may help alert physicians, scientists, and health officials to diseases that result from exposure to environmental chemicals. The data are also useful for establishing reference ranges that can be used to identify people with unusually high exposure or the percentage of the population that has pollutant exposures above levels considered to be elevated (e.g., lead).⁵⁴

Health and environmental agencies are using biomonitoring measures and trend data to improve understanding of the relationship between exposure to environmental pollutants and health. For example, CDC is using biomonitoring data to assess environmental pollutant exposures in the U.S. population. In 2001, CDC provided data on 27 pollutants present in the blood and urine of a small sample of the U.S. population.⁵⁵ In January 2003, CDC released data on blood and urine residues for 116 environmental chemicals in a much larger, nationally representative population sample.⁵⁶

Biomonitoring data are already available for metals (e.g., lead, mercury, cadmium), cotinine (a measure of environmental tobacco smoke [ETS]), volatile organic chemicals, organophosphate pesticides, organochlorine pesticides, phthalates, polychlorinated biphenyls (PCBs), dioxin and dioxin-like compounds, and polycyclic aromatic hydrocarbons (PAHs). Future biomonitoring will build the trend data showing whether levels of other pollutants are increasing or decreasing in the population.

Although biomonitoring data are highly useful, they have several limitations as an indicator of exposure. These data do not provide information about how the exposure occurred or the source(s) of exposure, and in some cases, they do not distinguish among different pollutants that may leave identical



residues in the body. For example, biomonitoring can determine that a person has been exposed to carbon monoxide, but not whether the source is ETS, a faulty gas stove, or vehicle emissions on a highway. These limitations may make it difficult to identify actions that would reduce or prevent such exposures or to correlate them to disease. Nonetheless, for some pollutants national biomonitoring data are useful indicators of exposure on a national scale.

The following three examples—the heavy metals lead and mercury, ETS, and organophosphate pesticides—highlight the findings of the ongoing CDC biomonitoring efforts and how these findings can advance efforts to protect human health.

Heavy Metals

Gathering information on heavy metals in the U.S. population is important because those metals are highly toxic at sufficiently high doses, and even low-level residues of certain metals may be of concern. Concentrations of lead in blood—a demonstrated indicator of harmful effects on the nervous system—have declined significantly, especially since the 1970s, when lead was banned from gasoline.



Environmental exposure to mercury, another heavy metal, is of particular concern. Mercury can be transformed into methylmercury by bacteria in soil and sediments and then can move up the food chain, accumulating in fish, which are a major source of exposure for people. Methylmercury has been associated with harmful effects on the nervous system, especially in a developing fetus. When a pregnant woman eats methylmercury-contaminated fish, the child she is carrying may later experience harmful effects, including learning and developmental problems.⁵⁷ The same is true for young children exposed to methylmercury directly. Indigenous and tribal populations and others who rely heavily on fish as a major food source may also suffer nervous system effects.

In 1999 and 2000, total mercury blood levels (both inorganic and organic forms) were evaluated in a nationally represen-

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tative survey of approximately 700 young children (ages 1 to 5 years) and 1,700 women of childbearing age (16 to 49 years). The results show that the mercury levels in women of child-bearing age were less than 58 ppb—a level associated with a doubling of risk of abnormal performance on neurodevelopmental tests in children exposed in utero.^{58,59} Adverse health effects may also occur at levels below 58 ppb. To account for many uncertainties, EPA has determined that children born to women with blood levels of mercury above 5.8 ppb are at some increased risk of adverse health effects. Based on the 1999–2000 survey, about 8 percent of women of child-bearing age had at least 5.8 ppb of mercury in their blood.^{60,61} Health officials have been working to promote education and awareness of the hazards of methylmercury-contaminated fish. (See “Consumption of Fish and Shellfish” in Chapter 2 – Purer Water.)

Environmental Tobacco Smoke

Environment tobacco smoke (ETS) is of special concern in indoor air, where it can concentrate and persist.

Cotinine, a breakdown product of nicotine that can be quantified in blood, hair, urine, and saliva, can be used as a measure of exposure to tobacco smoke from both active and passive means. Overall, children's median (50th percentile) blood levels of cotinine have declined 56 percent between the periods 1988–1991 and 1999–2000 (Exhibit 4-11).⁶² Between the periods 1991–1994 and 1999–2000, cotinine levels in urine decreased 58 percent for children ages 3 to 11, 55 percent for adolescents ages 12 to 19, and by 75 percent in non-smoking adults, according to a national survey of almost 6,000 people.⁶³ The declines in children's cotinine levels are in part attributable to the declining number of adult smokers. However, non-smoking children between the ages of 3 and 19 have cotinine levels more than twice those of adults.⁶⁴ In 1999–2000, African Americans (all age groups combined) had cotinine levels more than twice those of whites.⁶⁵

ETS is a known cancer-causing agent in people, and long-term exposure to ETS is associated with an increased risk for lung cancer and other diseases.⁶⁶ Children are at particular risk from ETS, which may exacerbate asthma in children who have the disease and greatly increase the risk for lower respiratory-



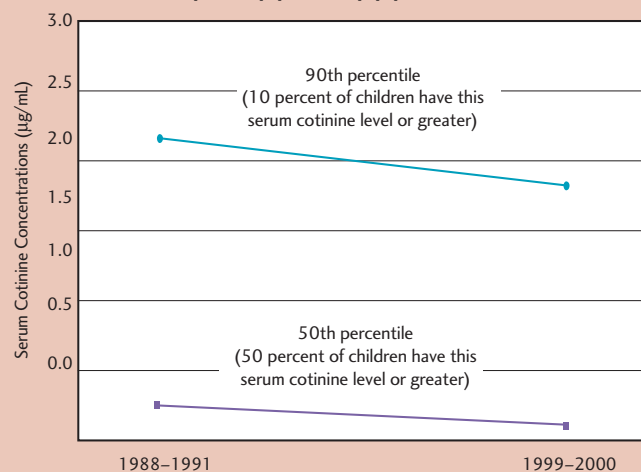
tract illness, such as bronchitis and pneumonia, among young children.⁶⁷

Organophosphate Pesticides

Organophosphate pesticides account for about half of the insecticides used in the U.S. Exposure to these pesticides occurs primarily from ingestion of food products or from home and garden uses, like lawn and crack and crevice treatments, although many household uses are being phased out or have stopped altogether in recent years. In a 1999–2000 nationwide survey, common breakdown products of several organophosphate pesticides were found in the urine of approximately 50 percent of the nearly 2,000 people sampled, demonstrating fairly widespread public exposure to these pesticides.⁶⁸ This study also showed that these pesticide residues were consistently higher in children than in adults.⁶⁹ Like lead and mercury, these pesticides can harm the nervous system, but it is not yet known what minimum level causes these effects. Future research will build the trend data showing whether levels of these pesticides are increasing or decreasing in the population and, as noted, CDC has an effort under way to collect those data.

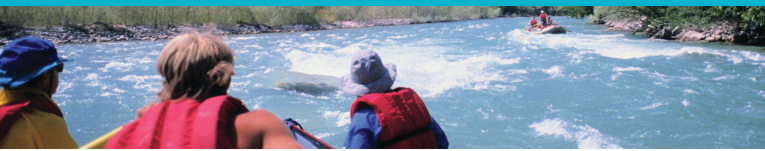


Exhibit 4-11: Concentrations of cotinine in children's blood, 1988-1991 and 1999-2000



Source: EPA. *America's Children and the Environment—Measures of Contaminants, Body Burdens, and Illnesses, Second Edition*. February 2003. Data from CDC, National Center for Health Statistics, National Health and Nutrition Examination Surveys, 1988-1991 and 1999-2000.

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Challenges in Developing Human Health Indicators

Human health indicators provide important tools that regulatory agencies can use to identify environmental health problems, develop programs to reduce the problems, then gauge the success of those efforts. For example, the declining levels of lead in children's blood confirm that the nation's strategies to remove lead from gasoline, water, and paint have successfully reduced exposure to lead. Similarly, the decline in urinary cotinine levels confirms that efforts to reduce smoking have been successful in reducing exposures to ETS.

For many other pollutants, major knowledge gaps and challenges remain in linking environmental pollution to health problems. Sorting out the role of the environment, the role of other factors (e.g., genetic make-up, lifestyle choices such as diet and exercise), and the importance of their interactions remains an enormous scientific challenge. The time between exposure and the development or diagnosis of disease, as well as the problems of tracking a mobile population, further complicate the issue of clarifying connections between exposure and harm to health. An emerging area of science involves examining the possible combined (additive), synergistic, and cumulative effects of numerous pollutants in the environment. This field of study merits greater development. Finally, not all chemical exposures result in harm to health. With a better understanding of the contribution of environmental factors to the development of disease, EPA will be able to use established health outcome measures—disease trend and exposure data—to enhance environmental management efforts and to assess the effectiveness of those efforts.

Disease registries could be improved to provide valuable assistance in tracking many diseases. Currently, most disease indicators are based on mortality data, which have serious limitations for linking environmental exposures to disease. Data on the number of new cases (incidence) of a disease or the existing cases (prevalence) of a disease in a population can provide better information, but no comprehensive nationwide systems exist for collecting these data. For example, there is currently no national registry for birth defects. Also,

it is nearly impossible to get an accurate national picture of the number of people affected by outbreaks of waterborne diseases. Occurrence of endemic waterborne disease is grossly underreported. Submission of waterborne disease information to CDC is strictly voluntary, and state-level data pose problems because the list of gastrointestinal diseases that must be reported varies by state. Also, for an outbreak to be detected, many people need to become ill at the same time, and many cases go unreported or are not diagnosed.

Better national-level disease data that could be linked directly with environmental monitoring data would support efforts to establish connections between disease and environmental exposures. For meaningful comparisons, all data sets should have similar timeframes (the same months or number of years) and locations. Also, national-level efforts would benefit from more data that can be sorted by several relevant factors, such as race (which can help in identifying disparities in health status and outcomes), income, occupation, and residence. Such data can be gathered only through better collaboration between and among environmental and health agencies at all levels, as well as hospitals, clinics, and medical offices. As EPA works to develop environmental indicators that reliably signal trends in exposures and disease, the Agency will also work to improve cooperation with the federal and state agencies that collect relevant information.

Appropriate indicators that address these challenges can help the agencies responsible for monitoring and managing the nation's health to flag and respond to potential problems, such as an upsurge in cases of an environmentally related disease or rising contaminant levels in human tissues. The same indicators might, ideally, show whether pollution control actions are actually reducing the number of people who develop diseases associated with environmental agents. This information will help EPA and other agencies to enhance priority-setting to best protect the health of the nation's people.

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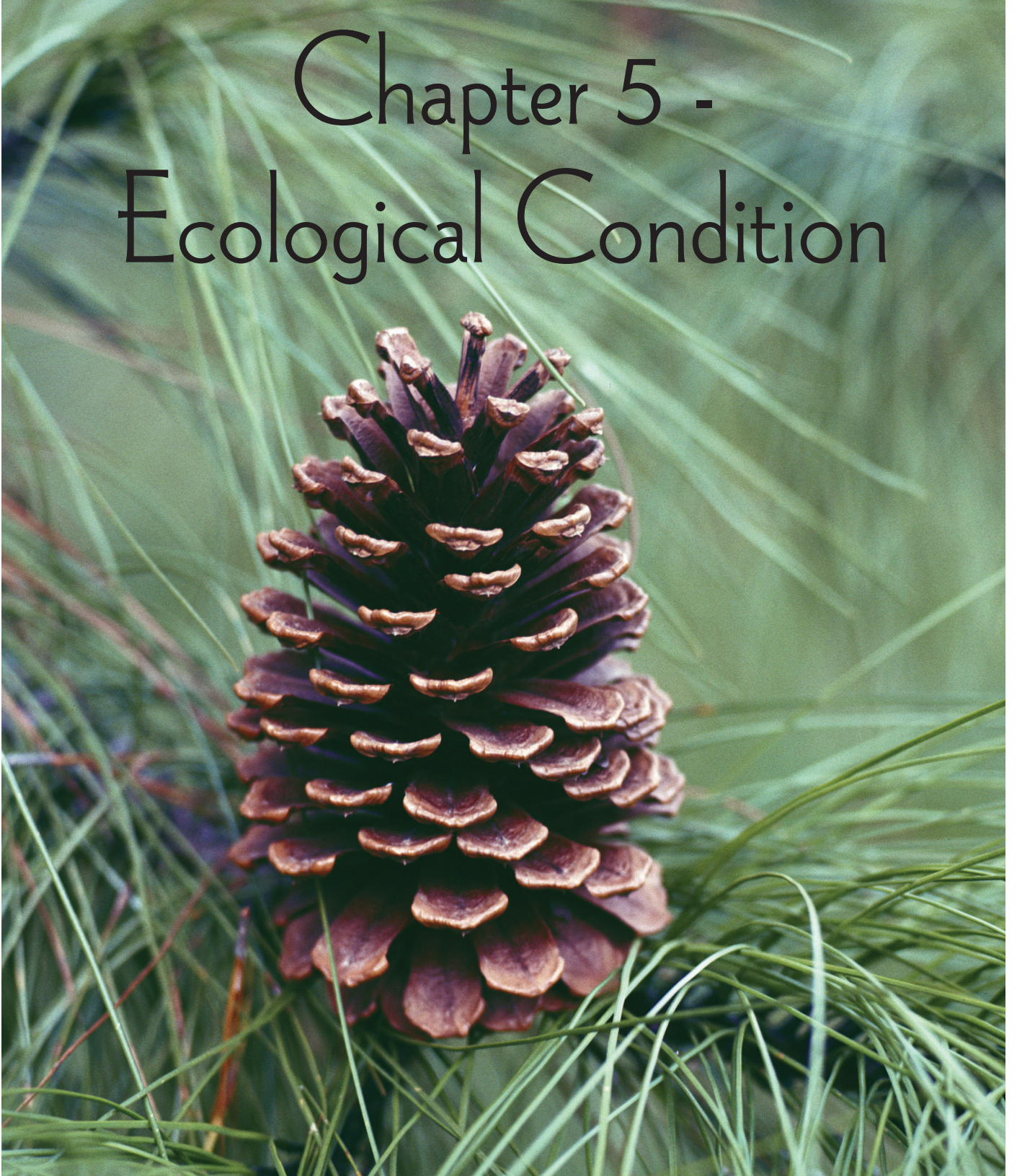
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Chapter 5 - Ecological Condition





Introduction

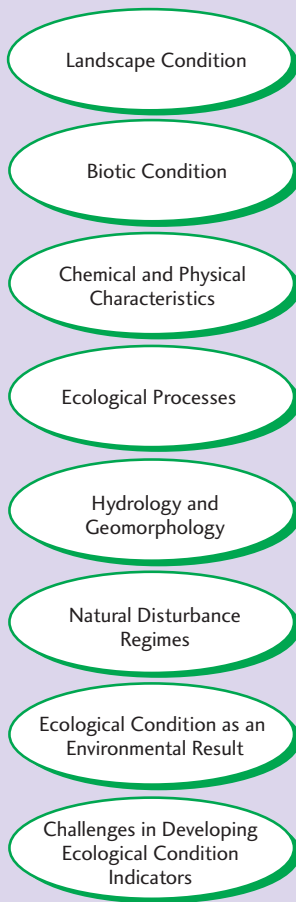
Air, water, land—these are elements of “the environment” that the Environmental Protection Agency (EPA) seeks to protect. But assessing the state of the environment requires looking at a bigger picture. Air, water, and land are connected by natural cycles. For example, nitrogen-laden topsoil eroded from the Midwest may travel down the Mississippi River and pollute the Gulf of Mexico, or chemicals released to the air in the Great Lakes region may find their way into the waters in the Northeast. Living things inhabit virtually all of the nation’s air, water, and land and are affected by innumerable natural and human events.

How can researchers, managers, policymakers, and the public track this big picture? One forward-looking way is to link the state of the nation’s air, water, land, and living organisms into a broad framework termed “ecological condition”—the sum total of the physical, chemical, and biological components of ecosystems and how they interact. Ecological condition is ever changing, multifaceted, and specific to place and ecosystem. Understanding ecological condition is crucial because humans depend on, and are responsible for, the nation’s ecosystems—forests, grasslands, shrublands, farmlands, urban and suburban environments, fresh waters, and coasts and oceans. These systems provide food, fiber, and shelter, as well as “housekeeping” functions ranging from water filtration and crop pollination to waste decomposition and recycling.

Trends in ecological condition, like disease trends described in Chapter 4 – Human Health, reflect the outcome of many different events and activities, both natural and human induced. Ecosystem condition is the result of natural resource management at national and state levels, local zoning and

land use decisions, pollution and pollution prevention activities, natural disturbances, and many other factors. EPA is one of many federal, state, tribal, and local government and private partners working to understand ecological condition and to protect the nation’s ecosystems. Most EPA programs focus on managing environmental stressors, such as minimizing chemicals in air and water or reducing toxic substances and hazardous waste. Measuring ecological condition will help EPA systematically assess how its management of stressors affects overall ecosystem health.

Chapter 5: Ecological Condition



This chapter is organized around the framework of six essential ecological attributes developed by EPA’s Science Advisory Board (SAB) (Exhibit 5-1): landscape condition, biotic condition, chemical and physical characteristics, ecological processes, hydrology and geomorphology, and natural disturbance regimes. Within each of these areas, indicators have been defined for each of the six ecosystem or land cover types identified by the H. John Heinz Center for Science Economics, and the Environment (Exhibit 5-2). The Technical Document for this EPA report describes each of these indicators, including the available data, data limitations, and data sources.¹

This chapter describes some of these indicators, including indicators for which national data are available and others for which national data are limited. In addition, the chapter illustrates some examples of promising approaches for using ecological condition to evaluate environmental protection efforts. The chapter closes by summarizing both the state of data for assessing ecological condition and key challenges.







Chapter 5 - Ecological Condition

Recent Ecological Condition Research Efforts

The chapter presents initial work toward identifying indicators to help answer the question, "What is the ecological condition of the United States?" This work draws primarily on two previous research efforts:

- "Framework for Assessing and Reporting on Ecological Condition"² developed by EPA's Science Advisory Board (SAB). The SAB Framework designates "essential ecological attributes" (Exhibit 5-1) that provide a means to examine ecological condition as well as to consider the effects of stressors on condition.
- "The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States,"³ a nationwide effort of government and the private sector led by The H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center). Many of the indicators in this chapter and in the Technical Document accompanying this report are derived from the Heinz report.

Exhibit 5-1: EPA Science Advisory Board essential ecological attributes

Essential Ecological Attribute	Description	Example Indicators
 Landscape Condition	The extent, composition, and pattern of habitats in a landscape.	<ul style="list-style-type: none"> - Status and change in extent of ecosystems
 Biotic Condition	The condition or viability of communities, populations, and individual biota.	<ul style="list-style-type: none"> - Imperiled species in the U.S. - At-risk native species - Trends in invasive and non-invasive birds in grasslands and shrublands
 Ecological Processes	Metabolic function of ecosystems - energy flow, element cycling, and the production, consumption, and decomposition of organic matter.	<ul style="list-style-type: none"> - Primary productivity - Movement of nitrogen
 Chemical and Physical Characteristics	Physical parameters (e.g., temperature) and concentrations of chemical substances (e.g., nitrogen) present in the environment.	<ul style="list-style-type: none"> - Nitrate, phosphate, and other chemical levels in streams
 Hydrology and Geomorphology	The interplay of water flow and land forms.	<ul style="list-style-type: none"> - Soil erosion - Change in stream flow rates
 Natural Disturbance Regimes	The historical function of discrete and recurrent disturbances that shape ecosystems.	<ul style="list-style-type: none"> - Forest disturbances: fire, insects, and disease

Source: EPA, Science Advisory Board. *Framework for Assessing and Reporting on Ecological Condition*. June 2002.

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Introduction

Exhibit 5-2: Ecosystem types as described by The Heinz Center

Ecosystem Type	Description
Forest Lands	Lands at least 10 percent covered by trees of any size, at least 1 acre in extent.
Grasslands and Shrublands	Lands in which the dominant vegetation is grasses and other non-woody vegetation or where shrubs (with or without scattered trees) are the norm. This ecosystem type includes bare rock deserts, alpine meadows, and arctic tundra.
Farmlands	Lands used for production of annual and perennial crops and livestock and areas on the larger farm landscape (e.g., field borders and windbreaks, small woodlots, grasslands and shrubland areas, wetlands, farmsteads, small villages and other built-up areas) within or adjacent to croplands.
Urban and Suburban	Places where the land is primarily devoted to buildings, houses, roads, concrete, grassy lawns, and other elements of human use and construction.
Fresh Waters	Rivers and streams, including those that flow part of the year; lakes, ponds, and reservoirs; ground water; fresh water wetlands, vegetated margins of streams and rivers (riparian areas).
Coasts and Oceans	Estuaries and ocean waters under U.S. jurisdiction. Estuaries are partially enclosed bodies of water (including bays, sounds, lagoons, and fjords) considered to begin at the upper end of tidal or saltwater influence and end where they meet the ocean.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002.

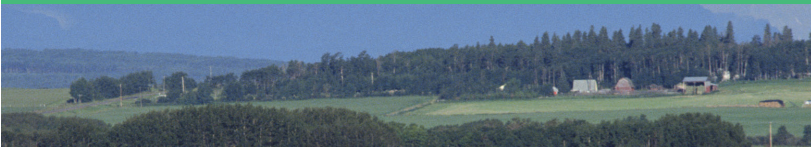
What is the ecological condition of the United States?

Basic questions about the health of the nation's ecosystems and the overall ecological condition of the U.S. have proven difficult to answer in a few summary statements. Ecosystems are dynamic assemblages of organisms that change and adapt continuously to a variety of natural disturbances and stressors, such as fires and floods, as well as to pollutants and land use changes. A variety of ecosystem management practices are used to support human survival and economic growth.

Because of these complexities, measuring ecological condition goes beyond monitoring air or water to determine whether pollutant concentrations or temperatures exceed a legal standard. Trying to characterize overall condition by looking at only one factor, such as stressors, is like the blind-

folded men trying to describe an elephant after touching only one part of the animal. In the same way, we cannot determine the overall condition of an ecosystem by looking at isolated environmental measures, such as insect outbreaks in a forest, chemical concentrations in water, or declines in the number of certain species. Assessments of ecological condition must incorporate measures of different characteristics, potentially at different times and different places within a system. The importance of multidimensional measurements to understand multidimensional systems is described in more detail in "Ecological Condition as an Environmental Result" later in this chapter. This section illustrates indicators that provide insights into the six attributes identified by the Science Advisory Board.

Chapter 5 - Ecological Condition



Landscape Condition

Landscape condition, a term that applies to both terrestrial and aquatic ecosystems, includes such aspects of ecosystems as extent, age, composition, and juxtaposition with other land cover types and land uses. Landscape condition determines, in part, the ability of ecosystems to sustain themselves, as well as respond to human needs—for example, to supply crops and timber, fish and shellfish, clean water and air, and wildlife nurseries. This section focuses on one aspect of landscape condition—extent. Indicators addressing age, composition, and patterns of ecosystems are described in the accompanying Technical Document.

Extent provides basic information on how much of an ecosystem exists, where it is, and whether it is shrinking or expanding. Changes in the extent of various cover types in the U.S. have been driven primarily by human land (and water) uses over the past 400 years (Exhibit 5-3). As of 1997, approximately 25 percent of forests, 3 to 12 percent of grasslands and shrublands, and more than 50 percent of wetlands, had been converted to other uses since European settlement.^{4,5,6}

Most of the changes in ecosystem acreage since the 1980s have stemmed from agriculture and development activities. Between 1982 and 1997, approximately 7 million acres of agricultural land and 10 million acres of forest land were converted to residential, transportation, industrial, urban, and other uses.⁷ Another 22 million acres of pasture and rangeland (including some grasslands and shrublands) were converted to crop production.⁸

Only limited information exists on the total extent of water ecosystems, both fresh water and coastal, other than wetlands. Small streams may disappear because of mining, damming, or water withdrawals. However, because there is no widely accepted way to classify streams for ecological monitoring, no national dataset exists for reporting on their gains or losses.⁹ The extent and composition of most, but not all, of the nation's coastlines have been established by the National Oceanic and Atmospheric Administration.¹⁰ Eight percent or 400,000 acres of coastal wetlands were converted

to other uses between the mid-1950s and mid-1990s.¹¹ For coral reefs, shellfish beds, and submerged aquatic vegetation, baseline information is inadequate, although a survey in Chesapeake Bay indicated that acres of submerged aquatic vegetation have increased from 41,000 to 69,000 since 1978.¹² The structure and pattern of estuarine landscapes, and their contribution to ecological condition, remain inadequately measured or understood.

The changes in ecosystem acreages described above may represent a small percentage of a specific cover type on a national basis. In some cases, however, even small changes can have direct effects on species associated with ecosystems locally. NatureServe, a non-profit organization that tracks species diversity and loss nationwide, has stated that loss of habitats due to changes in extent of land cover constitutes the single greatest threat to species survival.¹³

As land use and acreage change, the mix of living things and ecosystem types also change, with uncertain ripple effects. Wetland ecosystems, for example, are critical to the life cycles of plants, fish, shellfish, migratory birds, and other wildlife. More than one-third of threatened and endangered species in the U.S. live only in wetlands, and nearly half use wetlands at some point in their lives.¹⁴ Forested wetlands often become shrub wetlands after the trees are removed, and these two types of ecosystems do not support the same plants and animals. Over the last 50 years, the amount of non-stocked forest has decreased, while the amount of forest with older trees has increased.¹⁵ (For more information on these effects, see Chapter 2 – Purer Water and Chapter 3 – Better Protected Land.)



Landscape Condition Indicators

Extent of ecosystem/land cover types (forests, farmlands, urban/suburban, grasslands/shrublands, fresh waters, coasts and oceans)

Exhibit 5-3: Historical and current extent of land cover classes

Land Cover Class	Pre-European Acreage Estimate	1977-1982 Acreage Estimate	1997-2002 Acreage Estimate
Forest Lands	1 billion ^b	744 million ^b	749 million ^b
Grasslands and Shrublands ^a	900 million - 1 billion ^c	872 million (based on loss of 11 million acres of non-federal) ^{d, e}	861 million (an additional 205 million in Alaska) ^d
Farmlands (Acreage Shown is for Croplands and Pasturelands) ^a	0	553 million ^e	530 million ^e
Urban and Suburban (Acreage Shown is for Developed Lands) ^a	0	73 million ^f	98 million ^f
Fresh Waters	No data	No data	41.6 million acres of lakes, ponds, and streams ^g 60.2 millions acres - Great Lakes ^g 3.7 million miles of streams and rivers ^{a, g}
Wetlands ^a	221 million ^h	106.1 million ^h	105.5 million ^h (Alaska: 170 million acres) ⁱ
Coasts and Oceans	No data	No data	57.9 million acres of estuarine surface area ^j 66,645 miles of coastline ^j

Note: All estimates are in acres.

a Does not include Alaska.

b USDA, Forest Service. *U.S. Forest Facts and Historical Trends*. April, 2001 and USDA, Forest Service. Draft Resource Planning Act Assessment Tables. May 3, 2002 (updated August 12, 2002). (September 2003; http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf).

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i Dahl, T.E. *Wetlands Losses in the United States 1780's to 1980's*. 1990.

j EPA, Office of Water. *The Quality of Our Nation's Waters, A Summary of the National Water Quality Inventory: 1998 Report to Congress*. 2000.

Chapter 5 - Ecological Condition



Biotic Condition

Every ecosystem contains living components; their very presence or absence, along with their diversity, signals the capacity of a place to support life. Because living organisms respond to multiple factors, their condition—known as biotic condition—provides a snapshot of many other conditions within their environment. Thus, indicators of biotic condition, such as species at risk, competition from non-native species, or rates of disease and deformity, are vital to assessing ecological condition.

Currently, the data to support such indicators are limited, and no data are available to accurately measure biotic condition on a national basis. Data do exist on a small fraction of the total number of native species in the U.S. and on the presence of “invasive” bird species in grassland and shrubland

ecosystems. Additionally, data on forest lands in 37 states provide a partial view of tree condition as an indicator of biotic condition. This section summarizes the data available for these measures of biotic condition.

Roughly 200,000 native plant, animal, and microbial species inhabit the U.S.¹⁶

NatureServe is tracking approximately 16,000 native plant and 6,000 native animal species. Of these, about 19 percent of the animal and 15 percent of the plant species are estimated to be imperiled or critically imperiled, as shown in Exhibit 5-4.¹⁷ (Note that the ranking criteria, evidence requirements, taxonomic coverage, and purposes for gathering this information vary from those of the Endangered Species Act, and thus the categories do not match official “threatened and endangered” species listings.¹⁸) Increased risk levels for a particular species may be due to historical or recent population declines or may reflect natural rarity.¹⁹

Imperiled species have been examined by ecosystem. Fresh water species show the highest rates of imperilment (Exhibit 5-5).²⁰ One percent of plants and 3 percent of animals may already be extinct.²¹

Birds, which are highly mobile (and “monitored” by many people for pleasure), respond quickly to environmental change. Changes in the mix of native and alien—and invasive and non-invasive—birds often signal changes in grassland and shrubland condition. The presence of native non-invasive species generally reflects relatively intact, high-quality native grasslands and shrublands. Conversely, increases in both native and non-native invasive species, such as American crows or European starlings, often accompany land conversion to agriculture or grazing uses, landscape fragmentation due to suburban and rural development, and the spread of

Biotic Condition Indicators

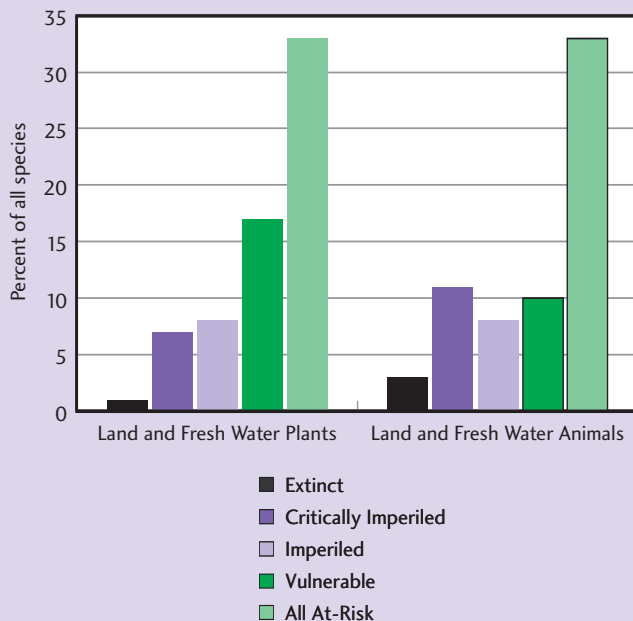
At-risk native species

Benthic Community Index

Population trends of invasive and native non-invasive bird species

Tree condition

Exhibit 5-4: At-risk land and fresh water plant and animal native species, 2000



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002. Data from NatureServe and its Natural Heritage member programs.

Chapter 5 - Ecological Condition

Biotic Condition

Exhibit 5-5: Percent of imperiled species by ecosystem, 2000

Land Cover Class	Number of Animal Species	Percentage Imperiled Species	Percentage Critically Imperiled Species	Percentage Presumed/Possibly Extinct
Forest Lands	~ 1700	5%	3.5%	1.5%
Grasslands and Shrublands	~ 1700	6%	3.5%	0.5%
Farmlands	-	-	-	-
Urban and Suburban Ecosystems	-	-	-	-
Fresh Water Ecosystems	~ 4000	8%	13%	4%
Coasts and Oceans	-	-	-	-
All U.S.	22,000 plant and animal species	15% of plants and 19% of animals		1% of plants and 3% of animals

Source: Based on the Heinz Center. *The State of the Nation's Ecosystems*. 2002. Data from NatureServe and its Natural Heritage member programs.

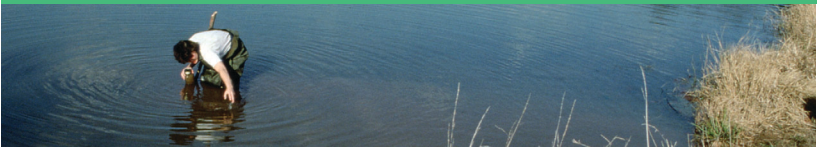
exotic vegetation.²² From the mid-1960s until the last half-decade, invasive and non-invasive bird species changed in similar proportions in grasslands and shrublands. From 1996 to 2000, however, the population of birds representing invasive species climbed steeply.²³ This increase might represent a short-term fluctuation in bird populations, or it could signal changes in grassland and shrubland ecosystem condition.

The health and physiology of individual organisms are also signs of ecosystem condition. In an assessment of forest con-

dition, for example, data from the U.S. Department of Agriculture (USDA) Forest Service Forest Health Monitoring Program (currently available for only 37 states) examined the number of dead or dying trees, the number of forests with thin canopies, and the extent to which buildup of flammable material threatened to alter the ecosystem significantly. Although the data are insufficient to assess 39 percent of forested areas, analyses show that nearly 41 percent of sampled trees were in fair or good condition and 20 percent were in poor condition.²⁴

Chapter 5 - Ecological Condition

Biotic Condition



Chemical and Physical Characteristics

Chemical and physical properties, like other non-living ecosystem attributes, help shape the environment of living things. Many of EPA's specific environmental protection responsibilities include measuring and addressing chemical changes. Chemical measurements are often based on water sampling for, among other substances, nitrogen and phosphorus compounds, dissolved oxygen, pesticides, and heavy metals.

Some data on chemical characteristics in U.S. waters have been collected by the U.S. Geological Survey National Water Quality Assessment (NAWQA) program. In an analysis done for the Heinz report, NAWQA reported on contaminants in stream waters from 109 sites and in sediments from 558 stream sites in 36 watersheds across the U.S. At least half of monitored streams had contaminant concentrations that exceed water quality criteria for wildlife.²⁵ However, no analyses yet relate these concentrations to the status of fish or invertebrate communities in the streams. Nitrate levels were highest in farmland streams, with 10 percent of the samples

exceeding drinking water standards (Exhibit 5-6).²⁶

The NAWQA program provides consistent and comparable information on nutrient and pesticide concentrations in streams in agricultural areas, although the network design and number of sites do not allow estimates to be

made for agricultural streams nationally. Nitrate loss from most forests does not appear to be resulting in high-nitrate concentrations in forest streams, but few streams are sampled in parts of the country where nitrate deposition tends to be high (e.g., eastern states).

A number of physical and chemical indicators are being monitored in Atlantic and Gulf Coast estuaries to help diagnose and interpret information on biotic condition. Eighteen percent of mid-Atlantic estuaries show high nitrogen concentrations, and 12 percent show high phosphorus concentrations. Twenty percent of Atlantic and Gulf Coast estuaries have low dissolved oxygen concentrations (i.e., less than 5 milligrams per liter). On average, 75 percent of the sediments contain elevated pesticide concentrations, and 40 percent show elevated concentrations of heavy metals.²⁷

Chemical and Physical Characteristics Indicators

Nitrate levels in streams by ecosystems

Exhibit 5-6: Nitrate levels in streams by ecosystem, 1992 - 1998

Land Cover Class	Number of Streams Sampled	Nitrate Levels
Forests	36	50% < 0.1 mg/L 75% < 0.5 mg/L 3% > 1.0 mg/L (1 sample)
Grasslands and Shrublands	No data	No data
Farmlands	50	50% < 2.0 mg/L 10% > 10 mg/L (exceeds drinking water standard)
Urban and Suburban Ecosystems	21	40% > 1.0 mg/L 25% < 0.5 mg/L 3% < 0.1 mg/L

Source: USGS, National Water Quality Assessment. *The Quality of Our Nation's Waters—Nutrients and Pesticides*. 1999.

Chapter 5 - Ecological Condition

Chemical and Physical Characteristics



Ecological Processes

Ecological processes comprise the cycling of chemicals and energy through ecosystems. Like the flow of raw materials and labor through a factory, these processes keep ecological systems running. Ecosystems are solar powered: plants turn energy from the sun, carbon dioxide from the air, and nutrients from the soil into food for other organisms. Water and nutrients such as carbon and nitrogen—fundamental building blocks of living tissue—also cycle continuously through ecosystems. Changes in nutrient cycles or disruption in water cycles not only affect the operation of an ecosystem locally, but also may reach well beyond ecosystem boundaries.

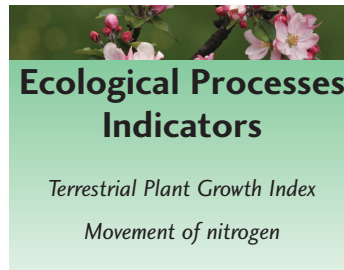
The amount of solar energy captured by plants is a key indicator of ecosystem function.^{28,29} The energy brought into an ecosystem is a key factor in determining the amount of photosynthesis, and the amount of plant growth that occurs each year.³⁰ Plant growth may increase under plant-friendly conditions, for instance, when rainfall or nutrients increase, or it may decrease under stressful conditions, as in the presence of toxic substances or disease. Changing growth affects, and additionally may change, the way ecosystems function, altering yields of crops and timber, and the diversity and mix of animal and other species.

For the 11-year period between 1988 and 2000, annual estimates of plant growth reveal no overall trend for any land cover type or any region of the U.S., although they do fluctuate year to year by as much as 40 percent of the 11-year average.³¹ Long-term monitoring will be required to separate consistent trends from year-to-year variability caused by rainfall and other factors. No estimates yet exist for phytoplankton or submerged vegetation in fresh water or coastal systems.

Nitrogen is a critical element for plant growth and a basic constituent of proteins. In excess, however, it can make soil conditions less favorable for plant growth, damage aquatic life, and impair human health. Although nitrogen gas makes up nearly 80 percent of Earth's atmosphere, organisms can-

not use it until it is converted to active forms by nitrogen-fixing bacteria, fertilizer production, or fossil fuel combustion. Over the past century, the forms of nitrogen traveling through air, water, and soil have changed dramatically, leading to ecosystem effects.³² Nitrogen compounds falling in rain acidify soils and surface waters and can stimulate heavy growths of algae, which may take up so much oxygen that few other organisms survive. Nitrogen compounds can leach into and contaminate ground water used for drinking and have harmful effects in surface water systems. Movement of excess nitrogen from agricultural sources in the upper Mississippi River basin, for example, has been correlated with high levels of plant productivity (eutrophication) and a lack of oxygen (hypoxia) more than 1,000 miles downstream in the northern Gulf of Mexico.³³ The lack of oxygen kills fish, shrimp, and bottom-dwelling communities, causing economic losses to commercial fisheries and diminishing regional biodiversity.

Biologically active forms of nitrogen enter the air as pollutants from industrial facilities, cars, and feedlots and then pass into ecosystems via plants, soils, and water bodies. Nitrogen from septic tanks, animal waste, and excess fertilizer also leaches into the soil and ground water or runs off the land, moving through streams, rivers, and lakes until it eventually reaches estuaries. Some enters streams directly from wastewater treatment plants, and some is lost again to the atmosphere as it moves downstream. The yield of nitrogen in runoff varies in different parts of the country, reflecting differences in atmospheric deposition, fertilizer use, population density, and ecosystem characteristics. An analysis of estimated nitrogen yield shows that watersheds in the upper Midwest and Northeast experience between 4.7 and 15.6 pounds of nitrogen in runoff per acre per year, but watersheds in the mountains of the West yield less than 10 percent of that amount (Exhibit 5-7).³⁴



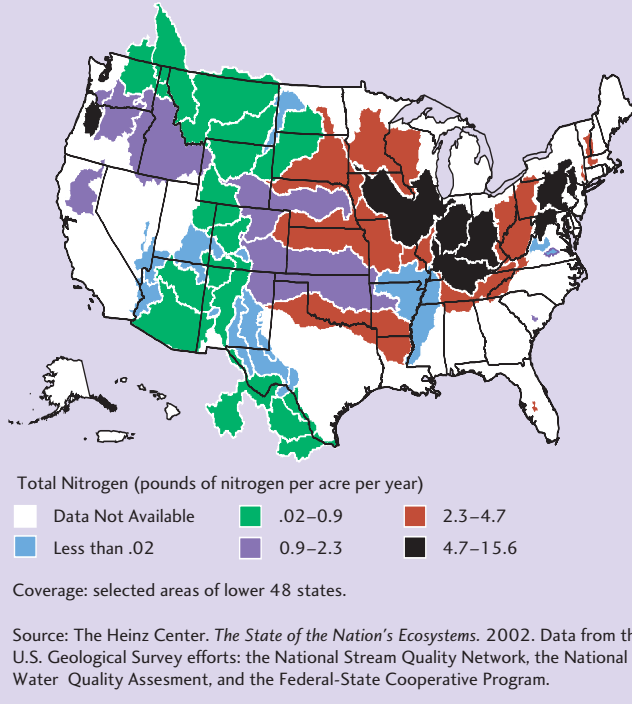
Ecological Processes Indicators

Terrestrial Plant Growth Index

Movement of nitrogen

Chapter 5 - Ecological Condition

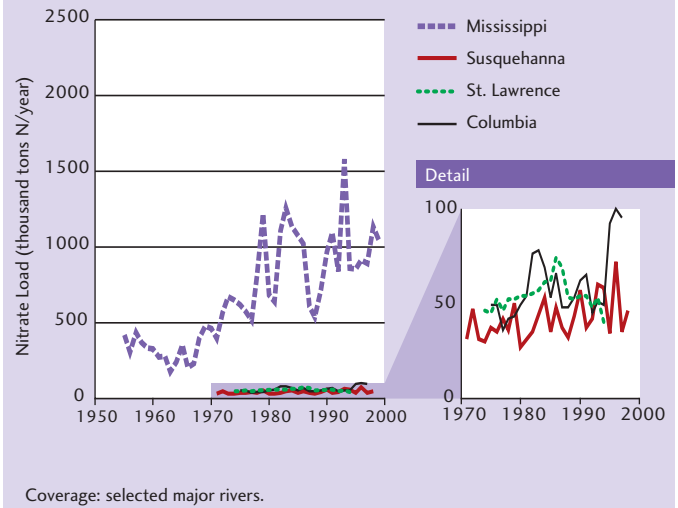
Exhibit 5-7: Yield of total nitrogen from major watersheds, 1996-1999



The *yield* of nitrogen from major watersheds is characterized as pounds of nitrogen per acre of watershed area that enters rivers and streams through discharges, runoff, and other sources. The *load* of nitrate, a common form of nitrogen, from major rivers is defined as the tons of nitrate carried to the ocean each year by the four largest U.S. rivers.³⁵

Nitrate load in the Mississippi River has been monitored since the mid-1950s and from the Susquehanna, St. Lawrence, and Columbia rivers since the 1970s. The Mississippi drains the

Exhibit 5-8: Nitrate load carried by major rivers, 1950s-2000



Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002. Data from three U.S. Geological Survey efforts: the National Stream Quality Network, the National Water Quality Assessment, and Federal-State Cooperative Program.

nation's midwestern breadbasket, where fertilizer use and soil erosion are often high. Although fluctuating from year to year, the Mississippi's nitrate load has increased from approximately 250,000 tons per year in the early 1960s to approximately 1 million tons per year during the 1980s and 1990s (Exhibit 5-8).³⁶ Nitrate loads in the other three rivers have oscillated around 50,000 tons per year since the 1970s, although the Columbia River spiked to 100,000 tons per year in the late 1990s.³⁷

Chapter 5 - Ecological Condition



Hydrology and Geomorphology

Like the framing of a house, the properties, distribution, and circulation of water (hydrology) and the relief features of the earth's surface (geomorphology) help give environments their character. The quantity and timing of water flows influence many ecosystem parts and processes, including those with direct effects on human activities. Loss of topsoil, which can take millennia to replenish, has obvious implications for agriculture, and moving sediment can cause sedimentation in harbors and other facilities and can carry chemicals for long distances.

High and low water flows have important implications for ecosystem health. Low water flows define the smallest area available to stream biota during the year, and high flows shape stream channels and wash out silt and debris. Some fish depend on high flows for spawning. The timing of high and low flows affects the status of aquatic species as well as human water supplies and the flooding of farms, towns, and cities. Climate, dams, water withdrawals, and changes in land use all affect the flow of water.

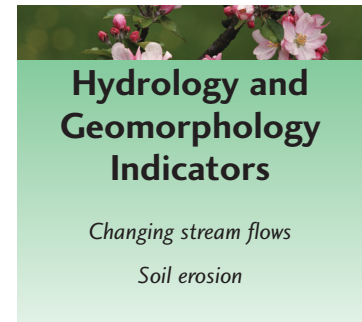
High and low flows for 867 streams and rivers with appropriate data (records between 1930 and 1949, and during the 1970s, 1980s, and 1990s) show little change from the 1970s to the 1990s.³⁸ The same is true for the timing of high and low flows. However, the number of streams with high flows well above their historic (1930 to 1949) rates rose markedly from the 1980s to the 1990s.³⁹ This increase may be attributable, in part, to earlier droughts, but may also be linked to widespread changes in land use.

Erosion can also have significant effects on ecosystem condition. Wind and water erode soils naturally, changing the character of the landscape. Human activities such as development, road construction, timber harvesting, and agricultural practices that disturb the soil surface or remove anchoring

vegetation increase the potential for erosion. Soil loss not only reduces soil quantity and quality but can degrade water quality by carrying nutrients, pesticides, and other contaminants downstream. Sedimentation can raise costs to maintain reservoirs, navigation channels, and water treatment plants and can degrade habitat for aquatic organisms.

Reductions in erosion can occur through improved tilling or management practices, removal of marginal land from production, and land conservation efforts like the Conservation Reserve Program (CRP). Reducing erosion contributes not only to improved soil quality but also to improved water quality in adjacent and downstream aquatic ecosystems.

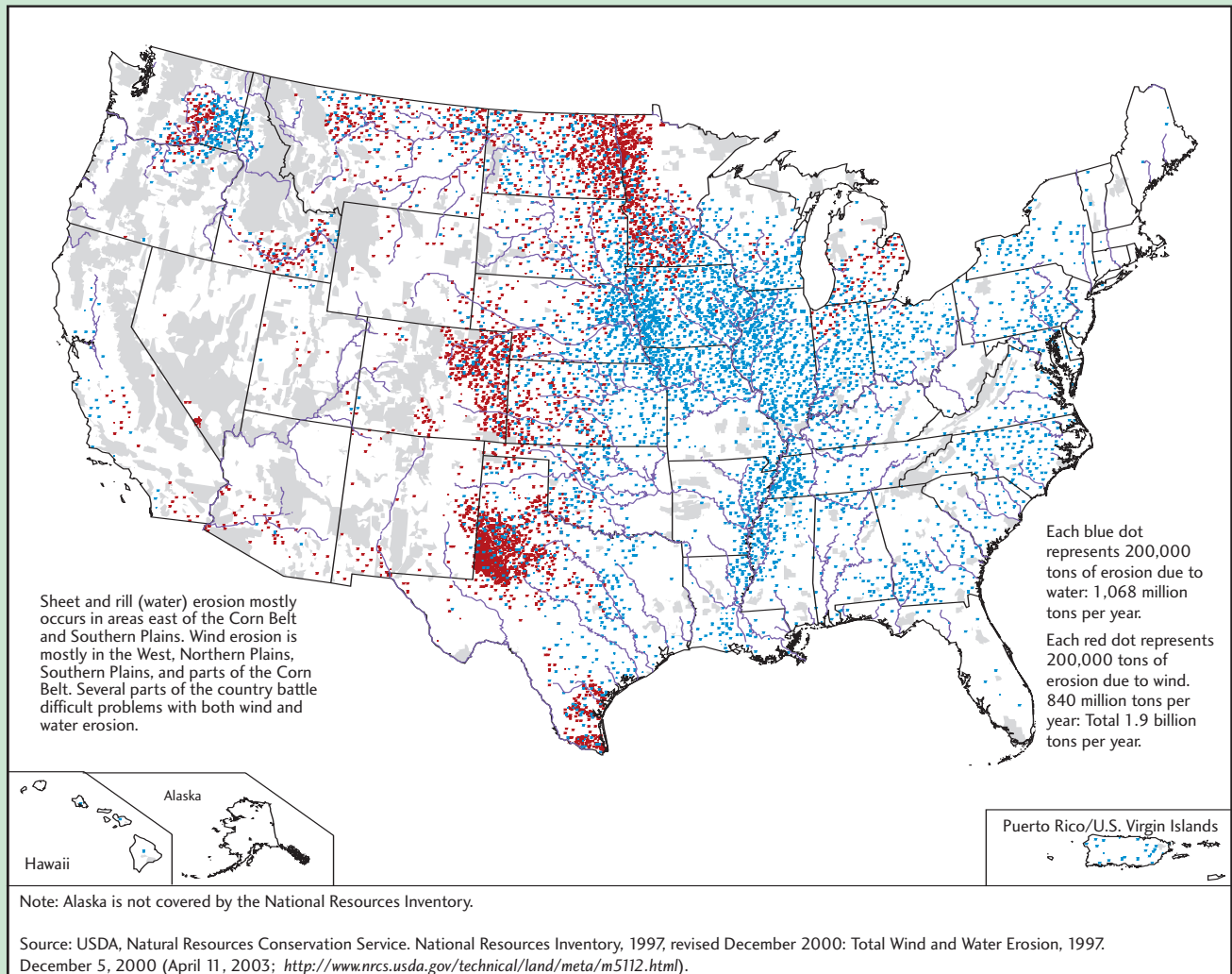
Data on the 409 million acres of croplands and CRP lands show that erosion from water and wind decreased from a total of more than 3 billion tons per year in 1982 to about 1.9 billion tons in 1997.⁴⁰ (Not all of this soil actually moved off-site.) The croplands and CRP lands experiencing erosion in 1997 are shown in Exhibit 5-9. About 15 percent of U.S. cropland and CRP land is estimated to have a high potential for wind erosion, based on an analysis of several factors including soil properties, landscape characteristics (e.g., vegetative cover, rainfall), and management practices (e.g., wind barriers, terracing). This represents a decrease in acreage of almost 33 percent between 1982 and 1997.⁴¹ The acreage with the highest potential for water erosion, based on similar factors, also decreased by about 33 percent to 89 million acres. This represents about 22 percent of U.S. cropland.⁴²



Chapter 5 - Ecological Condition

Hydrology and Geomorphology

Exhibit 5-9: Wind and water erosion on croplands and Conservation Reserve Program (CRP) lands, 1997



Chapter 5 - Ecological Condition

Hydrology and Geomorphology



Natural Disturbance Regimes

Disturbance and change, particularly over long periods of time, are part of all ecosystems. Natural disturbances, from ice ages to droughts, can alter ecosystem characteristics. Some attributes of ecosystems depend on various types of disturbances—for example, some coniferous species depend on fire to open cones and clear ground cover for germination and growth of native species.

Understanding the roles that natural disturbances play in the evolution of ecosystems is key to determining how land use and management practices can improve ecosystem conditions. For example, an unprecedented epidemic of Southern Pine beetle currently is damaging many forests in the southeastern U.S. Understanding this pest and its disturbance patterns can assist in developing appropriate responses to restore ecological balance. The extensive acreages burned from wildfires in the western U.S. in recent years pose similar forest ecosystem challenges and opportunities for developing appropriate responses.

There have been few attempts to document regional or national natural disturbance regimes as indicators. The USDA Forest Service Forest Health Monitoring Program is an exception. Statistical data from the forest inventories conducted between 1979 and 1995 have been used to establish short-term baselines for natural disturbances such as climatic

events, fire frequency, and insect and disease outbreaks. Several recent events proved to be outside the range of natural disturbance patterns in the 1979 to 1995 timeframe, including:

- El Niño from 1997 to 2000.
- Northeast ice storm in 1998.
- Spruce beetle outbreak in 1996, Spruce budworm outbreak in 1997, and a Southern Pine beetle outbreak in 2000.
- National acres burned in 2000 and the area burned in the West in 1996, 1998, and 2000.⁴³

Disturbance regimes can be changed by resource management. For example, in the two decades between 1980 and 1999, wildfires burned between 2 million and 7 million acres annually, down from a high of 52 million acres in 1930.⁴⁴ The decline is primarily due to fire suppression policies.⁴⁵ Wildfires in 2000, however, reached 8.4 million acres.⁴⁶

Natural Disturbance Indicators

*Forest disturbances:
fire, insects, and disease*



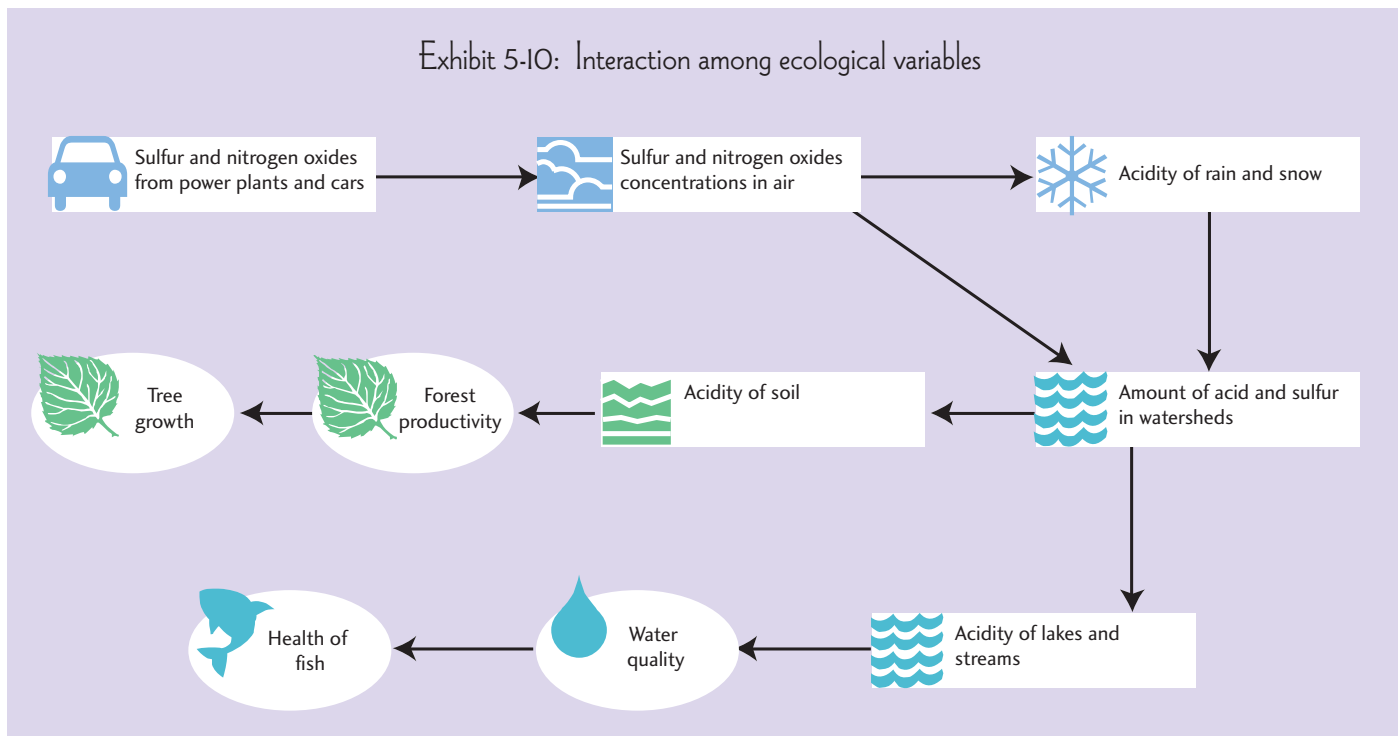
Ecological Condition as an Environmental Result

Ecological condition, like human health, is a crucial measure of the results of environmental protection activities. As a regulatory agency, EPA has long monitored environmental stressors, as described in the chapters of this report on air, water, and land. However, as discussed earlier in this chapter, stressors alone are not good proxies for understanding the condition of an entire ecosystem. One might compare measuring ecosystem health to measuring the health of the economy. Economic indices such as the consumer price index integrate multiple indicators—prices of many consumer goods. Information on only one consumer product or one sector would not be enough to judge trends in national pricing or spending. Similarly, monitoring only stressors, rather than the living things that are stressed, or monitoring ecosystem attributes in isolation does not convey a full and accurate picture of ecological condition. Using ecological condition as an environmental result requires understanding the relationships between ecological condition (as described by the

SAB's essential ecological attributes) and stressors that represent the focus of EPA's current responsibilities for environmental stewardship. EPA can build on decades of monitoring stressors while it develops and monitors appropriately multi-dimensional and better-linked ecological condition indicators. Some promising approaches to identifying such indicators are described below.

Many factors stress ecosystems. How ecosystems are affected varies significantly according to the nature of the stress, its duration and frequency, and the conditions in the ecosystem before the stress occurred. For instance, the flows and interactions related to sulfur and nitrogen oxides as air pollutants depicted in Exhibit 5-10 provide an example of the effects of stress in ecosystems. Arrows depict sulfur and nitrogen in different forms as they move through a watershed. Any of the components in Exhibit 5-10 could be measured as an indicator, but each alone contributes only a piece to the under-

Exhibit 5-10: Interaction among ecological variables



Chapter 5 - Ecological Condition

standing ecological condition. Monitoring the concentrations of pollutants at various points in the flow can contribute to understanding the effectiveness of pollution control programs. The success of a sulfur reduction program, however, can be assessed only by tracking whether lower sulfur emissions actually lessen sulfur concentrations in air, water, soil, fish, and forests.

Using this type of integrated approach, EPA and its partners were able to confirm that, following emissions reductions required by regulations under the 1990 Clean Air Act Amendments, acid rain decreased by 40 percent across broad areas of the northeastern and upper midwestern U.S. in the 1990s.⁴⁷ The decrease in acid rain itself was accompanied by significant reductions in the number of ecosystems affected by acid deposition.⁴⁸ Moreover, continuing regional lake and stream sampling has shown that in the Northeast, Upper Midwest, and Appalachians, one-quarter to one-third of lakes and streams previously affected by acid rain are no longer acidic (although they are still sensitive to changes in acid deposition).⁴⁹

Just as important as measuring multiple variables is the choice of what to measure. In the case of sulfur in the ecosystem, measurements of emissions and conditions such as acidity of soil or water are not enough. Those measures do not provide any knowledge of the outcomes—the growth of trees or the health of fish. These biotic components are critical pieces in understanding the ecological condition of the system.

One approach that addresses the need to measure critical multiple variables is the index of biotic integrity (IBI), which has been applied with fish, bottom-dwelling invertebrates, and diatoms.⁵⁰ Just as the consumer price index combines the price of many consumer goods, the IBI combines measurements of a number of biological attributes, called “metrics,” that reflect the ecological condition of a place, including biological diversity; relative abundance of indicator groups of organisms, such as predators, highly tolerant species, or non-

native species; the health of individual organisms; and ecological relationships such as food web structure.⁵¹

In a demonstration project in mid-Atlantic streams, EPA applied a fish IBI along with measurements of several prominent stressors. In a statistical sample of streams representing 90,000 total stream miles, IBI was used to evaluate the biological differences between minimally altered reference streams in the region and streams with varied levels and types of stressors. The study revealed that sought-after sport fish declined in more turbid streams and in streams with increased streamside agriculture.⁵² In addition, acidification lowered the number of minnow, bottom-dwelling, and sensitive species but raised the number of individuals belonging to non-native species. Regionally, the results indicated that 27 percent of the streams were in “good condition” relative to the reference streams that represented the best current conditions in the region (specifically, the IBIs of “good” streams ranked within the top 25 percent of reference stream IBIs), 38 percent were in “fair condition” (their IBIs ranked with the other 75 percent of reference streams), and 14 percent were in “poor condition” (below the lowest 1 percent of reference stream IBIs) (Exhibit 5-11).⁵³

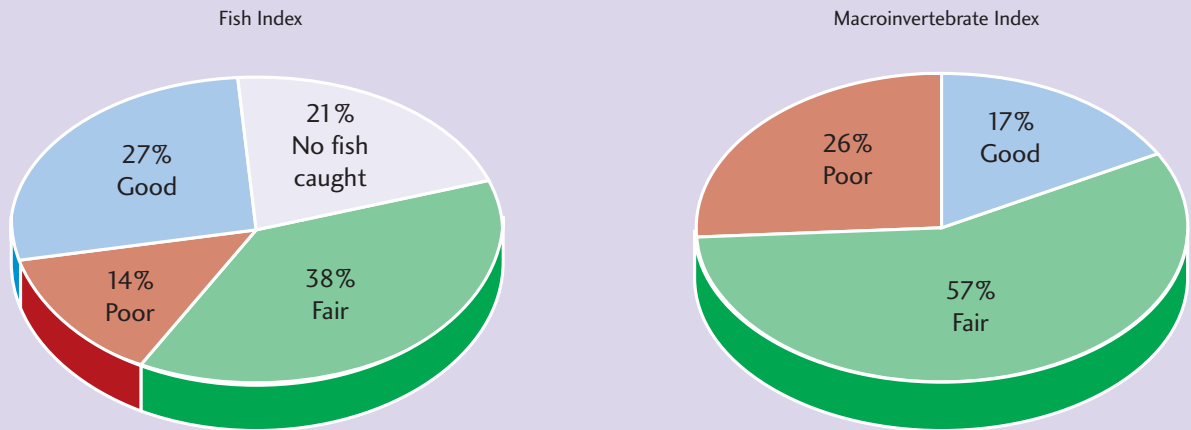
A macroinvertebrate IBI was also applied in the mid-Atlantic streams demonstration project. Stream conditions were classified in much the same way as with the fish IBI. Based on the macroinvertebrate IBI, 17 percent of the streams were in “good condition” (within the top 25 percent of reference stream IBIs), 57 percent were in “fair condition” (within the lower 75 percent of reference stream IBIs), and 26 percent were in poor condition (within the lowest 1 percent of reference stream IBIs) (Exhibit 5-11).⁵⁴

These results are applicable regionwide, providing decision-makers with a clearer picture of the ecological condition in the region's streams, a catalog of specific biological responses associated with that condition, and insight about the effects of specific stressors on condition. Collectively, this knowledge

Chapter 5 - Ecological Condition

Ecological Condition as an Environmental Result

Exhibit 5-II: Fish and Macroinvertebrate Indices of Biotic Integrity



Note: No fish caught does not indicate poor condition. Some streams naturally do not have fish.

Source: McCormick F.H., et al. *Development of an Index of Biotic Integrity for the Mid-Atlantic Highlands Region*. 2001.

Source: Klemm D.J., et al. *Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highlands Streams*. 2003.

tells policymakers which stressors need to be managed to protect or restore ecological condition.

In sum, using ecological condition as an outcome of environmental protection efforts will require monitoring strategies that take into account both of the following:

- The stressors—factors, activities, or variables—that create or contribute to changes in ecological attributes (e.g., changes in biotic condition or ecological processes; changes in habitat pattern and extent; physical, chemical,

and hydrologic changes; and changes in natural disturbance regimes).

- The actual outcomes of EPA's efforts to control these factors and actions (e.g., wetland protection, pollution reduction or prevention, registration of pesticides, proper waste disposal, public information)—that is, whether EPA's efforts maintain or improve ecological condition.

Chapter 5 - Ecological Condition



Challenges in Developing Ecological Condition Indicators

Americans recognize the value of consistent and unbiased surveys of indicators focused on the state of the economy as elements in maintaining a strong economy. Such surveys develop and track numbers on poverty, agricultural productivity, consumer prices, housing starts, and a host of business parameters. Each of these indicators is backed by a process for collecting and reporting the information and a sound rationale for its use as one indicator of economic condition.

Although not everyone understands the exact calculations or data sources, almost everyone seems to pay close attention to the indicators' ups and downs.

No comparable system exists to measure the ecological state of the nation. As a result, adequate data for nationwide trends exist for only a few indicators of ecological condition (shown by the solid circles in Exhibit 5-12). Other indicators (open circles) do have some data, but the data have only been collected once or for limited geographic regions. The clear message is that most of the data needed to track ecological condition have only begun to be collected, and only for limited parts of the nation thus far. This situation will improve over the next few years, but most of the gaps in Exhibit 5-12 are likely to remain for some time to come, because of several major challenges to developing adequate indicators of national ecological condition:

- Indicators must be tied to conceptual models that capture how ecosystems respond to single and multiple stressors at various scales.
- Federal, state, and local monitoring organizations must find a way to coordinate and integrate their activities to meet multiple, potentially conflicting, data needs.
- Mechanisms must be found to ensure long-term commitments to measuring selected indicators over long periods and in standardized ways, to establish comparable baselines and trends.
- Indicators must simplify complex data in ways that make them meaningful and useful to decision-makers and the public.

None of these challenges appears insurmountable, but the gaps in Exhibit 5-12 indicate that much remains to be done.



Chapter 5 - Ecological Condition

Challenges in Developing Ecological Condition Indicators

Exhibit 5-12: Distribution of available ecological indicators across the ecosystem types

Essential Ecological Attribute	Forests	Farmlands	Grasslands/ Shrublands	Urban/ Suburban	Fresh Waters	Coasts and Oceans	The Nation
Landscape Condition							
Extent of Ecological System/Habitat Types	●●	●	●	●	●●	●	●
Landscape Composition	○	●		○	○	○○	
Landscape Pattern/Structure	○						
Biotic Condition							
Ecosystems and Communities	○		●○		○○○○○	○○○	○
Species and Populations	○				○	○	○
Organism Condition	●○○				○	○○	
Ecological Processes							
Energy Flow							●
Material Flow	○						●
Chemical and Physical Characteristics							
Nutrient Concentrations	○	○○		○○	○○	○○	
Other Chemical Parameters	○○				○	○○	
Trace Organic/Inorganic Chemicals		○○○○		●○	○	○○	○
Physical Parameters	○					○	
Hydrology and Geomorphology							
Surface and Ground Water Flows	●		●		●		
Dynamic Structural Conditions							
Sediment and Material Transport	○	○○			○		
Natural Disturbance Regimes							
Frequency	○						

● Adequate national data for assessing condition ○ Limited national data for assessing condition

Note: Each circle, whether open or solid, represents an indicator presented in the Technical Document.

Chapter 5 - Ecological Condition

Endnotes

¹ Chapter 5 – Ecological Condition, of the Report on the Environment Technical Document accompanying this report is organized differently, posing questions about the condition of various ecosystem types and presenting a broader set of indicators that report on essential ecological attributes for each ecosystem type.

² U.S. Environmental Protection Agency. *Framework for Assessing and Reporting on Ecological Condition*, EPA SAB-EPEC-02-009. Washington, DC: U.S. Environmental Protection Agency, Science Advisory Board, June 2002.

³ The H. John Heinz III Center for Science, Economics and the Environment. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, New York, NY: Cambridge University Press, September 2002.

⁴ U.S. Department of Agriculture Forest Service. Draft Resource Planning and Assessment Tables. August 12, 2002. (September 2003; http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf).

⁵ The Heinz Center. *State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, 2002. op. cit.

⁶ Dahl, T.E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Washington, DC: U.S. Fish and Wildlife Service, 2000.

⁷ U.S. Department of Agriculture. *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, Washington, DC: Natural Resources Conservation Service and Ames, Iowa: Iowa State University, Statistical Laboratory, 2000.

⁸ Ibid.

⁹ The Heinz Center. *State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States*, 2002. op. cit.

¹⁰ Ibid.

¹¹ Ibid.

¹² Moore, K.A., D.J. Wilcox, and R.J. Orth. Analysis of the abundance of submersed aquatic vegetation communities in the Chesapeake Bay. *Estuaries* 23 (1): 115-127 (2000).

¹³ Stein, B.A., L.S. Kutner, and J.S. Adams. *Precious Heritage: The Status of Biodiversity in the United States*, New York, NY: Oxford University Press, 2000.

¹⁴ U.S. Environmental Protection Agency, *America's Wetlands: Our Vital Link Between Land and Water*, EPA 843-K-95-001. Washington, DC: U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, December 1995.

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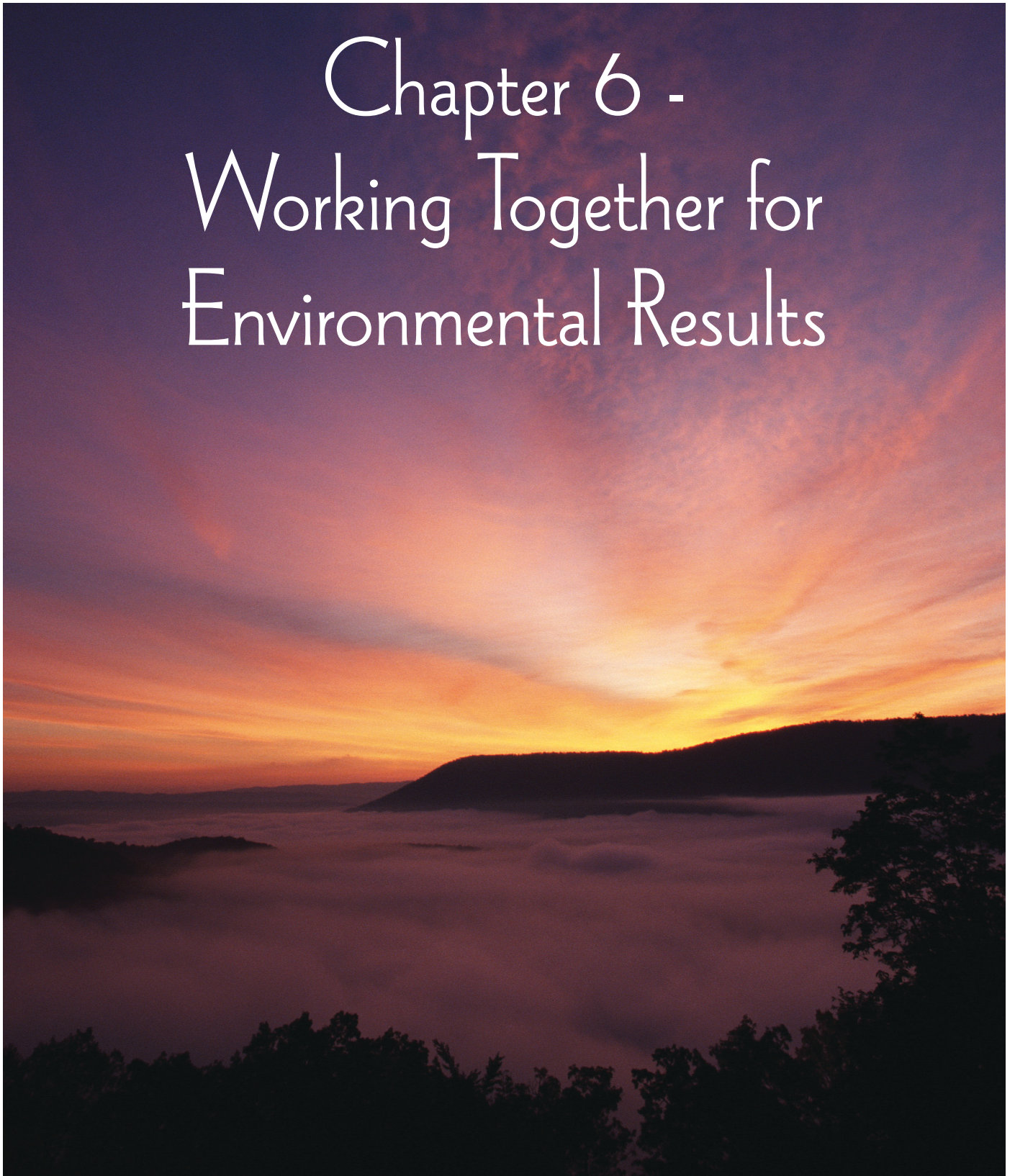
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Chapter 5 - Ecological Condition

Chapter 6 - Working Together for Environmental Results





As this report shows, the United States has made great strides in meeting environmental challenges over the past three decades. Our air is cleaner, our drinking water safer, our waste management practices more sound. The health of the American people is generally improving. Yet environmental and health challenges remain and there is much we don't know about the condition of the environment and human health. To better understand the status of and trends in the environment, and to better manage environmental protection programs, we need better indicators of environmental and human health.

Using an integrated system of local, regional, and national indicators and monitoring would strengthen our approach to protecting the environment. With such a system in place, we could better:

- Assess and document the current state of the environment at the national level and measure our progress toward reaching our environmental goals.
- Understand the relationships between stressors on the environment and their ultimate effects on ecological condition and human health.
- Focus our environmental protection resources on areas of greatest concern.
- Communicate with the American people about what is happening, why, and how best to safeguard human health and the environment.

With this picture in mind, this final chapter explores the key challenges in developing better indicators, and the next steps that EPA proposes to take with its partners to address these challenges.

Key Challenges

Developing a useful set of environmental indicators is a daunting task. EPA has identified some of the major issues that require careful consideration as a system of indicators is developed and implemented.

Addressing Data Needs to Support Better Indicators.

Because of a lack of national indicators, we cannot provide complete answers to many of the questions posed in this report. (Similarly, 44 percent of the indicators in the Heinz Center's *The State of the Nation's Ecosystems* could not be reported nationally.¹) In addition, many "national" data sets do not cover the entire country, but only a subset, such as the coastal U.S., major watersheds, or the Pacific Northwest. Further, for many indicators, data are not available for more than one time period, limiting our ability to discern a trend in environmental condition or human health. This draft report begins to identify where additional data are needed to support national indicators, but a thorough review is needed to identify data needs and to set priorities.

Improving Data Collection and Analysis. Improving how we collect and analyze data remains a significant challenge. Many government agencies and other groups gather similar environmental data to satisfy various program objectives and goals. Yet, differences—and, in some cases, inadequacies—in approaches to data collection and analysis often limit the broader use of these data. For example, states gather comprehensive data on water quality, but differences in monitoring approaches limit our ability to provide a picture of the water quality at the national level. Developing and applying standard data collection and analysis approaches are critical to ensuring comparability of data, and to enabling greater use of the extensive environmental and health data already being collected.

Chapter 6 - Working Together for Environmental Results

Reaching Agreement on an Integrated Set of Indicators.

National indicators provide a picture of the overall condition of our nation's environment and health, and inform national environmental policy. But regional and local indicators are also needed to guide regional and local policy while answering the questions Americans have about the conditions in their backyard that affect them most: Is my drinking water safe? Does the air in my community meet health standards? National, regional, and local indicators all serve important roles in informing the public and assisting governments and others in protecting our environment and human health. A major challenge before us is reaching agreement on an integrated core set of national, regional, and local indicators and putting them into practice.

Making Indicators More Understandable and Usable.

Indicators can be powerful tools, but only if they clearly communicate environmental conditions to decision-makers and the public. For example, many Americans are familiar with the color-coded alerts associated with the Air Quality Index and adjust their activity accordingly when "code red" days occur. Because of their technical nature, however, indicators often can be difficult to understand. An important challenge, therefore, is developing more indices that clearly communicate environmental conditions and trends. Further, for an indicator or index to be useful for decision-makers, thresholds or criteria distinguishing acceptable from unacceptable conditions are needed. Such thresholds or criteria currently do not exist for many indicators, and need to be identified.

Understanding Cause and Effect. Effective public policies and programs to protect the health and environment require knowing the causes of the problems they seek to correct. In some cases, current science supports causal linkages between a specific exposure and known effects on human health or ecological condition—for example, the link between exposure to environmental tobacco smoke and an increased risk of developing lung cancer. But the link between specific environmental pollutants and the effect on human health and ecological condition is complex and often difficult to describe. Understanding and quantifying causality—that is, sorting out the role of the environment and the role of other factors and their interactions—remains a significant scientific challenge.

Partnerships for Better Environmental Indicators

Addressing the challenges described above is a task far greater than EPA can undertake alone. Success requires a sustained and coordinated commitment from many partners: other federal agencies; state, tribal, and local governments; the research community; nongovernmental organizations; and industry. It will also require collaborative analysis and replication of many of the indicator projects under way nationwide, and around regional resources of great environmental importance. (For more information about such projects, see <http://www.epa.gov/indicators/>).

Such cooperative efforts are already in progress. As mentioned, many of the indicators included in this draft report were developed by other federal, state, regional, local, and tribal governments and the nonprofit sector. Additionally, in December 2002, the White House Council on Environmental Quality (CEQ) launched a new effort to enhance coordination among federal agencies and to develop policy guidance on the future development of environmental and sustainable development indicators. The CEQ working group will:

- Develop agreement around a set of national-level environmental indicators that can be linked to regional and local conditions.
- Explore opportunities for collaboration among and between federal agencies, state, regional, and local agencies, nongovernmental organizations, and private-sector groups to improve the validity, reliability, consistency, and coverage of the data used for indicators.
- Consider how statistical reporting and data collection should be organized within the federal government, recognizing the data needs of agencies' programs and statutory authorities.

The goal of this effort is to have interlocking sets of environmental and human health indicators that can inform decisions at the local, state, regional, and national levels.

Next Steps

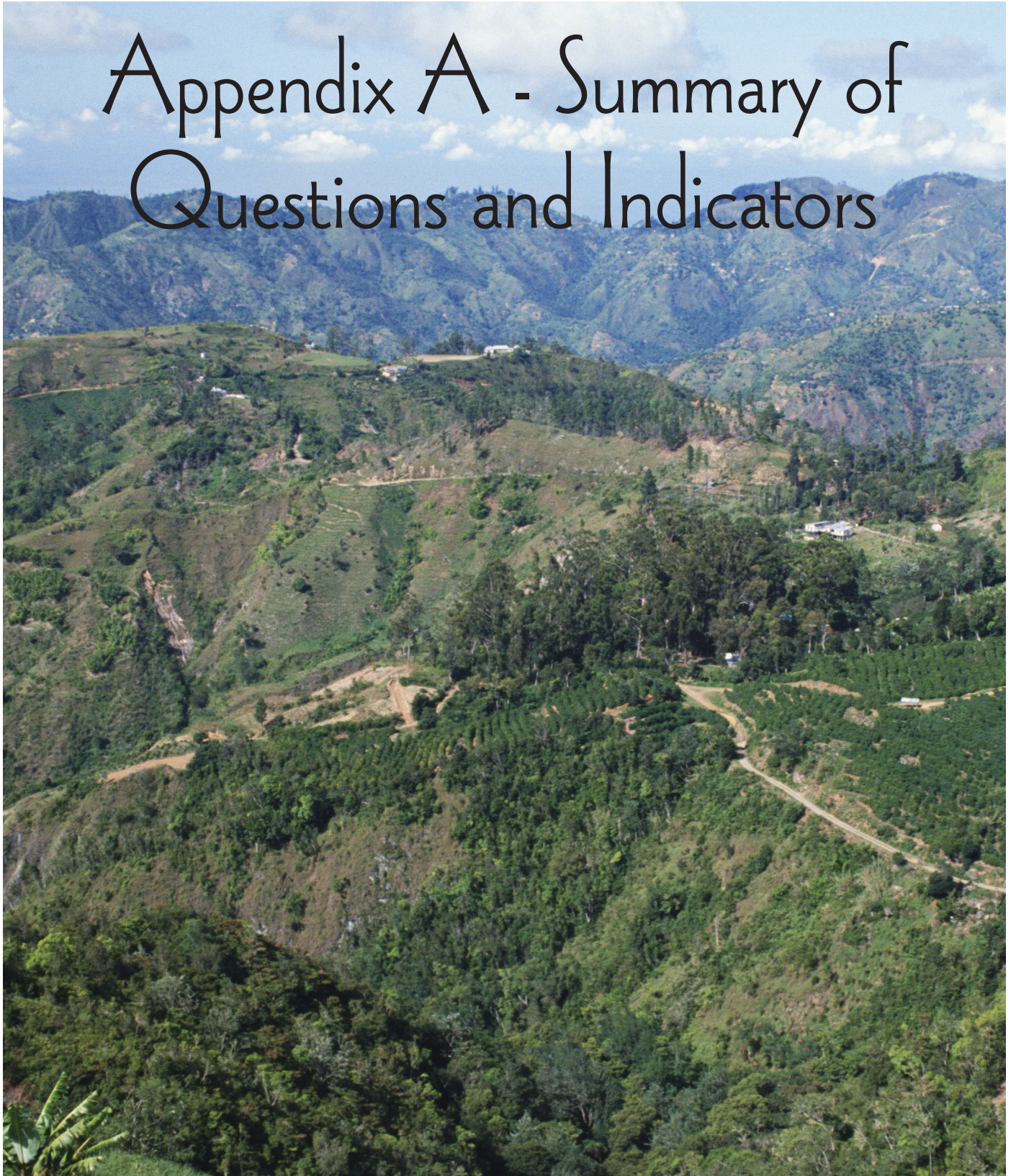
EPA is committed to being an active partner in this national effort. Within EPA, the next step is to develop—in concert with the CEQ indicators working group—a long-term strategy for environmental indicators that builds on this draft report. Key components of that strategy will be based on ideas generated by discussions with EPA's partners and the general public. Through such discussions, we intend to collaborate with other government agencies to reach agreement on an integrated set of national, regional, and local indicators and how best to put them into practice in planning and managing programs and in communicating environmental and health outcomes to the nation.

Your participation and feedback, therefore, is a vital component of the success of the Environmental Indicators Initiative. Please visit our web site at <http://www.epa.gov/indicators/>, to learn more about the Environmental Indicators Initiative activities and to provide your input. Together, we are working toward a results-based management system that will ensure cleaner air, purer water, and better protected land for generations of Americans to come.

Endnote

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Appendix A - Summary of Questions and Indicators



Cleaner Air - Summary of Questions and Indicators

Outdoor Air Quality		
Question	Indicator Name	Technical Document Reference
What is the quality of outdoor air in the United States?	Number and percentage of days that Metropolitan Statistical Areas have Air Quality Index (AQI) values greater than 100	1.1.1
	Number of people living in areas with air quality levels above the National Ambient Air Quality Standards (NAAQS) for ozone (8-hour) and Particulate Matter (PM _{2.5})	1.1.1.a
	Ambient concentrations of ozone, 8-hour	1.1.1.b
	Ambient concentrations of particulate matter (PM _{2.5})	1.1.1.b
	Visibility	1.1.1.c
	Deposition: wet sulfate and wet nitrogen	1.2.1
	Ambient concentrations of selected air toxics	1.1.1.d
What contributes to outdoor air pollution?	Emissions of particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds	1.1.2.a
	Lead emissions	1.1.2.a
	Air toxics emissions	1.1.2.b
	Emissions (utility): sulfur dioxide and nitrogen oxides	1.2.2
What human health effects are associated with outdoor air pollution?	No indicator identified. Also see Human Health Chapter.	1.1.3
What ecological effects are associated with outdoor air pollution?	No indicator identified. Also see Ecological Condition Chapter.	1.1.4 & 1.2.3
Indoor Air Quality		
What is the quality of the air in buildings in the United States?	U.S. homes above EPA's radon action levels	1.3.1
	Percentage of homes where young children are exposed to environmental tobacco smoke	1.3.1
What contributes to indoor air pollution?	No indicator identified	1.3.2
What human health effects are associated with indoor air pollution?	No indicator identified	1.3.3
Global Issues		
What is happening to the Earth's ozone layer?	Ozone levels over North America	1.4.1
What is causing changes to the ozone layer?	Worldwide and U.S. production of ozone-depleting substances	1.4.2
What human health and ecological effects are associated with stratospheric ozone depletion?	No indicator identified	1.4.3 & 1.4.4

Appendix A - Summary of Questions and Indicators

Purer Water - Summary of Questions and Indicators

Waters and Watersheds		
Question	Indicator Name	Technical Document Reference
What is the condition of waters and watersheds in the United States?	No indicator identified	2.2.1
What is the condition of coastal waters?	Water clarity in coastal waters	2.2.3
	Dissolved oxygen in coastal waters	2.2.3
What are the extent and condition of wetlands?	Wetland extent and change	2.2.2
	Sources of wetland change/loss	2.2.2
What are stressors on waters and watersheds?	Altered fresh water ecosystems	2.2.1
	Percent urban land cover in riparian areas	2.2.4.a
	Agricultural land in riparian areas	2.2.4.a
	Changing stream flows	2.2.4.a
	Atmospheric deposition of nitrogen	2.2.4.b
	Nitrate in farmland, forested, and urban streams and ground water	2.2.4.b
	Total nitrogen in coastal waters	2.2.4.b
	Phosphorus in farmland, forested, and urban streams	2.2.4.b
	Total phosphorus in coastal waters	2.2.4.b
	Phosphorus in large rivers	2.2.4.b
	Atmospheric deposition of mercury	2.2.4.c
	Chemical contaminants in streams	2.2.4.c
	Sediment contamination of inland waters	2.2.4.c
	Sediment contamination of coastal waters	2.2.4.c
	Pesticides in farmland streams, and ground water	2.2.4.c
Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs	2.2.4.c	
What ecological effects are associated with impaired waters?	Benthic Community Index (coastal waters). Also see Ecological Condition Chapter.	2.2.5
Drinking Water		
What is the quality of drinking water?	Population served by community water systems that meet all health-based standards	2.3.1
What are sources of drinking water contamination?	No indicator identified	2.3.2
What human health effects are associated with drinking contaminated water?	No indicator identified. Also see Human Health Chapter.	2.3.3
Recreation in and on the Water		
What is the condition of waters supporting recreational use?	Number of beach days that beaches are closed or under advisory	2.4.1
What are sources of recreational water pollution?	No indicator identified. Also see Ecological Condition Chapter.	2.4.2
What human health effects are associated with recreation in contaminated waters?	No indicator identified. Also see Human Health Chapter.	2.4.3
Consumption of Fish and Shellfish		
What is the condition of waters that support consumption of fish and shellfish?	Percent of river miles and lake acres under fish consumption advisories	2.5.1
	Contaminants in fresh water fish	2.5.1
	Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue	2.5.1
What are contaminants in fish and shellfish, and where do they originate?	No indicator identified	2.5.2
What human health effects are associated with consuming contaminated fish and shellfish?	No indicator identified	2.5.3

Appendix A - Summary of Questions and Indicators

Better Protected Land - Summary of Questions and Indicators

Land Use		
Question	Indicator Name	Technical Document Reference
What is the extent of developed lands?	Extent of developed lands	3.1.1
	Extent of urban and suburban lands	3.1.1
What is the extent of farmlands?	Extent of agricultural land uses	3.1.2
What is the extent of grasslands and shrublands?	Extent of grasslands and shrublands	3.1.3
What is the extent of forest lands?	Extent of forest area, ownership, and management	3.1.4
What human health effects are associated with land use?	No indicator identified	3.1.5
What ecological effects are associated with land use?	No indicator identified. Also see Ecological Condition Chapter.	3.1.6
Chemicals in the Landscape		
How much and what types of toxic substances are released into the environment?	Quantity and type of toxic chemicals released and managed	3.2.1
What are the volume, distribution, and extent of pesticide and fertilizer use?	Agricultural pesticide use	3.2.2
	Fertilizer use	3.2.3
What is the potential disposition of chemicals from land?	Pesticide residues in foods	3.2.4
	Potential pesticide runoff from farm fields	3.2.4
	Risk of nitrogen export	3.2.4
	Risk of phosphorus export	3.2.4
What human health effects are associated with pesticides, fertilizers, and toxic substances?	No indicator identified	3.2.5
What ecological effects are associated with pesticides, fertilizers, and toxic substances?	No indicator identified	3.2.6
Waste and Contaminated Lands		
How much and what types of waste are generated and managed?	Quantity of municipal solid waste (MSW) generated and managed	3.3.1
	Quantity of RCRA hazardous waste generated and managed	3.3.1
	Quantity of radioactive waste generated and in inventory	3.3.1
What is the extent of land used for waste management?	Number and location of municipal solid waste (MSW) landfills	3.3.2
	Number of RCRA hazardous waste management facilities	3.3.2
What is the extent of contaminated lands?	Number and location of Superfund National Priority List (NPL) sites	3.3.3
	Number and location of RCRA Corrective Action sites	3.3.3
What human health effects are associated with waste management and contaminated lands?	No indicator identified	3.3.4
What ecological effects are associated with waste management and contaminated lands?	No indicator identified	3.3.5

Appendix A - Summary of Questions and Indicators

Human Health - Summary of Questions and Indicators

Health Status of the United States		
Question	Indicator Name	Technical Document Reference
What are the trends and indicators for health and disease in the United States?	Life expectancy	4.3.1
	Cancer incidence	4.3.2
	Cancer mortality	4.3.2
	Cardiovascular disease mortality	4.3.2
	Cardiovascular disease prevalence	4.3.2
	Chronic obstructive pulmonary disease mortality	4.3.2
	Asthma mortality	4.3.2
	Asthma prevalence	4.3.2
	Cholera prevalence	4.3.3
	Cryptosporidiosis prevalence	4.3.3
	<i>E. coli</i> O157:H7 prevalence	4.3.3
	Hepatitis A prevalence	4.3.3
	Salmonellosis prevalence	4.3.3
	Typhoid Fever prevalence	4.3.3
Shigellosis prevalence	4.3.3	
What are the trends for children's environmental health issues?	Infant mortality	4.3.4
	Low birthweight incidence	4.3.4
	Childhood cancer mortality	4.3.4
	Childhood cancer incidence	4.3.4
	Childhood asthma mortality	4.3.4
	Childhood asthma prevalence	4.3.4
	Deaths due to birth defects	4.3.4
	Birth defect incidence	4.3.4
Environmental Pollution and Disease		
What is the role of the environment in disease?	Blood lead level	4.4.3
	Cardiovascular disease mortality	4.3.2
	Chronic obstructive pulmonary disease mortality	4.3.2
	Cholera prevalence	4.3.3
	Typhoid fever prevalence	4.3.3
Measuring Exposure to Environmental Pollution		
How can exposure data advance understanding of the role of the environment in disease?	Blood lead level	4.4.3
	Blood mercury level	4.4.3
	Blood cotinine level	4.4.4
	Urine organophosphate level to indicate pesticides	4.4.6

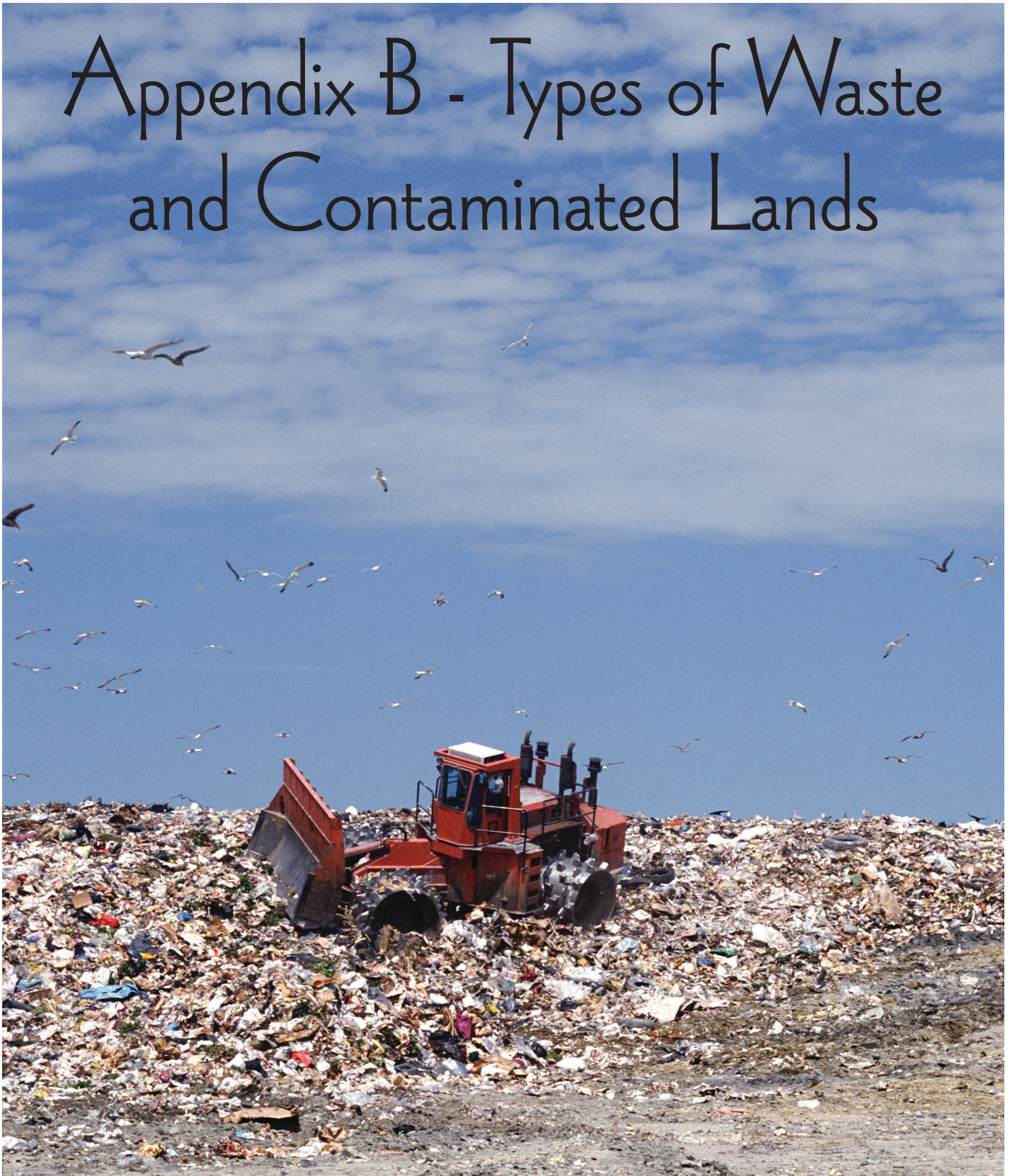
Appendix A - Summary of Questions and Indicators

Ecological Condition - Summary of Questions and Indicators

National Ecological Condition		
Question	Indicator Name	Technical Document Reference
What is the ecological condition of the United States?		5.8
Landscape Condition	Extent of ecosystem/land cover types (forests, farmlands, urban/suburban, grasslands/shrublands, fresh waters, coasts and oceans)	3.1.1, 3.1.2, 3.1.3, 3.1.4, 5.6, 5.7
Biotic Condition	At-risk native species	5.8
	Benthic Community Index	5.7
	Populations trends of invasive and native non-invasive bird species	5.4
	Tree condition	5.2
Chemical and Physical Characteristics	Nitrate levels in streams by ecosystems	2.2.4.b
Ecological Processes	Terrestrial Plant Growth Index	5.8
	Movement of nitrogen	5.8
Hydrology and Geomorphology	Changing stream flows	2.2.4.a
	Soil erosion	5.2, 5.3
Natural Disturbance Regimes	Forest disturbances: fire, insects, and disease	5.2

Appendix A - Summary of Questions and Indicators

Appendix B - Types of Waste and Contaminated Lands



Types of Waste

Type	Description
Municipal Solid Waste	Municipal Solid Waste (MSW) is the waste discarded by households, hotels/motels, and commercial, institutional, and industrial sources. MSW typically consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. It does not include waste water. In 2000, 232 million tons of MSW were generated. ¹
RCRA Hazardous Waste	The term "RCRA hazardous waste" applies to certain types of hazardous wastes that appear on EPA's regulatory listing (RCRA) or that exhibit specific characteristics of ignitability, corrosiveness, reactivity, or excessive toxicity. More than 40 million tons of RCRA hazardous waste were generated in 1999. ²
Radioactive Waste	Radioactive waste is the garbage, refuse, sludge, and other discarded material, including solid, liquid, semi-solid, or contained gaseous material that must be managed for its radioactive content. ³ The technical names for the types of waste that are considered "radioactive waste" for this report are high-level waste, spent nuclear fuel, transuranic waste, low-level waste, mixed low-level waste, and contaminated media (see Appendix D for definitions of these terms).
Extraction Wastes	Extraction activities such as mining and mineral processing are large contributors to the total amount of waste generated and land contaminated in the U.S. EPA estimates that 5 billion tons of mining wastes were generated in 1988. ⁴
Industrial Non-Hazardous Waste	Industrial non-hazardous waste is process waste associated with electric power generation and manufacturing of materials such as pulp and paper, iron and steel, glass, and concrete. This waste usually is not classified as either municipal waste or RCRA hazardous waste by federal or state laws. State, tribal, and some local governments have regulatory programs to manage industrial waste. EPA estimated that 7.6 billion tons of industrial non-hazardous wastes were generated in 1988. ⁵
Household Hazardous Waste	Most household products that contain corrosive, toxic, ignitable, or reactive ingredients are considered household hazardous waste. Examples include most paints, stains, varnishes, solvents, and household pesticides. Special disposal of these materials is necessary to protect human health and the environment, but some amount of this type of waste is improperly disposed of by pouring the waste down the drain, on the ground, in storm sewers, or by discarding the waste with other household waste as part of municipal solid waste. EPA estimates that Americans generate 1.6 million tons of household hazardous waste per year, with the average home accumulating up to 100 pounds annually. ⁶

Appendix B - Types of Waste and Contaminated Lands

Types of Waste

Type	Description
Agricultural Waste	<p>Agricultural solid waste is waste generated by the rearing of animals and the production and harvest of crops or trees. Animal waste, a large component of agricultural waste, includes waste from livestock, dairy, milk, and other animal-related agricultural and farming practices. Some of this waste is generated at sites called Confined Animal Feeding Operations (CAFOs). The waste associated with CAFOs results from congregating animals, feed, manure, dead animals, and production operations on a small land area. Animal waste and wastewater can enter water bodies from spills or breaks of waste storage structures (due to accidents or excessive rain), and non-agricultural application of manure to crop land.^{7,8} National estimates are not available.</p>
Construction and Demolition Waste	<p>Construction and demolition debris is waste generated during construction, renovation, and demolition projects. This type of waste generally consists of materials such as wood, concrete, steel, brick, and gypsum. (The MSW data in this report do not include construction and demolition debris, even though sometimes construction and demolition debris are considered MSW.) National estimates are not available.</p>
Medical Waste	<p>Medical waste is any solid waste generated during the diagnosis, treatment, or immunization of human beings or animals, in research, production, or testing. National estimates are not available.</p>
Oil and Gas Waste	<p>Oil and gas production wastes are the drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas that are conditionally exempted from regulation as hazardous wastes. National estimates are not available.</p>
Sludge	<p>Sludge is the solid, semisolid, or liquid waste generated from municipal, commercial, or industrial wastewater. National estimates are not available.</p>

Types of Contaminated Lands

Type	Description
Superfund National Priorities List Sites	Congress established the Superfund Program in 1980 to clean up abandoned hazardous waste sites throughout the U.S. The most seriously contaminated sites are on the National Priorities List (NPL). As of October 2002, there were 1,498 sites on the NPL. ⁹
RCRA Corrective Action Sites	EPA and authorized states have identified 1,714 hazardous waste management facilities that are the most seriously contaminated and may pose significant threats to humans or the environment. ¹⁰ Some RCRA Corrective Action sites are also identified by the Superfund Program as NPL sites.
Leaking Underground Storage Tanks	Many petroleum and hazardous substances are stored in underground storage tanks (USTs). EPA regulates many categories of UST systems, including those at gas stations, convenience stores and bus depots. USTs that have failed due to faulty materials, installation, operating procedures, or maintenance systems are categorized as leaking underground storage tanks (LUSTs). LUSTs can contaminate soil, ground water, and sometimes drinking water. Vapors from UST releases can lead to explosions and other hazardous situations if those vapors migrate to a confined area such as a basement. LUSTs are the most common source of groundwater contamination, and petroleum is the most common groundwater contaminant. ^{11, 12} According to EPA's corrective action reports, in 1996, there were 1,064,478 active tanks located at approximately 400,000 facilities. In 2002, there were 697,966 active tanks (a 34 percent decrease) and 1,525,402 closed tanks (a 42 percent increase). The number of national USTs within each area of the U.S. has not fluctuated significantly between 1996–2001. As of the fall of 2002, 427,307 UST releases (LUSTs) were confirmed. ¹³
Accidental Spill Sites	Each year, thousands of oil and chemical spills occur on land and in water. Oil and gas materials that have spilled include drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas. Accurate national spill data are not available.
Land contaminated with radioactive and other hazardous materials	Approximately 0.54 million acres of land spanning 129 sites in over 30 states are contaminated with radioactive and other hazardous materials as a result of activities associated with nuclear weapons production and research. Although DOE is the landlord at most of these sites, other parties, including other federal agencies, private parties, and one public university, also have legal responsibilities over these lands. ¹⁴
Brownfields	Brownfields are real property, the expansion, redevelopment or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminate. ¹⁵ Brownfields are often found in and around economically depressed neighborhoods. As brownfields are cleaned and redeveloped, surrounding communities benefit from a reduction of health and environmental risks, more functional space, and improved economic conditions. A complete inventory of brownfields does not exist. According to the General Accounting Office (1987), there are approximately 450,000 brownfields nationwide. ¹⁶ The EPA's national Brownfield tracking system includes a large volume of data on brownfields across the nation, but does not track all of them. EPA's Brownfield Assessment Pilot Program includes data collected from over 400 pilot communities. ¹⁷

Appendix B - Types of Waste and Contaminated Lands

Types of Contaminated Lands

Type	Description
Some Military Bases	Some (exact number or percentage unknown) military bases are contaminated as a result of a variety of activities. A national assessment of land contaminated at military bases has not been conducted. However, under the Base Realignment and Closure (BRAC) laws, closed military bases undergo site investigation processes to determine extent of possible contamination and the need for site cleanup. Currently, 204 military installations that have been closed or realigned are undergoing environmental cleanup. These installations collectively occupy over 400,000 acres, though not all of this land is contaminated. Thirty-six of these installations are on the Superfund NPL list, and, of these, 32 are being cleaned up under the Fast Track program to make them available for other uses as quickly as possible. ¹⁸
Waste management sites that were poorly designed or poorly managed	Prior to the 1970s, untreated waste was typically placed in open pits or directly onto the land. Some of these early waste management sites are still contaminated. In other cases, improper management of facilities (that were typically used for other purposes such as manufacturing) resulted in site contamination. Federal and state cleanup efforts are now addressing those early land disposal units and poorly-managed sites that are still contaminated.
Illegal dumping sites	Also known as "open dumping" or "midnight dumping," illegal dumping of such materials as construction waste, abandoned automobiles, appliances, household waste, and medical waste raises concerns for safety, property values, and quality of life. People tend to dump illegally because legal dumping costs money and/or is inconvenient. While a majority of illegally dumped waste is not hazardous, some of it is, creating contaminated lands.
Abandoned mine lands	Abandoned mine lands are sites that have historically been mined and have not been properly cleaned up. These abandoned or inactive mine sites may include disturbances or features ranging from exploration holes and trenches to full blown, large-scale mine openings, pits, waste dumps, and processing facilities. The Department of the Interior's (DOI) Bureau of Land Management (BLM) is presently aware of approximately 10,200 abandoned hardrock mines located within the roughly 264 million acres under its jurisdiction. Various government and private organizations have made estimates over the years about the total number of abandoned and inactive mines in the U.S., including estimates for the percent land management agencies, and State and privately-owned lands. Those estimates range from about 80,000 to hundreds of thousands of small to medium-sized sites. The BLM is attempting to identify, prioritize, and take appropriate actions on those historic mine sites that pose safety risks to the public or present serious threats to the environment. ¹⁹

Appendix B - Endnotes

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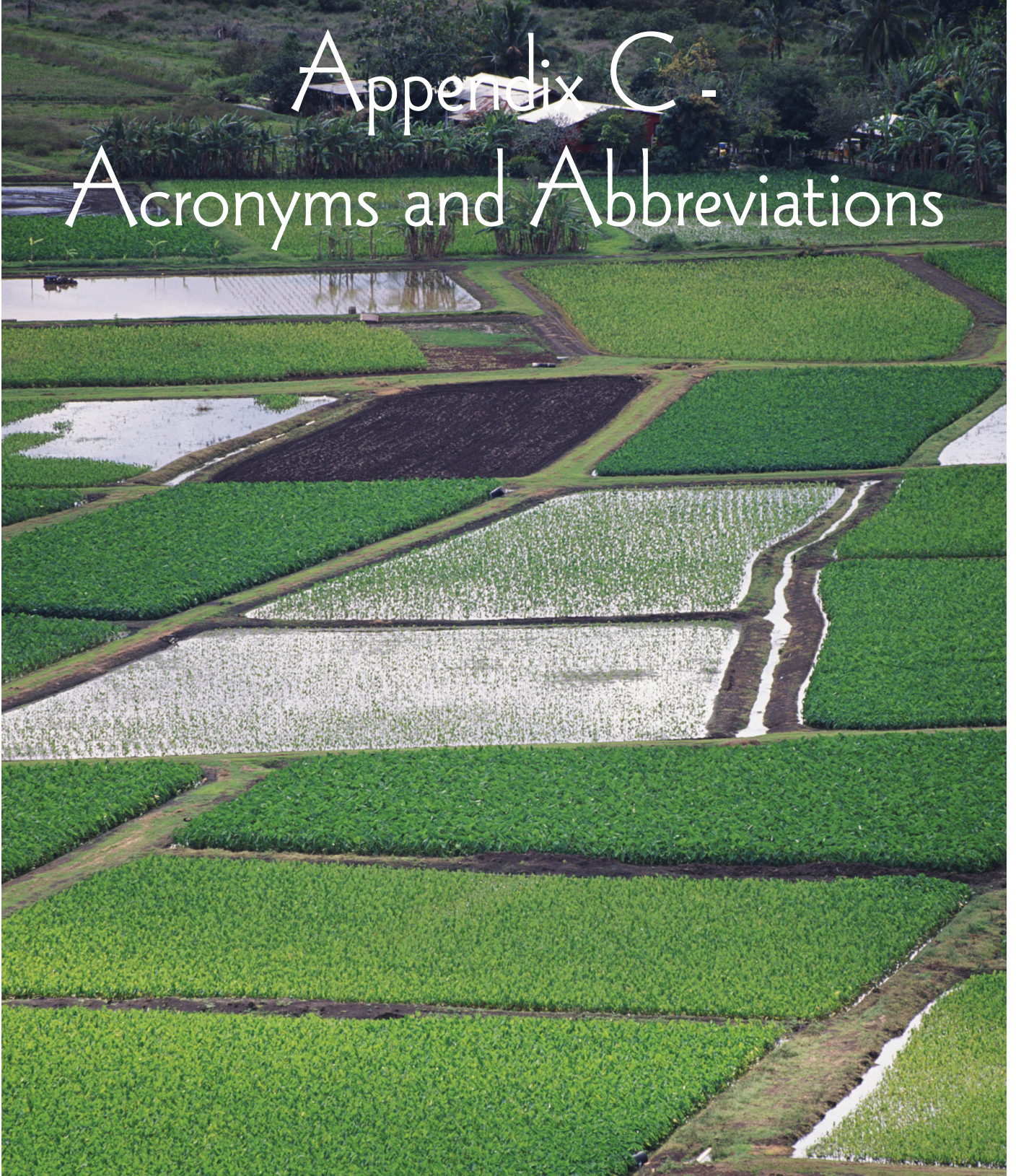
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Appendix B - Types of Waste and Contaminated Lands

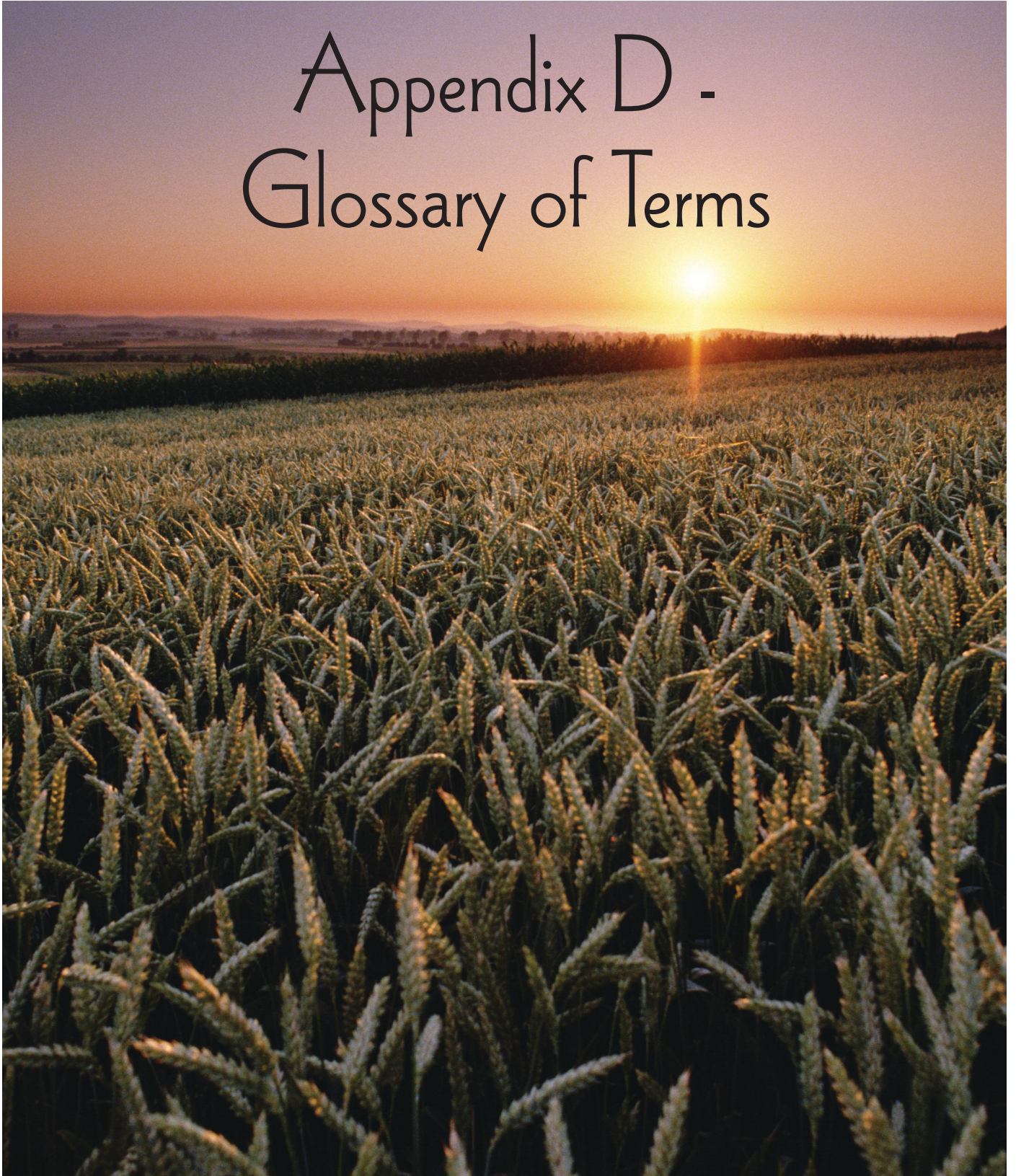
Appendix C - Acronyms and Abbreviations



AQI: Air Quality Index	NOAA: National Oceanic and Atmospheric Administration
BASE: Building Assessment Survey and Evaluation	NPL: National Priorities List
BEACH: Beaches Environmental Assessment and Coastal Health Program	NRCS: Natural Resources Conservation Service
CDC: Centers for Disease Control and Prevention	NRI: National Resources Inventory
CO: carbon monoxide	PBTs: persistent bioaccumulative toxics
COPD: chronic obstructive pulmonary disease	PCBs: polychlorinated biphenyls
CRP: Conservation Reserve Program	PDP: Pesticides Data Program
CWA: Clean Water Act	POPs: persistent organic pollutants
CWS: community water system	PM_{2.5}: particulate matter less than or equal to 2.5 micrometers in diameter
DDT: dichlorodiphenyl trichlorethane	PM₁₀: particulate matter less than or equal to 10 micrometers in diameter
EMAP: Environmental Monitoring and Assessment Program	POPs: persistent organic pollutants
EPA: Environmental Protection Agency	RCRA: Resource Conservation and Recovery Act
ETS: environmental tobacco smoke	SAB: EPA Science Advisory Board
GLFMP: Great Lakes Fish Monitoring Program	SAV: submerged aquatic vegetation
IBI: index of biotic integrity	SO₂: sulfur dioxide
IQ: intelligence quotient	TESS: Toxic Exposure Surveillance System
LUST: leaking underground storage tank	TRI: Toxics Release Inventory
MBSS: Maryland Biological Stream Survey	USDA: U.S. Department of Agriculture
MSW: municipal solid waste	USGS: U.S. Geological Survey
NAWQA: National Water Quality Assessment Program	UST: underground storage tank
NCFAP: National Center for Food and Agricultural Policy	UV: ultraviolet radiation
NEI: National Emissions Inventory	VOCs: volatile organic compounds
NLCD: National Land Cover Dataset	WBDO: waterborne disease outbreak
NO₂: nitrogen dioxide	WMPC: waste minimization priority chemicals
NO_x: nitrogen oxides	

Appendix C - Acronyms and Abbreviations

Appendix D - Glossary of Terms



A complete glossary reference list can be found in EPA's Report on the Environment Technical Document, Appendix E.

A

acid deposition: A complex chemical and atmospheric phenomenon that occurs when emissions of sulfur and nitrogen compounds are transformed by chemical processes in the atmosphere and then deposited on earth in either wet or dry form. The wet forms, often called "acid rain," can fall to earth as rain, snow, or fog. The dry forms are acidic gases or particulate matter.

advisory: A nonregulatory document that communicates risk information to those who may have to make risk management decisions.

aerosol: 1. Small droplets or particles suspended in the atmosphere, typically containing sulfur. They are emitted naturally (e.g., in volcanic eruptions) and as a result of human activities such as burning fossil fuels. 2. The pressurized gas used to propel substances out of a container.

agricultural waste: Byproducts generated by the rearing of animals and the production and harvest of crops or trees. Animal waste, a large component of agricultural waste, includes waste (e.g., feed waste, bedding and litter, and feedlot and paddock runoff) from livestock, dairy, and other animal-related agricultural and farming practices.

air pollutant: Any substance in air that could, in high enough concentration, harm man, other animals, vegetation, or material. Pollutants may include almost any natural or artificial composition of matter capable of being airborne. It may be in the form of solid particles, liquid droplets, gases, or a combination thereof. Generally, they fall into two main groups: (1) those emitted directly from identifiable sources and (2) those produced in the air by interaction between two or more primary pollutants, or by reaction with normal atmospheric con-

stituents, with or without photoactivation. Exclusive of pollen, fog, and dust, which are of natural origin, about 100 contaminants have been identified. Air pollutants are often grouped in categories for ease in classification; some of the categories are: solids, sulfur compounds, volatile organic chemicals, particulate matter, nitrogen compounds, oxygen compounds, halogen compounds, radioactive compound, and odors.

air pollution: The presence of contaminants or pollutant substances in the air that interfere with human health or welfare or produce other harmful environmental effects.

air quality criteria: The levels of pollution and lengths of exposure above which harmful health and welfare effects may occur.

air quality standards: The level of pollutants prescribed by regulations that are not to be exceeded during a given time in a defined area.

air toxics: Air pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Examples of toxic air pollutants include benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries.

algal blooms: Sudden spurts of algal growth, which can degrade water quality and indicate potentially hazardous changes in local water chemistry.

ambient air: Any unconfined portion of the atmosphere; open air, surrounding air.

ambient air quality standards: See criteria pollutants and National Ambient Air Quality Standards.

anthropogenic: Originating from humans, not naturally occurring.

aquatic ecosystems: Salt water or fresh water ecosystems, includes rivers, streams, lakes, wetlands, estuaries, and coral reefs.

aquifer: An underground geological formation, or group of formations, containing water; source of ground water for wells and springs.

arsenic: A silvery, nonmetallic element that occurs naturally in rocks, soil, water, air, and plants and animals. It can be released into the environment through natural activities such as volcanic action, erosion of rocks, and forest fires or through human actions. Approximately 90 percent of industrial arsenic in the U.S. is used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps, and semiconductors. Agricultural applications (used in rodent poisons and some herbicides), mining, and smelting also contribute to arsenic releases in the environment. It is a known human carcinogen.

asbestos: Naturally occurring strong, flexible fibers that can be separated into thin threads and woven. These fibers resist heat and chemicals and do not conduct electricity. Asbestos is used for insulation, making automobile brake and clutch parts, and many other products. These fibers break easily and form a dust composed of tiny particles that are light and sticky. When inhaled or swallowed they can cause health problems.

assemblage: The association of interacting populations of organisms in a selected habitat.

B

beach day: A day that a beach would normally be open to the public.

benthic: Occurring at or near the bottom of a body of water.

benthic organisms: The worms, clams, crustaceans, and other organisms that live at the bottom of the estuaries and the sea.

benthos: In fresh water and marine ecosystems, organisms attached to, resting on, or burrowed into bottom sediments.

bioaccumulation: A process whereby chemicals (e.g., DDTs, PCBs) are retained by plants and animals and increase in concentration over time. Uptake can occur through feeding or direct absorption from water or sediments.

biodiversity: The variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. The term encompasses three basic levels of biodiversity: ecosystems, species, and genes.

biological diversity: See *biodiversity*.

biomass: All of the living material in a given area; often refers to vegetation.

biomonitoring: The assessment of human exposure to chemicals by measuring the chemicals or their metabolites (break-down products) in human tissues or fluids such as blood or urine. Blood and urine levels reflect the amount of the chemical in the environment that actually gets into the body.

biotic: Refers to living organisms.

biotic condition: The state of living things.

biotic integrity: The ability to support and maintain balanced, integrated functionality in the natural habitat of a given region.

body burden: The amount of various contaminants retained in a person's tissues.

brownfield: Real property, the expansion, redevelopment or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.

C

cadmium: A metal found in natural deposits as ores containing other elements. The greatest use of cadmium is primarily for metal plating and coating operations, including transportation equipment, machinery and baking enamels, photography, and television phosphors. It is also used in nickelcadmium and solar batteries and in pigments.

carcinogen: An agent that causes cancer.

chained dollars: A measure used to adjust for the effects of inflation in the U.S. currency from year to year, such that a consistent monetary value can be understood over time. A chained dollar is based on the average weights of the cost of goods and services in successive pairs of years. It is “chained” because the second year in each pair, with its weights, becomes the first year of the next pair.

chlorine: A greenish-yellow gas that is slightly soluble in water. Chlorine is often used in disinfection of water and treatment of sewage effluent as well as in the manufacture of products such as antifreeze, rubber, and cleaning agents.

chromium: A heavy metal that occurs naturally in rocks, plants, soil, and volcanic dust and gases. It is tasteless and odorless. It can damage living things at low concentrations and tends to accumulate in the food chain.

cleanup: Action taken to deal with a release or threat of release of a hazardous substance that could affect humans, the environment, or both. The term “cleanup” is sometimes used interchangeably with the terms “remedial action,” “removal action,” “response action,” or “corrective action.”

coastal and ocean ecosystem: An ecosystem that consists primarily of estuaries and ocean waters under a country's jurisdiction. U.S. waters extend to the boundaries of the U.S. Exclusive Economic Zone, 200 miles from the U.S. coast.

coastal wetland: Ecosystem found along the coasts and closely linked to the nation's estuaries, where sea water mixes with fresh water to form an environment of varying salinities. The plants in coastal wetlands have adapted to fluctuating water levels and salinities to create tidal salt marshes, mangrove swamps, and tidal fresh water wetlands, which form beyond the upper edges of tidal salt marshes where the influence of salt water ends. Fresh water coastal wetlands can also be found adjacent to the Great Lakes.

community water system: A public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

construction and demolition debris: Waste generated during building, renovation, and wrecking projects. This type of waste generally consists of materials such as wood, concrete, steel, brick, and gypsum.

contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.

contaminated land: Ground that has been polluted with hazardous materials and requires cleanup or remediation. Contaminated sites may contain both polluted objects (e.g., buildings, machinery) and land (e.g., soil, sediments, and plants).

contaminated media: Materials such as soil, sediment, water, and sludge that are polluted at levels requiring cleanup or further assessment.

contamination: Introduction into water, air, or soil of microorganisms, chemicals, toxic substances, wastes, or waste

water in a concentration that makes the medium unfit for its next intended use. Also applies to surfaces of objects, buildings, and various household and agricultural use products.

conterminous: Enclosed within one common boundary (e.g., the 48 conterminous states).

cotinine: A breakdown product (metabolite) of nicotine that can be measured in urine.

criteria air pollutants: A group of six widespread and common air pollutants regulated by the EPA on the basis of standards set to protect public health or the environment. These six criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

cropland: A National Resources Inventory land cover/use category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland comprises land in row crops or close-grown crops and also other cultivated cropland, for example, hayland or pastureland that is in a rotation with row or close-grown crops. Noncultivated cropland includes permanent hayland and horticultural cropland.

D

designated uses: Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act. Uses can include fishing, shellfish harvesting, public water supply, swimming, boating, and irrigation.

developed land: A combination of National Resource Inventory land cover/use categories: large urban and built-up areas, small built-up areas, and rural transportation land.

dioxin: A group of chemically similar compounds, known chemically as dibenzo-p-dioxins, that are created inadvertent-

ly during combustion, chlorine bleaching of pulp and paper, and some types of chemical manufacturing. Tests on laboratory animals indicate that it is one of the more toxic anthropogenic (manmade) compounds.

disinfection by-product: A compound formed by the reaction of a disinfectant such as chlorine with organic material in the water supply; a chemical byproduct of the disinfection process.

dry deposition: The settling of gases and particles out of the atmosphere. Dry deposition is a type of acid deposition, more commonly referred to as "acid rain."

E

ecological indicators: Measurable characteristics related to the structure, composition, or functioning of ecological systems; a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components; any expression of the environment that quantitatively estimates the condition of ecological resources, the magnitude of stress, the exposure of biological components to stress, or the amount of change in condition.

ecological processes: The metabolic functions of ecosystems—energy flow, elemental cycling, and the production, consumption, and decomposition of organic matter.

ecosystem: 1. The interacting system of a biological community and its nonliving environmental surroundings. 2. A geographic area including all living organisms (people, plants, animals, and microorganisms), their physical surroundings (such as soil, water and air), and the natural cycles that sustain them.

emissions standard: The maximum amount of air-polluting discharge legally allowed from a single source, mobile or stationary.

endangered species: Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (human-caused) or natural changes in their environment. Requirements for declaring a species “endangered” are contained in the Endangered Species Act.

enrichment: The addition of nutrients (e.g., nitrogen, phosphorus, carbon compounds) from sewage effluent, agricultural or urban runoff, or other sources to surface water. Enrichment greatly increases the growth potential for algae and other aquatic plants.

environmental indicators: Scientific measurements that track help measure over time the state of air, water, and land resources, pressures on those resources, and resulting effects on ecological condition and human health. Indicators show progress in making the air cleaner and the water purer and in protecting land.

environmental tobacco smoke (ETS): A mixture of smoke exhaled by a smoker and the smoke from the burning end of a smoker's cigarette, pipe, or cigar. Also known as secondhand smoke.

erosion: The wearing away of land surface by wind or water, intensified by land-clearing practices related to farming, residential or industrial development, road building, or logging.

estuaries: Partially enclosed bodies of water (this term includes bays, sounds, lagoons, and fjords); they are generally considered to begin at the upper end of tidal or saltwater influence and end where they meet the ocean.

eutrophic: Pertaining to a lake or other body of water characterized by large nutrient concentrations, resulting in high productivity of algae.

eutrophication: The slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears. During the later stages of this process, the water

body is choked by abundant plant life that result from higher levels of nutritive compounds such as nitrogen and phosphorus. Human activities can accelerate the process.

extraction waste: Byproducts produced as a result of mining practices.

F

farmlands: Include both croplands lands used for production of annual and perennial crops and livestock and on the surrounding landscape, which includes field borders and windbreaks, small woodlots, grassland or shrubland areas, wetlands, farmsteads, small villages and other built-up areas, and similar areas within and adjacent to croplands.

fertilizers: Supplements to improve plant growth that are commonly used on agricultural lands, as well as in urban, industrial, and residential settings.

fish kill: A large-scale die-off of fish caused by factors such as pollution, noxious algae, harmful bacteria, and hypoxic conditions.

flora: Plant or bacterial life.

forage: Food for animals especially when taken by browsing or grazing.

forests: Lands at least 10 percent covered by trees of any size, at least one acre in extent. This includes areas in which trees are intermingled with other cover, such as chaparral and pinyon, juniper areas in the Southwest, and both naturally regenerating forests and areas planted for future harvest (plantations or tree farms).

forest land: Land that is at least 10 percent stocked by forest trees of any size, including land that formerly had tree cover and that will be naturally or artificially regenerated. The minimum area for classification of forest land is one acre.

Appendix D - Glossary of Terms

fresh water systems: Include:

- Rivers and streams, including those that flow only part of the year
- Lakes, ponds, and reservoirs, from small farm ponds to the Great Lakes
- Ground water, which is often directly connected to rivers, streams, lakes, and wetlands
- Fresh water wetlands, including forested, shrub, and emergent wetlands (marshes), and open water ponds
- Riparian areas—the usually vegetated margins of streams and rivers (although this term can also apply to lake margins).

G

grasslands and shrublands: Lands in which the dominant vegetation is grasses and other nonwoody vegetation, or where shrubs (with or without scattered trees) are the norm (also called rangelands); includes bare-rock deserts, alpine meadows, arctic tundra, pastures, and haylands (an overlap with the farmland system). Less-managed pastures and haylands fit well within the grassland/shrubland system; more heavily managed ones fit well as part of the farmlands system.

groundlevel ozone: See *ozone*.

ground water: Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

H

habitat: The place where a population (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and nonliving.

hazardous waste: Byproducts of society that can pose a substantial or potential threat to human health or the environment when improperly managed. Hazardous waste possesses at least one of four characteristics: ignitability, corrosivity, reactivity, or toxicity.

health outcomes: An outcome measured by the quality of life, likelihood of disease, life expectancy and overall health of individuals or communities.

heavy metals: Metallic elements with high atomic weights (e.g., mercury, chromium, cadmium, arsenic, lead); can damage living things at low concentrations and tend to accumulate in the food chain.

herbicide: A form of pesticide used to control weeds that limit or inhibit the growth of the desired crop.

high-level radioactive waste: Highly radioactive material produced as a byproduct of the reactions that occur inside nuclear reactors. High-level waste takes one of two forms: spent (used) reactor fuel; waste materials remaining after spent fuel is reprocessed.

household hazardous waste: Hazardous products used and disposed of by residential rather than industrial consumers. It includes paints, stains, varnishes, solvents, pesticides, and other materials or products containing volatile chemicals that can catch fire, react, or explode, or are corrosive or toxic.

hydrologic cycle: Movement or exchange of water between the atmosphere and earth.

hypoxia/hypoxic waters: Waters with low levels of dissolved oxygen concentrations, typically less than two ppm, the level generally accepted as the minimum required for most marine life to survive and reproduce.

I

impervious surface: A hard surface area that either prevents or retards the entry of water into the soil mantle or causes water to run off the surface in greater quantities or at an increased rate of flow. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, and gravel roads.

incidence rate of disease: The number of new cases of a disease or condition in a given period of time in a specified population.

indoor air: The breathable air inside a habitable structure or conveyance.

indoor air pollution: Chemical, physical, or biological contaminants in indoor air.

industrial waste: Process waste associated with manufacturing. This waste usually is not classified as either municipal waste or hazardous waste by federal or state laws.

industrial non-hazardous waste: Process waste associated with generation of electric power and manufacture of materials such as pulp and paper, iron and steel, glass, and concrete. This waste usually is not classified as either municipal waste or hazardous waste by federal or state laws.

infant mortality: The death of children in the first year of life.

invasive species: See *nonnative species*.

K-L

land cover: The ecological status and physical structure of the vegetation on the land surface.

land use: Describes how a piece of land is managed or used by humans. The degree to which the land reflects human activities (e.g., residential and industrial development, roads, mining, timber harvesting, agriculture, grazing, etc.).

landfills: 1. Sanitary landfills: Disposal sites for nonhazardous solid wastes spread in layers, compacted to the smallest practical volume, and covered by material applied at the end of each operating day. 2. Secure chemical landfills: Disposal sites for hazardous waste, selected and designed to minimize the chance of release of hazardous substances into the environment.

landscape: The traits, patterns, and structure of a specific geographic area, including its biological composition, its physical environment, and its anthropogenic or social patterns. An area where interacting ecosystems are grouped and repeated in similar form.

landscape condition: The extent, composition, and pattern of habitats in a landscape.

large urban built-up areas: A National Resources Inventory land cover/use category composed of developed tracts of at least 10 acres, meeting the definition of urban and built-up areas.

leaching: The process by which soluble materials in the soil, such as nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

lead: A heavy metal used in many materials and products. It is a natural element and does not break down in the environ-

Appendix D - Glossary of Terms

ment. When absorbed into the body, it can be highly toxic to many organs and systems.

levee: A natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.

lichen: Any of numerous complex thallophytic plants made up of an alga and a fungus growing in symbiotic association on a solid surface (e.g., a rock).

life expectancy: The probable number of years (or other time period) that members of a particular age class of a population are expected to live, based on statistical studies of similar populations in similar environments.

life expectancy (at birth): The average number of years that a group or cohort of infants born in the same year are expected to live.

low birth weight: Refers to children born weighing less than 2,500 grams (5.5 pounds).

low-level waste: Radioactive waste, including accelerator produced waste, that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in the Atomic Energy Act of 1954), or naturally occurring radioactive material.

M

media: Specific environments—air, water, soil—that are the subject of regulatory concern and activities.

medical waste: Any solid waste generated during the diagnosis, treatment, or immunization of human beings or animals, in research, production, or testing.

mercury: A metallic element that occurs in many forms and in combination with other elements. When combined with car-

bon, which readily occurs in water, it forms more bioavailable organic mercury compounds (e.g., methylmercury).

metabolites: Compounds that result from human digestion (metabolism) of contaminants and that serve as biomarkers of exposure.

microorganisms: Tiny life forms that can be seen only with the aid of a microscope. Some microorganisms can cause acute health problems when consumed; also known as microbes.

mobile sources: Moving objects that release pollution from combustion of fossil fuels, such as cars, trucks, buses, planes, trains, lawn mowers, construction equipment, and snowmobiles. Some mobile sources, such as some construction equipment or movable diesel generators, are called nonroad sources, because they are usually operated off road.

morbidity: Sickness, illness, or disease that does not result in death.

mortality: Death rate.

mortality rate: The proportion of the population who die of a disease, often expressed as a number per 100,000.

municipal solid waste: Waste discarded by households, hotels/motels, and commercial, institutional, and industrial sources. It typically consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. It does not include waste water.

N

National Ambient Air Quality Standards: Standards established by EPA under the Clean Air Act that apply to outdoor air throughout the country. See *criteria pollutants*.

nitrate: The primary chemical form of nitrogen in most aquatic systems; occurs naturally; a plant nutrient and fertilizer; can be harmful to humans and animals.

nitric oxide (NO): A gas formed by combustion under high temperature and high pressure in an internal combustion engine; it is converted by sunlight and photochemical processes in ambient air to nitrogen oxide. NO is a precursor of ground level ozone pollution, or smog.

nitrogen dioxide (NO₂): The result of nitric oxide combining with oxygen in the atmosphere; major component of photochemical smog.

nitrogen oxides (NO_x): The result of photochemical reactions of nitric oxide in ambient air; major component of photochemical smog. Product of combustion from transportation and stationary sources and a major contributor to the formation of ozone in the troposphere and to acid deposition.

non-community water system: A public water system that is not a community water system. Nontransient noncommunity water systems are those that regularly supply water to at least 25 of the same people at least six months per year but not year-round (e.g., schools, factories, office buildings, and hospitals that have their own water systems). Transient noncommunity water systems provide water in a place where people do not remain for long periods of time (e.g., a gas station or campground).

non-hazardous waste: See *solid waste*.

non-isolated intermediaries: An intermediate compound in a chemical manufacturing process that can be a by-product or can be released as a result of the process.

nonnative species: A species that has been introduced by human action, either intentionally or by accident, into areas outside its natural geographical range. Other names for these species include alien, exotic, introduced, and nonindigenous.

nonpoint source pollution: Pollution that occurs when rain-fall, snowmelt, or irrigation water runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, coastal waters, or ground water. Types of pollution include sediments, nutrients, pesticides, pathogens (bacteria and viruses), toxic chemicals and heavy metals that runoff from agricultural land, urban development, and roads.

nutrient: Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus, but is also applied to other essential and trace elements.

nutrient enrichment: See *eutrophication*.



oil and gas production wastes: Drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas that are conditionally exempted from regulation as hazardous wastes.

organic matter: Plant and animal material that is in the process of decomposing. When it has fully decomposed, it is called "humus." This humus is important for soil structure because it holds individual mineral particles together in clusters.

organophosphate: Pesticides that contain phosphorus; shortlived, but some can be toxic when first applied.

ozone: A very reactive form of oxygen that is a bluish irritating gas of pungent odor. It is formed naturally in the atmosphere by a photochemical reaction and is a beneficial component of the upper atmosphere. It is also a major air pollutant in the lower atmosphere, where it can form by photochemical reactions when there are conditions of air pollutants, bright sunlight, and stagnant weather.

Appendix D - Glossary of Terms

ozone depletion: Destruction of the stratospheric ozone layer, which shields earth from ultraviolet radiation harmful to life. This destruction of ozone is caused by the breakdown of certain compounds that contain chlorine, bromine, or both (chlorofluorocarbons or halons), which occurs when they reach the stratosphere and then catalytically destroy ozone molecules.

ozone hole: A well-defined, large-scale area of significant thinning of the ozone layer. It occurs over Antarctica each spring.

ozone layer: The protective stratum in the atmosphere, about 15 miles above the ground, that absorbs some of the sun's ultraviolet rays, thereby reducing the amount of potentially harmful radiation that reaches earth's surface.

ozone precursors: Chemicals that contribute to the formation of ozone.

P

particulate matter: Solid particles or liquid droplets suspended or carried in the air (e.g., soot, dust, fumes, mist).

passive smoking: Exposure to tobacco smoke, or the chemicals in tobacco smoke, without actually smoking. It usually refers to a situation where a nonsmoker inhales smoke emitted into the environment by other people smoking. This smoke is known as "environmental tobacco smoke" (ETS).

pastureland: A National Resources Inventory land cover/use category of land managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. For the NRI, it includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

pathogen: Microorganism (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals, and plants.

persistent organic pollutants: Chemicals that endure in the environment and bioaccumulate as they move up through the food chain. They include organochlorine pesticides, polychlorinated biphenyls (PCBs), dioxins, and furans.

pesticides: Any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any pest. Pests can be insects, mice and other animals, unwanted plants (weeds), fungi, or microorganisms such as bacteria and viruses. Though often misunderstood to refer only to insecticides, the term "pesticide" also applies to herbicides, fungicides, and various other substances used to control pests. Under U.S. law, a pesticide is also any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

phosphorus: An essential chemical food element that can contribute to the eutrophication of lakes and other water bodies. Increased phosphorus levels result from discharge of phosphorus containing materials into surface waters.

photosynthesis: The manufacture by plants of carbohydrates and oxygen from carbon dioxide mediated by chlorophyll in the presence of sunlight.

phytoplankton: That portion of the plankton community composed of tiny plants (e.g., algae, diatoms).

PM_{2.5}: Fine particles that are less than or equal to 2.5 micrometers in diameter.

PM₁₀: Particles less than or equal to 10 micrometers in diameter.

point source pollution: Effluent or discharges directly from a pipe into a waterway (e.g., from many industries and sewage treatment plants).

pollutant: Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.

pollution: Generally, the presence of a substance in the environment that, because of its chemical composition or quantity, prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the manmade or man-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media.

polychlorinated biphenyls (PCBs): A group of synthetic chemicals that can exist as oily liquids and waxy solids. They have been commercially used in electrical transformers and capacitors, hydraulic equipment, paint elasticizers, plastics, rubber products, pigments, dyes, and carbonless copy paper. PCBs can produce toxic effects and are probable carcinogens.

pressure: See *stressor*.

prevalence of disease: That part of the total population affected by a condition or disease.

production capacity: Chlorophyll per unit area for terrestrial ecosystems (including wetlands and riparian areas) and per unit volume for aquatic ecosystems.

productivity: The rate at which ecosystems use energy (principally solar energy) to fix atmospheric carbon dioxide.

R

radioactive waste: Garbage, refuse, sludge, and other discarded material, including solid, liquid, semisolid, or contained gaseous material that must be managed for its radioactive content. Types of radioactive waste include high-level waste, spent nuclear fuel, transuranic waste, low-level waste, mixed lowlevel waste, and contaminated media.

radon (Rn-222): A naturally occurring radioactive gas that has no color, odor, or taste and is chemically inert. Radon comes from the radioactive decay of uranium in soil, rock, and ground water and is found all over the U.S. It has a half-life of 3.8 days, emitting ionizing radiation (alpha particles) during its radioactive decay to several radioactive isotopes known as "radon decay products." It gets into indoor air primarily from soil under homes and other buildings. Radon is a known human lung carcinogen and represents the largest fraction of the public's exposure to natural radiation.

rangelands: A National Resources Inventory land cover/use category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland.

rare and at-risk species: Rare species are those that are particularly vulnerable to both human-induced threats and natural fluctuations and hazards. At-risk species are those classified by the Association for Biodiversity Information as vulnerable or more rare.

RCRA hazardous waste: Applies to certain types of hazardous wastes that appear on EPA's regulatory listing (RCRA) or that exhibit specific characteristics of ignitability, corrosiveness, reactivity, or excessive toxicity.

remediation: Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a contaminated site.

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risk: The probability that a health problem, injury, or disease will occur.

risk factor: A characteristic (e.g., race, sex, age, obesity) or variable (e.g., smoking, occupational exposure level) associated with increased probability of an adverse effect.

runoff: That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

rural transportation land: A National Resources Inventory land cover/use category that consists of all highways, roads, railroads, and associated right-of-ways outside urban and built-up areas; including private roads to farmsteads or ranch headquarters, logging roads, and other private roads, except field lanes.

S

secondhand smoke: See *environmental tobacco smoke*.

sedimentation: The process of forming or depositing sediment; letting solids settle out of wastewater by gravity during treatment.

sludge: Solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial wastewater facility.

small built-up areas: A National Resources Inventory land cover/use category consisting of developed land units of 0.25 to 10 acres, which meet the definition of urban and built-up areas.

solid waste: Nonliquid, nonsoluble materials ranging from municipal garbage to industrial wastes that contain complex and sometimes hazardous substances. Solid wastes also

include sewage sludge, agricultural refuse, demolition wastes, mining residues, and liquids and gases in containers.

species richness: The absolute number of species in an assemblage or community.

spent nuclear fuel: Nuclear reactor fuel that has been used to the extent that it can no longer effectively sustain a chain reaction.

spray drift: The physical movement of a pesticide through air at the time of application, or soon thereafter, to any site other than that intended for application.

stationary source: A place or object from which pollutants are released and that stays in one place. These sources include many types of facilities, including power plants, gas stations, dry cleaners, incinerators, factories, and houses.

stressor: A physical, chemical, or biological entity that can induce adverse effects on ecosystems or human health.

submerged aquatic vegetation (SAV): Rooted vegetation that grows under water in shallow zones where light penetrates.

Superfund: The program operated under the legislative authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) that funds and carries out EPA solid waste emergency and long-term removal and remedial activities. These activities include establishing the National Priorities List, investigating sites for inclusion on the list, determining their priority, and conducting and/or supervising cleanup and other remedial actions.

Superfund site: Any land in the U.S. that has been contaminated by hazardous waste and identified by EPA as a candidate for cleanup because it poses a risk to human health, the environment, or both.

surface water: Water in rivers, streams, lakes, ponds, reservoirs, estuaries, and wetlands (found at the surface, in contrast to ground water).

T

threatened and endangered species: Those species that are in danger of extinction throughout all or a significant portion of their range or are likely to become endangered in the future.

threshold: 1. The lowest dose of a chemical at which a specified measurable effect is observed and below which it is not observed. 2. The dose or exposure level below which a significant adverse effect is not expected.

timber land: Forest land that is capable of producing crops of industrial wood (at least 20 cubic feet per acre per year in natural stands) and not withdrawn from timber use by statute or administrative regulation.

Toxics Release Inventory (TRI): A publicly available EPA database that contains information on toxic chemical releases and other waste management activities reported annually by certain covered industries and federal facilities. TRI was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded by the Pollution Prevention Act of 1990.

toxic substance: Any substance that presents a significant risk of injury to health or the environment through exposure.

toxic waste: A waste that can produce injury if inhaled, swallowed, or absorbed through the skin.

troposphere: The layer of the atmosphere closest to the earth's surface.

U

ultraviolet (UV) radiation: Radiation from the sun that can be useful or potentially harmful. UV radiation from one part of the spectrum (UV-A) enhance plant life. UV radiation from other parts of the spectrum (UV-B) can cause skin cancer or other tissue damage. The ozone layer in the atmosphere partly shields the earth from UV radiation reaching the surface.

underground storage tanks: Tanks and their underground piping that have at least 10 percent of their combined volume underground.

urban and built-up areas: A National Resources Inventory land cover/use category consisting of residential, industrial, commercial, and institutional land construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary structures and spillways; small parks (less than 10 acres) within urban and built-up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas. Also included are tracts of less than 10 acres that do not meet the above definition but are completely surrounded by urban and builtup land.

urban and suburban areas: Places where the land is primarily devoted to buildings, houses, roads, concrete, grassy lawns, and other elements of human use and construction. Urban and suburban areas, in which about three-fourths of all Americans live, span a range of density, from the city center characterized by high-rise buildings and little green space to the suburban fringe where development thins to a rural landscape. This definition does not include all developed lands, for example, small residential zones, the area of rural interstate highways, farmsteads, and the like, which are developed but are not sufficiently built-up to be considered urban or suburban.

urbanization: The concentration of development in relatively small areas (cities and suburbs). The U.S. Census Bureau

defines “urban” as areas with densities of people greater than 1.5 people per acre.

V-Z

vehicle miles traveled: A measure of the extent of motor vehicle operation; the total number of vehicle miles traveled by all vehicles within a specific geographic area over a given period of time. Vehicle miles traveled and other variables are used to estimate air pollutant emissions.

volatile organic compounds: Chemicals, such as gasoline and perchloroethylene (a dry cleaning solvent) that contain carbon and vaporize readily.

waste minimization priority chemicals: A group of 30 chemicals—3 metals (lead, mercury, and cadmium) and 27 organic chemicals—identified as the highest priority for reduction in industrial and hazardous waste.

water clarity: A measure of how clear a body of water is; measured in the distance light penetrates into the water.

water quality criteria: Levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, irrigation, fish production, or industrial processes.

water quality standards: State-adopted and EPA-approved ambient standards for water bodies. The standards define the water quality goals of a water body by designating the uses of the water and setting criteria to protect those uses. The standards protect public health and welfare, enhance the quality of the water, and provide the baseline for surface water protection under the Clean Water Act.

waterborne disease outbreak: The significant occurrence of acute illness associated with drinking water from a public water system or exposure encountered in recreational or occupational settings as determined by appropriate local or state agencies. (The Centers for Disease Control and Prevention defines an outbreak as two or more cases associated with drinking water as the route of exposure.)

watershed: An area of land from which all water that drains from it flows to a single water body.

wetland ecosystems: Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Appendix E - Sources for Environmental Protection in Context



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