Welcome to Nonpoint Source Pollution

Pollution refers to the contamination of water, land, or the air by substances that can adversly impact the environment and human health (AHD, 1982). Usually, these substances are waste materials. The word pollution is derived from the Latin term *polluere*, which means to soil or defile. Examples of modern-day pollution include oil spills, smog, and even noise. Simply put, pollution is “something in the wrong place at the wrong time in the wrong quantity” (Holdgate, 1979).

Most nonpoint source pollution occurs as the result of runoff from rain or melted snow. View a video of runoff in an urban area.

Sometimes it is not the type of material, but its concentration, that determines if it is a pollutant. For example, nutrients such as nitrogen and phosphorus are essential elements for plant growth. If they are overabundant in a body of water, they can lead to conditions that have a negative effect on people's health.

This Discovery Kit has three sections to help you learn about nonpoint source pollution, which is pollution from diffuse sources that can't be tied to a specific location (city streets, farm fields, etc.) The Kit includes a tutorial, a roadmap to online resources, and formal lesson plans for educators.

The tutorial gives an overview of the history and types of nonpoint source pollution. It discusses methods used to detect pollutants, and to assess and reduce their damaging effects on the environment. The tutorial is made up of nine "chapters" or pages, and includes many images to enhance the text.

The Roadmap to Resources complements the information in the tutorial by directing you to online data and other pollution-related information from NOAA and other reliable sources.

The lesson plans integrate information presented in the tutorial with online offerings from the Roadmap, and have been developed for students in grades 9-12. The lessons focus on how scientists identify and measure nonpoint pollutants and determine their effects on living organisms using bioassays and chemical analyses.

Selected by Science Educators from NSTA

The National Science Teachers Association (NSTA) has included this online resource in its *SciLinks* database. *SciLinks* provide students and teachers access to Web-based,

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Runoff from rain in urban areas is a major source of nonpoint source pollution. Much of the urban environment is paved with asphalt or concrete. These surfaces are usually impervious, meaning that water runs off of them without being absorbed into the soil. Impervious surfaces make it easier for storm water to pick up, absorb, and carry pollutants. For example, water will flow across a parking lot and pick up oil left by cars driving and parking on the asphalt. This runoff then runs over the edge of the parking lot, and most likely, it eventually empties into a stream. The water flows downstream into a larger stream, and then to a lake, river, or ocean.

In addition to runoff from urban areas, agricultural operations account for a large percentage of nonpoint source pollution in the United States. In agriculture, large tracts of land are typically plowed to grow crops. Plowing the land exposes the soil, making it more vulnerable to erosion during rainstorms. This increases the runoff that carries fertilizers and pesticides away from the farm and into nearby waters.

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Nonpoint Source Pollution

A Brief History of Pollution

Pollution is not a new phenomenon. In fact, pollution has been a problem since the appearance of our earliest ancestors (Markham, 1994). Increasing human populations have opened the door to more bacteria and disease. During the Middle Ages, diseases such as cholera and typhoid fever broke out all across Europe. These epidemics were directly related to unsanitary conditions caused by human and animal wastes, and garbage. In 1347, the bacterium *Yersinia pestis*, carried by rats and spread by fleas, caused the "Black Death" -- an outbreak of bubonic plague. Unsanitary conditions provided the perfect environment for the deadly bacteria to flourish.

This is a magnified image of *Xenopsylla cheopis* (oriental rat flea) engorged with blood. This flea is the transmitter of plague diseases in Asia, Africa, and South America. **Click on image** for larger view.

By the 1800s, people began to understand that unsanitary living conditions and water contamination contributed to disease epidemics. This new awareness prompted major cities to take measures to control waste and garbage. In the mid-1850s, Chicago built the first major sewage system in the United States to treat wastewater. Soon, many other U.S. cities followed Chicago's lead (Merchant, 2002).

Improved sanitary conditions and less disease were important factors in making cities healthier places to live, and helped encourage people to move to urban areas. As cities became more populated towards the end of the 19th century, industrialized cities across Europe and the United States were experiencing a new kind of pollution: waste from industries and factories. In 1897, a report to the Royal Commission on River Pollution detailed the gross industrial contamination of the Tawe River in Wales, noting that it was polluted by "alkali works, copper works, sulfuric acid liquid, sulfate of iron from tin-plate works, and by slag, cinders and small coal" (Markham, 1994).

This map shows the layout of sewers in Chicago at the end of 1857. Chicago built one of the first sewage systems in the United States to treat wastewater. **Click on image** for larger view.

In the United States, industrial chemicals and wastes, including sulfuric acid, soda ash, muriatic acid, limes, dyes, wood pulp, and animal byproducts from industrial mills contaminated waters in the Northeast (Merchant, 2002).

Water and air pollution in U.S. urban areas continued to increase well into the 20th century. The Cuyahoga River in Cleveland, Ohio, which flows into Lake Erie, became so polluted that the water erupted into flames! The first fire occurred in 1936, when a spark from a blowtorch ignited floating debris and oils. Over the next 30 years,

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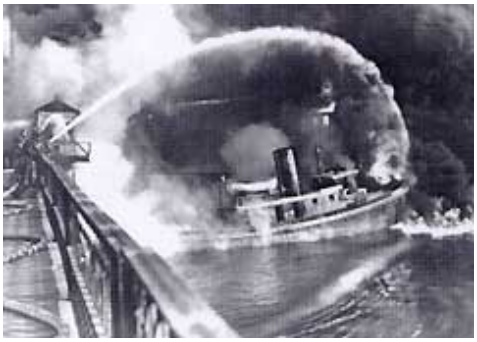
the river caught fire several more times.

In 1969, another major fire erupted. This time, with the help of news and magazine coverage, the fire prompted the nation to take immediate action against water pollution. The public response to this event helped create the Federal Water Pollution Control Act (1972), commonly called the Clean Water Act. This legislation provides money to improve sewage treatment plants (STPs) and sets limits on the things that industries and STPs can discharge into the water. The Cuyahoga River fires also provided the motivation to create the Great Lakes Water Quality Agreement; establish federal and state environmental protection agencies (Environmental Protection Agency, 2003); and pass the Oil Pollution Act of 1990, which prohibits the discharge of oil into navigable rivers.



This image shows the Cuyahoga River on fire in 1952. On the far left of the photograph you can see firefighters battling the blaze from a bridge. **Click on image** for larger view.

Air pollution from automobiles, industrial processes, and the burning of coal in factories and in homes has also been a serious problem. In the 19th century, episodes of "smog" (a combination of smoke and fog) in cities like New York and London resulted in many deaths. Air pollution continued to be a significant problem up through the middle of the 20th century. In late October of 1948, 20 people were asphyxiated and more than 7,000 became seriously ill as the result of severe air pollution over Donora, Pennsylvania (Pennsylvania Department of Environmental Protection, 2005).

Like the 1969 Cuyahoga River fire, the 1948 Donora incident led to the creation of the Air Pollution Control Act of 1955. This was the first federal attempt to control air pollution. Since then, clean air legislation has been revised and strengthened. The Clean Air Act of 1990 sets limits on the discharge of air pollutants from industrial facilities and motor vehicles, and addresses acid rain and ozone depletion (American Meteorological Society, 1999).

This eerie photograph was taken at noon on Oct. 29, 1948, in Donora, PA as deadly smog enveloped the town. **Click on image** for larger view.

These laws have significantly reduced the amount of pollution released into the environment. Grossly contaminated water and air are much less common today than they were 50 years ago. Nevertheless, some of today's experts are concerned about the possible risks of continuous low-level exposure to pollutants, and particularly to nonpoint source pollutants.

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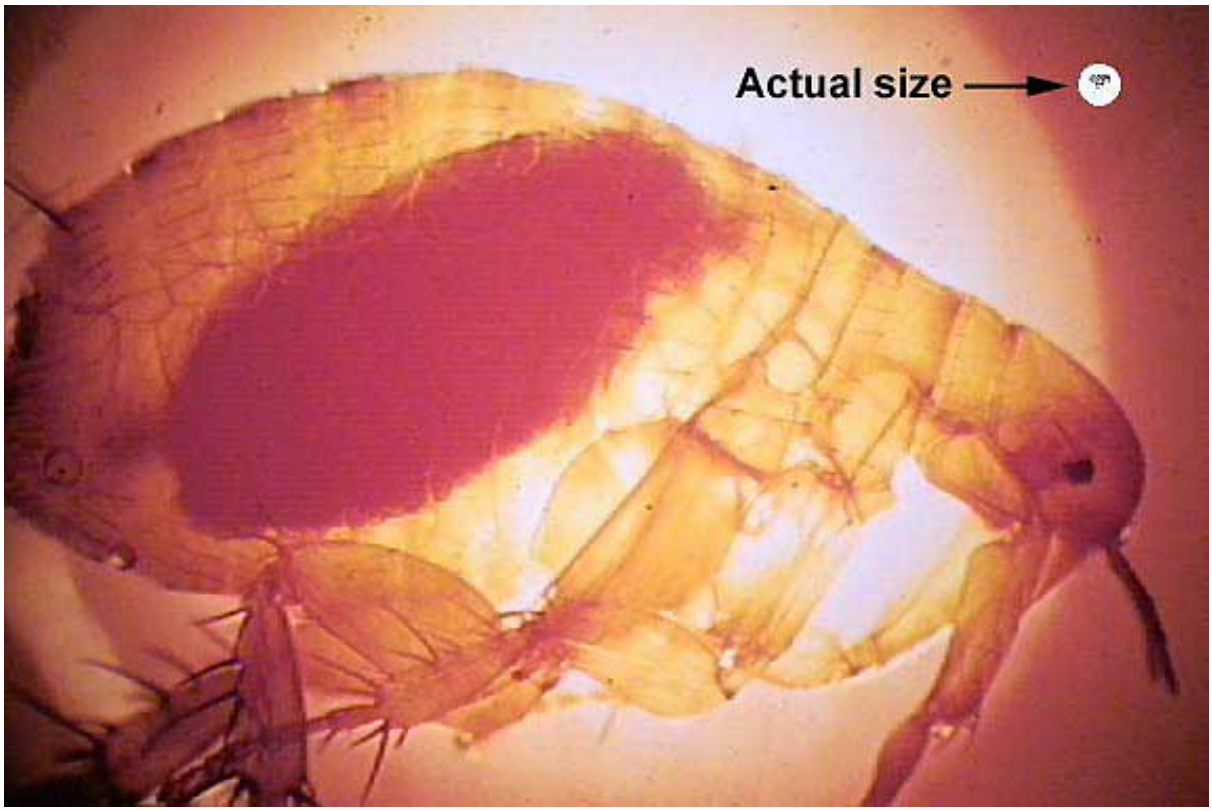
This is a magnified image of *Xenopsylla cheopis* (oriental rat flea) engorged with blood. This flea is the transmitter of plague diseases in Asia, Africa, and South America. Both male and female fleas can transmit the infection.



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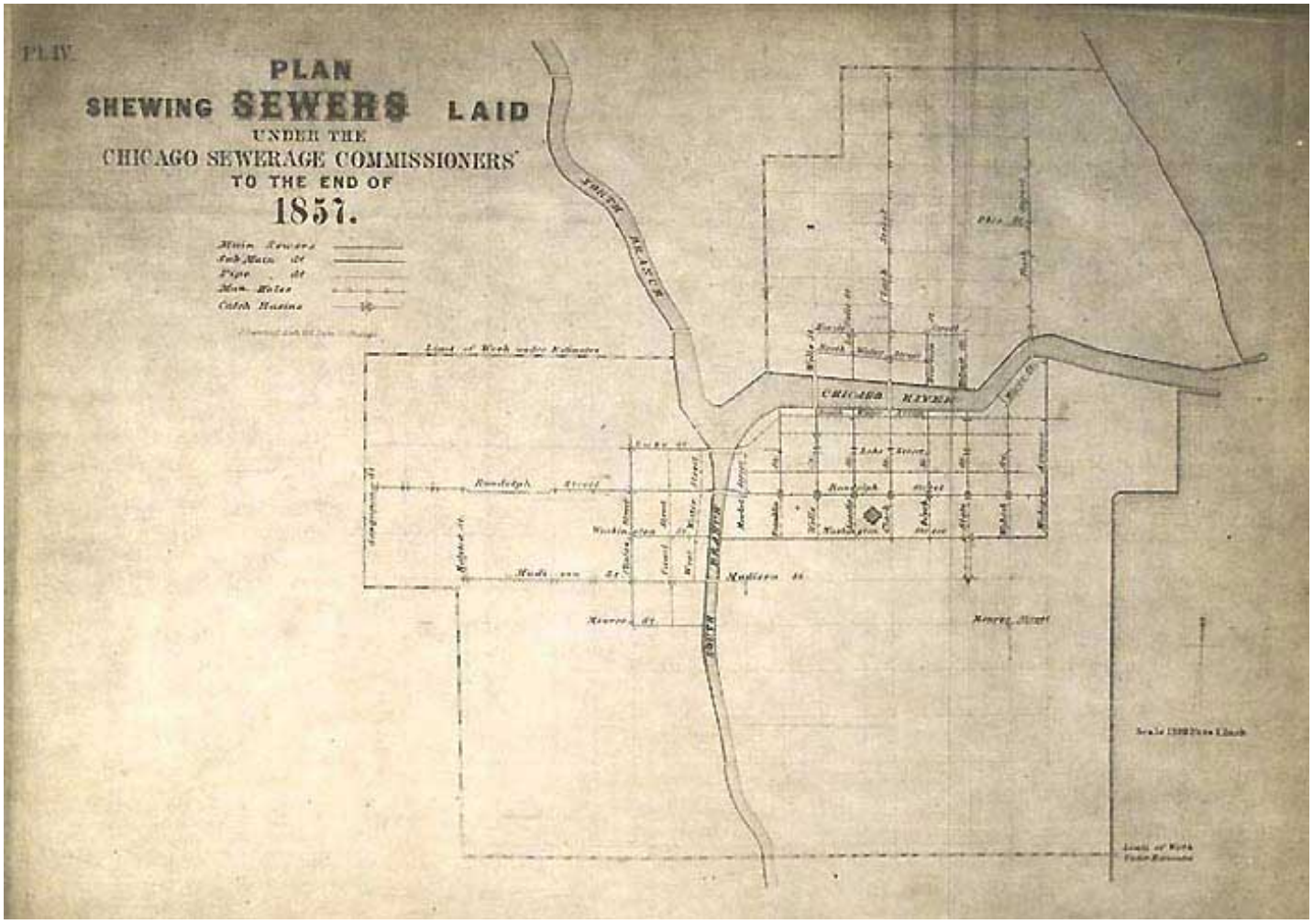
This map shows the layout of sewers in Chicago at the end of 1857. Chicago built one of the first sewage systems in the United States to treat wastewater. Photo: C.S. Chesbrough, Chicago sewerage report of the results of examinations made in relation to sewerage in several European cities, in the winter of 1856-57, Chicago, 1858.



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Firefighters battle a fire on Ohio's Cuyahoga River in 1952. The polluted river caught fire on several occasions between 1936 and 1969, when debris and oil had concentrated on the water's surface and ignited. A blaze in 1969 came at a time of increasing environmental awareness and symbolized years of environmental neglect. The Cuyahoga River fires helped spur grassroots activism that resulted in a wave of federal legislation devoted to taking serious action against air and water pollution.

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This eerie photograph was taken at noon on Oct. 29, 1948 in Donora, PA as deadly smog enveloped the town. 20 people were asphyxiated and more than 7,000 became seriously ill during this horrible event.

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Nonpoint Source Pollution

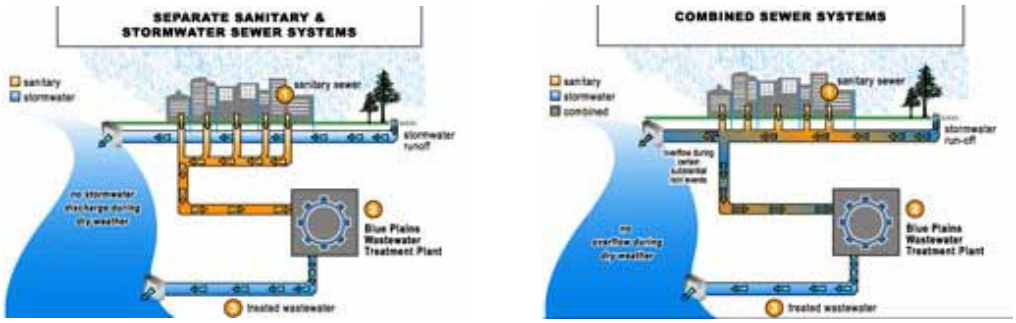
Categories of Pollution: Point Source

The U.S. Environmental Protection Agency (EPA) defines point source pollution as "any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack" (Hill, 1997).

This image shows a point source of industrial pollution along the Calumet River. **Click on image** for larger view.

Factories and sewage treatment plants are two common types of point sources. Factories, including oil refineries, pulp and paper mills, and chemical, electronics and automobile manufacturers, typically discharge one or more pollutants in their discharged waters (called effluents). Some factories discharge their effluents directly into a waterbody. Others treat it themselves before it is released, and still others send their wastes to sewage treatment plants for treatment. Sewage treatment plants treat human wastes and send the treated effluent to a stream or river.

Another way that some factories and sewage treatment plants handle waste material is by mixing it with urban runoff in a combined sewer system. Runoff refers to stormwater that flows over surfaces like driveways and lawns. As the water crosses these surfaces, it picks up chemicals and pollutants. This untreated, polluted water then runs directly into a sewer system.



These images show the difference between a combined sewer overflow system found in many older cities, and a sewer system where sanitary and stormwater are completely separated. **Click on image** for larger view.

When it rains excessively, a combined sewer system may not be able handle the volume of water, and some of the combined runoff and raw sewage will overflow from the system, discharging directly into the nearest waterbody without being treated. This combined sewer overflow (CSO) is considered point source pollution, and can cause severe damage to human health and the environment.

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can result in water pollution and unsafe drinking water, and can restrict activities like fishing and swimming. Some of the chemicals discharged by point sources are harmless, but others are toxic to people and wildlife. Whether a discharged chemical is harmful to the aquatic environment depends on a number of factors, including the type of chemical, its concentration, the timing of its release, weather conditions, and the organisms living in the area.

Large farms that raise livestock, such as cows, pigs and chickens, are other sources of point source pollution. These types of farms are known as concentrated animal feeding operations (CAFOs). If they do not treat their animals' waste materials, these substances can then enter nearby waterbodies as raw sewage, radically adding to the level and rate of pollution.

Large farms that raise livestock are often considered potential point sources of pollution because untreated animal waste may enter nearby waterbodies as untreated sewage. **Click on image** for larger view.

To control point source discharges, the Clean Water Act established the National Pollutant Discharge Elimination System (NPDES). Under the NPDES program, factories, sewage treatment plants, and other point sources must obtain a permit from the state and EPA before they can discharge their waste or effluents into any body of water. Prior to discharge, the point source must use the latest technologies available to treat its effluents and reduce the level of pollutants. If necessary, a second, more stringent set of controls can be placed on a point source to protect a specific waterbody.

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Point source pollution is defined by the U.S. Environmental Protection Agency (EPA) as “any single identifiable source of pollution from which pollutants are discharged, such as a pipe...” This image shows a point source of industrial pollution along the Calumet River. Photo: U.S. Environmental Protection Agency, Region V.

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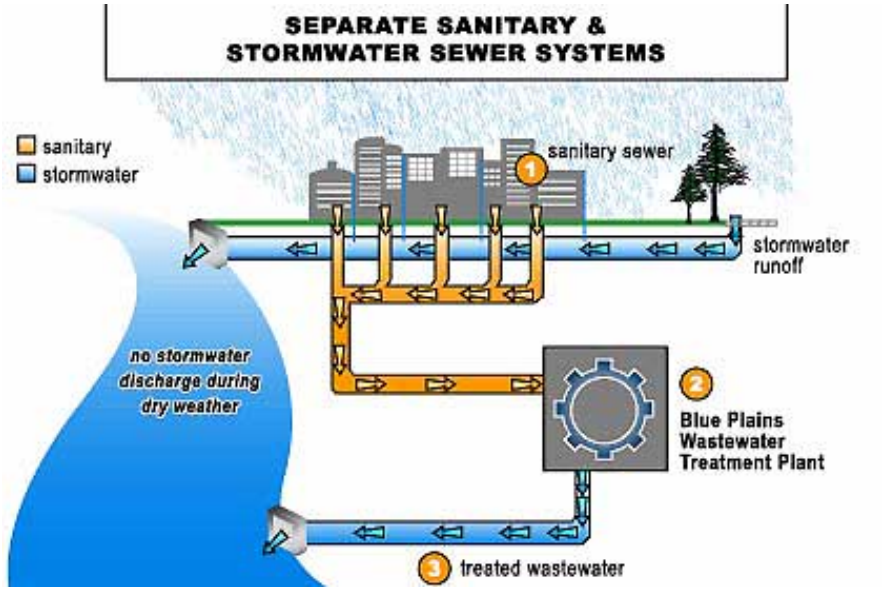
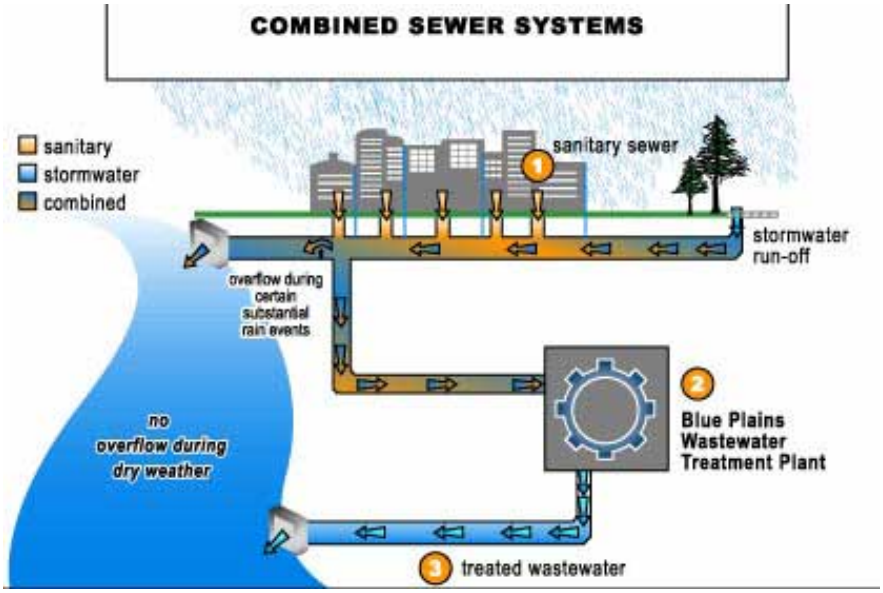
These images show the difference between a combined sewer overflow system found in many older cities, and a sewer system where sanitary and stormwater are completely separated. During heavy rains combined sewer overflow systems mix raw sewage with rainwater runoff and discharge it directly into the nearest waterbody without treatment. Photo: Washington DC Water and Sewer Authority.





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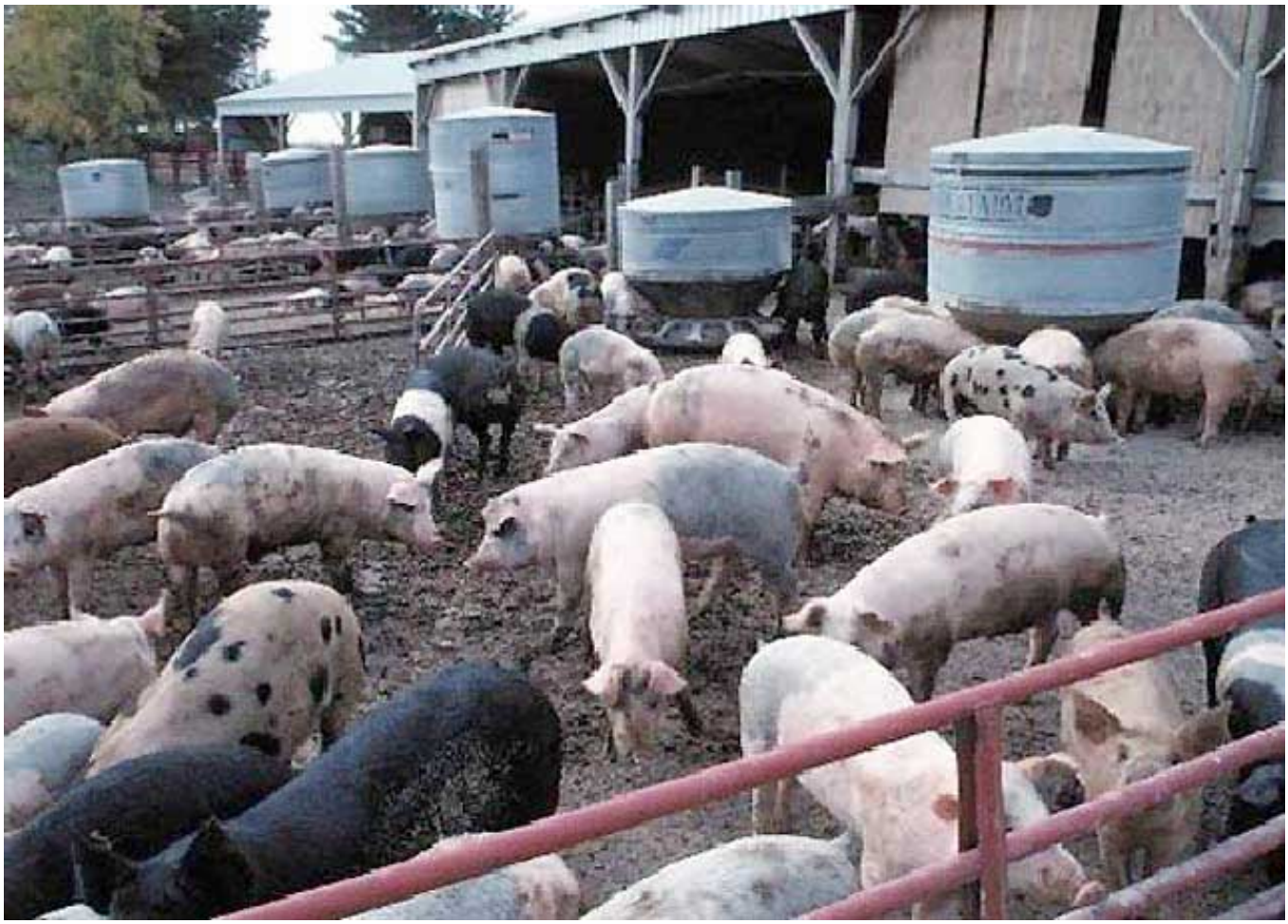
Large farms that raise livestock are often referred to as concentrated feeding operations (CFOs). These farms are considered potential point sources of pollution because untreated animal waste may enter nearby waterbodies as untreated sewage.



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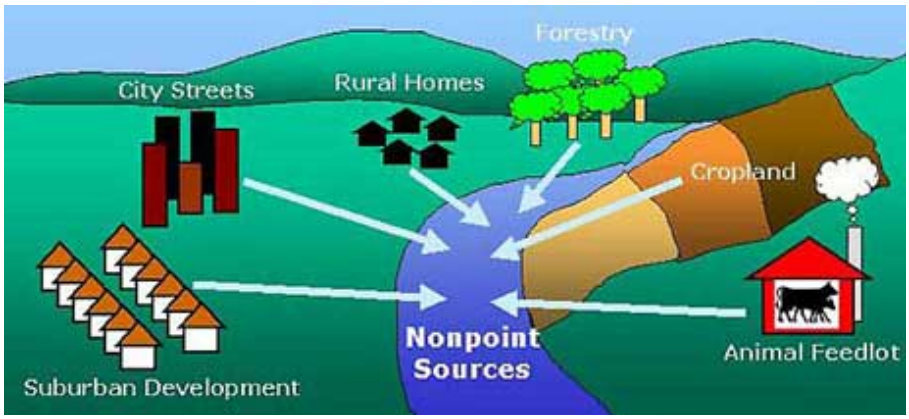

Nonpoint source pollution is difficult to control because it comes from many different sources and locations.

Most nonpoint source pollution occurs as a result of runoff. When rain or melted snow moves over and through the ground, the water absorbs and assimilates any pollutants it comes into contact with (USEPA, 2004b). Following a heavy rainstorm, for example, water will flow across a parking lot and pick up oil left by cars driving and parking on the asphalt. When you see a rainbow-colored sheen on water flowing across the surface of a road or parking lot, you are actually looking at nonpoint source pollution.

Motor oil and other oil-based chemicals can be recognized by a characteristic rainbow-colored sheen. **Click on image** for larger view.

This runoff then runs over the edge of the parking lot, and most likely, it eventually empties into a stream. The water flows downstream into a larger stream, and then to a lake, river, or ocean. The pollutants in this runoff can be quite harmful, and their sources numerous. We usually can't point to one discreet location of nonpoint source pollution like we can with a discharge pipe from a factory.

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Nonpoint source pollution not only affects ecosystems; it can also have harmful effects on the economy. U.S. Coastal and marine waters support 28.3 million jobs, generate $54 billion in goods and services through activities like shipping, boating, and tourism, and contribute $30 billion to the U.S. economy through recreational fishing alone (Leeworthy, 2000). If

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pollution leads to mass die-offs of fish and dirty-looking water, this area and others like it will experience deep financial losses.

Nonpoint source pollution affects the beauty and health of coastal lands and waters. If the physical and environmental well-being of these areas is diminished, people will naturally find it less appealing to visit the coast. Beaches will not provide the tranquility and leisure activities many people expect to experience. You can see how nonpoint source pollution plays an indirect, though powerful role in tourists' contributions to a coastal community's economic status.

Nonpoint source pollution can severely affect many aspects of a community especially the commercial fishing industry. **Click on image** for further details and larger view.

High densities of population along coastal regions can place great stress upon the environment, particularly through the effects of nonpoint source pollution. **Click on image** for further details and larger view.

The population in many coastal communities is also increasing at a rapid rate, and the value of waterfront property often relies on environmental and aquatic conditions. Excess nonpoint source pollution impacts the overall quality of life, and subsequently can drive property values down. If nonpoint source pollution continues to plague the waters surrounding coastal communities, their economies and social conditions may rapidly deteriorate.

Although the concentration of some pollutants from runoff may be lower than the concentration from a point source, the total amount of a pollutant delivered from nonpoint sources may be higher because the pollutants come from many places.

With increased control over point source pollution, scientists have begun to focus on nonpoint source pollution, how it affects the quality of the environment, and, even more importantly, how it can be controlled. Nonpoint source pollution is difficult to control because it comes from multiple locations. It also varies over time in terms of the flow and the types of pollutants it contains.

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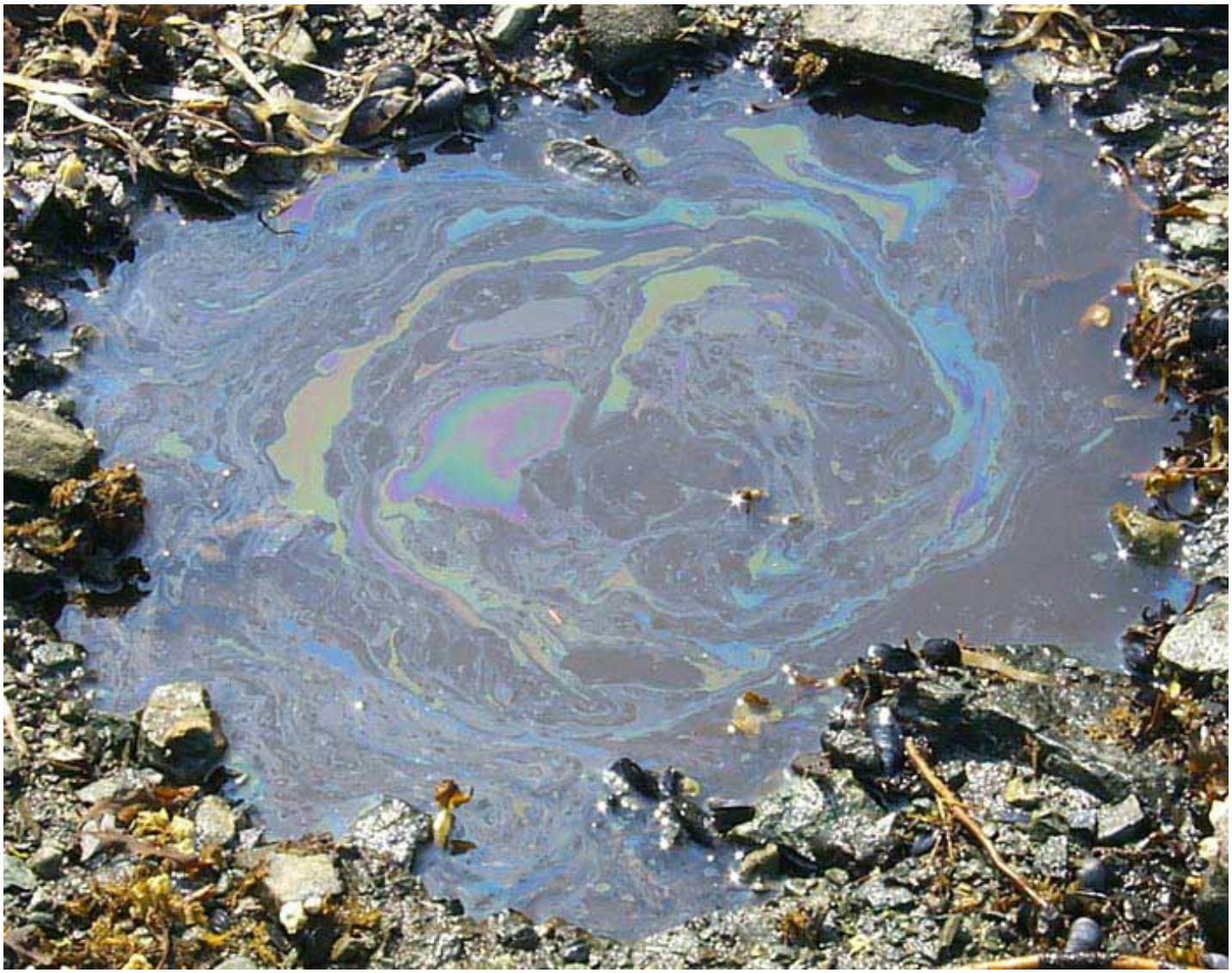
Motor oil and other oil-based chemicals can be recognized by a characteristic rainbow-colored sheen.



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Nonpoint source pollution can severely affect many aspects of a community especially the commercial fishing industry. Nonpoint source pollution can lead to massive fishkills due to severely decreased levels of oxygen in the water, a condition known as hypoxia. In addition, fish and shellfish can be poisoned by harmful algal blooms caused by an overabundance of nutrients in the water, a condition called eutrophication. Photo: Duluth, Minnesota. Minnesota Sea Grant

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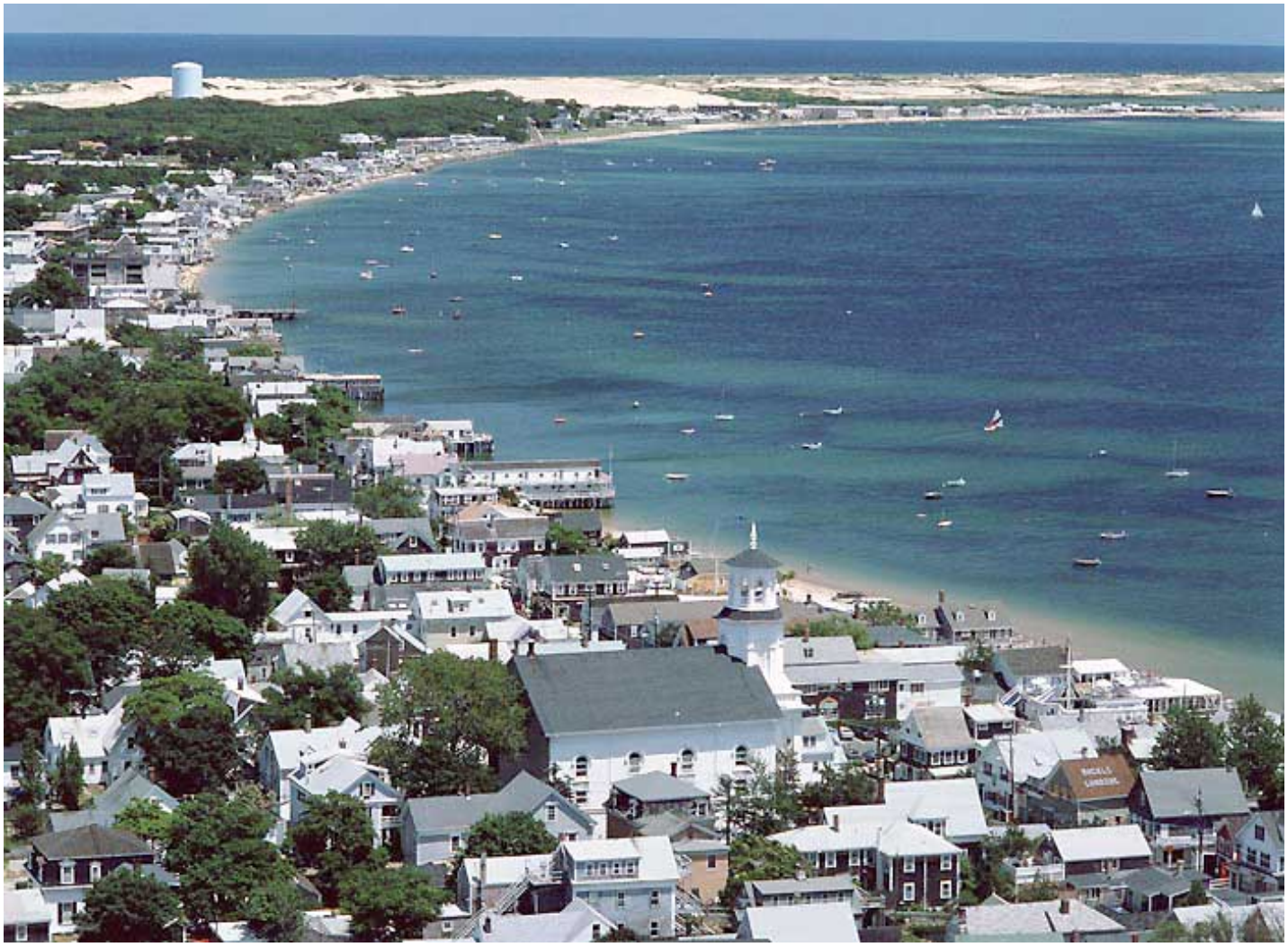
In the United States, coastal counties constitute only 17 percent of the total land area (not including Alaska), but account for 53 percent of the total population (Crossett et al. 2004). High densities of population along coastal regions can place great stress upon the environment, particularly through the effects of nonpoint source pollution.



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Nonpoint Source Pollution

Nonpoint Source Pollution : Urban and Suburban Areas

Runoff from urban and suburban areas is a major origin of nonpoint source pollution. Much of the urban environment is paved with asphalt or concrete, or covered with buildings. These surfaces are usually impervious, meaning that water runs off of them without being absorbed into the soil. These hard, impervious surfaces make it easier for stormwater to pick up, absorb, and carry pollutants.

Other environments in urban and suburban areas also add to nonpoint source pollution. At construction sites, soil that has been disturbed or piled up without being contained can easily erode. Discarded construction materials (plastics, wood, oils, trash) can also be carried away from these sites by runoff waters.

At construction sites, soil that is piled up carelessly or not contained, along with discarded materials, can end up in runoff waters. November 1998. Ipswich, Essex County, Massachusetts.

Many municipalities that border the Potomac River are painting words like "Drains to the Potomac" across their storm drains. **Click on image** for further details and a larger view.

In suburban areas, the chemicals used in lawn care, and even pet wastes, often end up in runoff and contribute to nonpoint source pollution. In many towns and cities the water flowing into storm drains is not treated before emptying into nearby waterbodies. That's why many municipalities, like those in suburban Maryland and Virginia that border the Potomac River and Chesapeake Bay, are painting words like "It Ends Up In The Bay" in large bright letters across their storm drains. This reminds residents in towns more than two hours away from the Chesapeake Bay that their very own nonpoint wastes, no matter how small, eventually contribute to polluting the great bay.

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In many towns and cities, the water flowing into storm drains is not treated before emptying into nearby waterbodies. Many municipalities in suburban Maryland and Virginia, as well as the District of Columbia, that border the Potomac River are painting words like "No Dumping", "Drains to the Potomac", and "It Ends Up In The Bay", in large bright letters across their storm drains. This reminds residents in towns more than two hours away from the Chesapeake Bay that their very own nonpoint wastes, no matter how small, eventually contribute to polluting the great bay.

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Welcome to Nonpoint Source Pollution

Nonpoint Source Pollution : Agricultural Operations

Agricultural operations account for a large percentage of nonpoint source pollution in the United States (USEPA, 2004c). According to the Census of Agriculture, approximately 940 million acres of farmland existed in the United States in 2002 (USDA, 2004). While the vast breadth of this land provides space for farming -- an industry that provides the backbone of the U.S. economy, not to mention much of the food we eat -- it also creates numerous opportunities for nonpoint source pollution.

In agriculture, large tracts of land are typically plowed to grow crops. Plowing the land exposes and disturbs the soil, making it more vulnerable to erosion during rainstorms. This increases the runoff that carries fertilizers and pesticides away from the farm and into nearby waters.

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Agricultural runoff accounts for a significant amount of nonpoint source pollution. **Click on image** for larger view.

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Agricultural runoff accounts for a significant amount of nonpoint source pollution. When large tracts of land are plowed, the exposed soil can erode during rainstorms. This runoff, which ends up in the nearest waterbody, often contains agricultural fertilizers and pesticides.

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Welcome to Nonpoint Source Pollution

Nonpoint Source Pollution : Atmospheric Inputs

Industrial facilities often discharge pollutants into the atmosphere, typically through some type of smokestack. These airborne pollutants (hydrocarbons, metals, etc.) can travel long distances. The pollutants are then deposited on surfaces (dry deposition) or washed out of the atmosphere in rain or snowfall (wet deposition).

The pollutants that industrial facilities discharge become airborne pollutants that are washed out of the atmosphere and deposited in rain or snowfall. **Click on image** for larger view.

Although the pollutants may have originated from a point source of air pollution such as a factory, the long-range transport and multiple sources of the pollutant make it a nonpoint source of pollution. Scientists estimate that approximately two-thirds of the lead and mercury and over half of the other trace elements that enter the Great Lakes originate from atmospheric inputs (Hill, 1997).

Acid rain has also become a major concern in some areas of the United States. Acid rain is created when sulfur dioxide and nitrogen oxides are discharged from industrial plants that burn fossil fuels like coal, oil, and natural gas. These compounds react with water, oxygen, and other atmospheric compounds to form acid rain.

Acid rain causes a cascade of effects that harm or kill fish and other aquatic organisms. As acid rain flows over and through soils, it releases aluminum into lakes and streams. Increased levels of aluminum are very toxic to fish. In addition, increased levels of aluminum cause fish to become chronically stressed. While chronic stress may not kill individual fish, it leads to lower body weight and smaller size, making the fish less able to compete for food and habitat (USEPA 2003a).

Acid rain also damages forests. For example, acid rain can damage the surfaces of leaves and needles, reduce a tree's ability to withstand cold, and inhibit plant germination and reproduction. Prolonged exposure can cause forest soils to lose valuable nutrients like calcium and magnesium. Lack of nutrients causes trees to grow more slowly or to stop growing altogether.

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The pollutants that industrial facilities discharge become airborne pollutants that are washed out of the atmosphere and deposited in rain or snowfall. This type of nonpoint source pollution can result in acid rain, which can slow forest growth and contaminate soil.

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Nonpoint Source Pollution

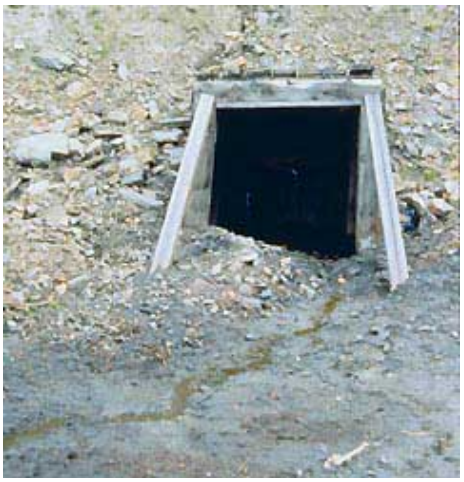
Nonpoint Source Pollution : Forestry and Mining Operations

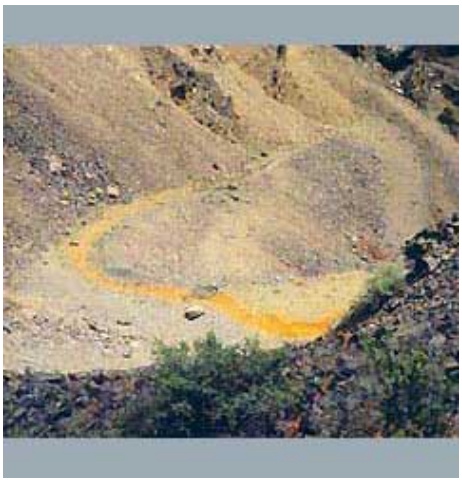
Forestry operations such as logging can generate significant amounts of nonpoint source pollution. The heavy machinery used to remove vegetation and trees exposes the soil, increasing the risk of erosion. In addition, the improper construction and use of “skid trails” - temporary paths used to transport logs out of the forest - can contribute to nonpoint source pollution. Skid trails that are constructed against the natural contour of a hillside are especially prone to erosion.

Logs are loaded onto a truck for transporting to a milling plant. Some forestry practices, such as clearcutting and the use of “skid trails” can expose soil and contribute to erosion. **Click on image** for larger view.

Abandoned mining operations can leach iron and other chemicals such as copper, lead and mercury into nearby waterbodies. **Click on image** for larger view.

Active mining operations are considered point sources of pollution. But drainage or runoff from abandoned mining operations often adds to nonpoint source pollution. In strip mining, for example, the top layers of soil and vegetation are removed to reveal the desired ore. If an area where strip mining occurred has not been properly reclaimed after mining activities have ended (soil replaced and graded, vegetation replanted), erosion can occur. In addition, the mixing of air, water and sulfur-containing rocks can cause chemical reactions that lead to the formation of sulfuric acid and iron hydroxide. This acidic runoff dissolves heavy metals such as copper, lead and mercury. These metals, in turn, contaminate streams and other waterbodies.





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The water that can seep out of mine openings often is very acidic and can be contaminated with zinc, copper, or arsenic. **Click on image** for larger view.

This creek - the yellowish streak - is devoid of life because high levels of copper have leached from the mine into the creek. **Click on image** for larger view.

Abandoned subsurface mines can also contribute significantly to nonpoint source pollution. The water that seeps out of them can become very acidic. In Colorado, copper, zinc, and arsenic contamination from abandoned mines have affected several streams (USEPA, 1984.) In the mid-Atlantic and Appalachian regions of the United States, acid mine drainage and associated contamination from abandoned mines have also affected waterbodies (USEPA, 1984.

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Return to Nonpoint Source Pollution: Forestry and Mining Operations

In this image, logs are loaded onto a truck for transporting to a milling plant in Superior National Forest in Minnesota. Some forestry practices, such as clearcutting and the use of “skid trails” can expose soil and contribute to erosion.

(top)

Return to Nonpoint Source Pollution: Forestry and Mining Operations

In this image, iron contamination is apparent in the Idaho Blackbird Creek, Lemhi County, Idaho. Abandoned mining operations can leach iron and other chemicals such as copper, lead and mercury into nearby waterbodies. Mining runoff can be prevented if soil is properly replaced and graded, and vegetation replaced after operations are complete.

Return to Nonpoint Source Pollution: Forestry and Mining Operations

This image shows an “adit” or mine opening, at Blackbird Mine, Lemhi County, Idaho, c. 1994-1998. The water that can seep out of mine openings often is very acidic and can be contaminated with zinc, copper, or arsenic.

Return to Nonpoint Source Pollution: Forestry and Mining Operations

This was the condition of the Blackbird Creek mining site in 1994. The Idaho Blackbird Creek - the yellowish streak - is on the left. This creek is devoid of life because high levels of copper have leached from the mine into the creek.

(top)

Nonpoint Source Pollution

Nonpoint Source Pollution : Marinas and Boating Activities

Marinas and boating activities can also contribute to nonpoint source pollution. Chemicals used to maintain and repair boats, such as solvents, oils, paints, and cleansers, may spill into the water, or make their way into waterbodies via runoff. Spilling fuel (gasoline or oil) at marinas or discharging uncombusted fuels from engines also contribute to nonpoint source pollution. In addition, poorly maintained sanitary waste systems aboard boats or poorly maintained pump-out stations at marinas can significantly increase bacteria and nutrient levels in the water.

A popular recreational activity, boating can also contribute to nonpoint source pollution. Chemicals used on boats may spill into the water; spilled fuel can also contaminate waters around marinas. **Click on image** for larger view.

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A popular recreational activity, boating can also contribute to nonpoint source pollution. Chemicals used on boats, such as oils, paints and cleansers, may spill into the water. Spilled fuel or discharged uncombusted fuels from engines can also contaminate waters around the marina. Poorly maintained pump-out stations can lead to high bacteria and nutrient levels in the water as well.

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Nonpoint Source Pollution

Pollutants from Nonpoint Sources: Nutrients

Excess algae like this can block sunlight needed by native bottom-dwelling plants, which can kill them. **Click on image** for larger view.

There are many types of nonpoint source pollutants. When these accumulate in high enough concentrations in a waterbody, they can seriously affect the environment and the organisms living there. They can also affect human health.

The primary nutrients of concern in nonpoint source pollution are nitrogen and phosphorus. Both are essential for plant growth, but if too much of these substances enters a waterbody, it can lead to a condition called eutrophication (pronounced you-tro-fi-kay-shun). Eutrophication results in an overproduction of organic matter, particularly the microscopic plants called algae (Bricker et al, 1999).

Fish kills can result from hypoxia, or very low levels of oxygen in the water. **Click on image** for larger view.

You may have seen green masses of algae growing on a pond or lake. This excess algae blocks the sunlight needed by native bottom-dwelling plants, often killing them. As the algae and bottom-dwelling plants die, they decay, using up oxygen in the water. This leads to a condition called hypoxia -- very low levels of oxygen in the water -- which makes it difficult for aquatic animals like fish and crabs to survive. A NOAA report notes that "potential consequences of eutrophication range from mere nuisances to serious human health threats" (NOAA, 2004).

In addition to hypoxia, eutrophication may be associated with conditions that result in harmful algal blooms (HABs). Harmful algae are often small, single-celled organisms that live in aquatic environments. Although these organisms are not harmful in small quantities, too many of them can negatively affect the environment and people's health. When fish and shellfish feed on HABs, they can accumulate toxins that the algae produce. Consequently, when people eat seafood with algal toxins in it, they may get sick. The distribution, frequency, and intensity of HABs appears to be increasing worldwide (National Research Council, 1999).

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Harmful algal blooms (HABs) may occur under eutrophic conditions. **Click on image** for larger view.

Shellfish that ingest harmful algae become poisonous to humans. **Click on image** for larger view.

Nonpoint sources of nutrients often originate from agricultural activities (EPA, 2004c). Excess nutrients applied to crops in the form of fertilizers are washed away in runoff, typically during rainstorms. Nutrients also originate from urban and suburban areas, from sources such as lawn fertilizers, and even pet wastes.

Nitrogen and phosphorus also come from atmospheric inputs. Scientists believe that the combustion of fossil fuels like oil and coal by power plants, large industries, and automobiles is a major source of nutrients in the atmosphere (USGS, 2004). Controlling nutrient inputs is proving to be very difficult because the nutrients frequently originate from multiple sources that are challenging to identify and control.

(top)

Nitrogen and phosphorus that come from smokestacks are significant sources of nutrients that end up in waterbodies and can lead to eutrophic conditions. **Click on image** for larger view.

Return to Nonpoint Source Pollution: Nutrients

Excess algae like this can block sunlight needed by native bottom-dwelling plants, which can kill them. Excess algae results from an overproduction of organic matter, or eutrophication. Eutrophication is a condition caused by excessive amounts of nutrients—such as nitrogen and phosphorus—in a waterbody.

(top)

Return to Nonpoint Source Pollution: Nutrients

Fish kills, like this one in the Chautauqua National Wildlife Refuge, can result from hypoxia, or very low levels of oxygen in the water. Hypoxia occurs when excessive algae block out sunlight, killing off underwater plants, which decay and deplete the oxygen in the water.

(top)

Return to Nonpoint Source Pollution: Nutrients

Harmful algal blooms (HABs) occur under eutrophic conditions. Although these organisms are not harmful in small quantities and exist naturally, they grow at rapid rates when eutrophication occurs. When fish and shellfish feed on HABs, they ingest toxins that the algae produce. If people eat this seafood, they can become sick.

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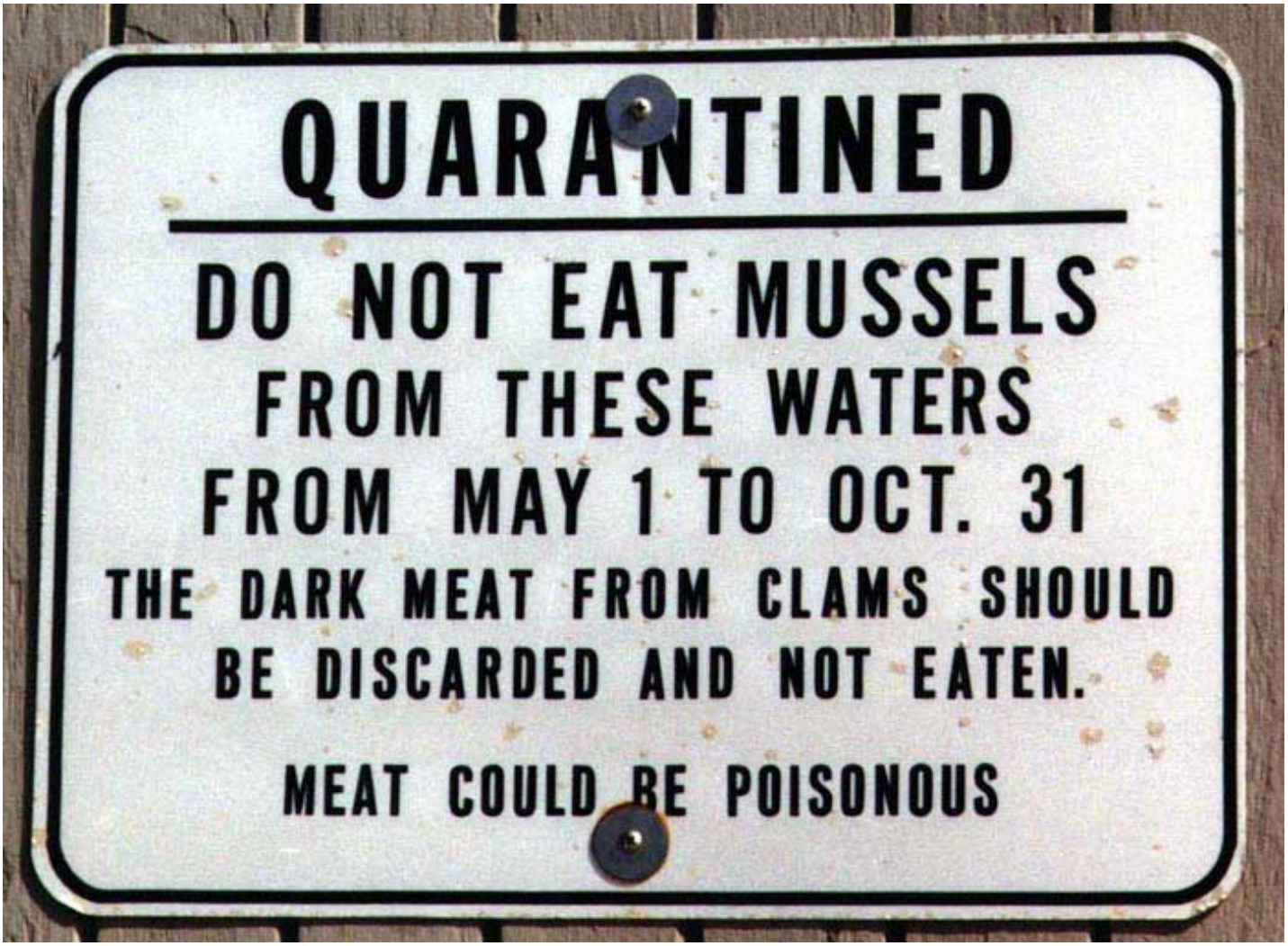
Shellfish that ingest harmful algae become poisonous to humans. Unfortunately, harmful algal blooms (HABs) affect many shellfisheries on a regular basis, requiring authorities to close the areas at certain times of the year.



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Return to Nonpoint Source Pollution: Nutrients

This image is an aerial view along the Fox River in Wisconsin. Nitrogen and phosphorus that come from smokestacks and combustible sources, such as automobiles, are significant sources of nutrients that end up in waterbodies and can lead to eutrophic conditions. Controlling atmospheric nutrient inputs is proving to be a challenge because their sources are difficult to identify.

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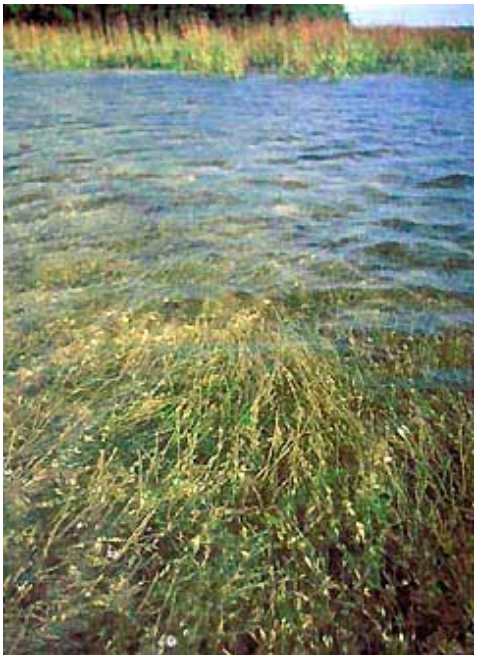
Nonpoint Source Pollution

Pollutants from Nonpoint Sources: Suspended Sediments

Runoff from agricultural fields, urban areas, and construction sites can carry away soil, producing cloudy or muddy water. Soil in the water, called suspended sediment, blocks out the sunlight that bottom-dwelling plants in lakes and rivers need to survive. If these plants, called submerged aquatic vegetation (SAV), are deprived of sunlight for extended periods, they will die.

SAV is an important component of the ecosystem because it provides a habitat for aquatic organisms, produces oxygen, and traps sediment. If hypoxic conditions occur - a state where the level of oxygen in the water is very low - the aquatic organisms living there must either move or die. Often, suspended sediments and excessive nutrients are both present, creating a harmful combination of eutrophic conditions - when there is an overproduction of organic matter - and cloudy water. Suspended sediments can also clog the gills of fish and other aquatic organisms (Hill, 1997).



Submerged aquatic vegetation (SAV) provides vital habitat for aquatic organisms, produces oxygen and traps modest amounts of sediment. **Click on image** for larger view.

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Submerged aquatic vegetation (SAV) provides vital habitat for aquatic organisms, produces oxygen and traps modest amounts of sediment. However, if there are excessive amounts of suspended sediment, or hypoxic conditions occur - a state where the level of oxygen in the water is very low - SAVs die, thus leading to unhealthy conditions for fish and other aquatic organisms that rely on SAV for habitat. This image shows a healthy aqautic ecosystem free of suspended sediments and abundant with healthy SAVs.

Nonpoint Source Pollution

Pollutants from Nonpoint Sources: Pesticides and Toxic Chemicals

Pesticides typically enter a waterbody through surface water runoff, often from a farm field or from neighborhoods where they are applied on lawns. Pesticides can also enter a waterbody as a result of "spray drift." This occurs when the pesticide is sprayed over an area, and the wind blows some of the spray into a nearby waterbody.

Pesticides applied to agricultural fields and lawns can end up in a waterbody as a result of "spray drift".

Pesticides are designed to be toxic to a target organism, but they often kill other organisms as well. The insecticide azinphos-methyl, for example, is used to control insects such as biting mites and aphids. It is also very toxic to fish and birds, however. For the most part, today's pesticides do not build up in the tissues of animals -- a process called bioaccumulation -- to the extent that older compounds like DDT did. On the other hand, many of the compounds used today are toxic at very low concentrations.

Toxic chemicals, such as spilled oils and fuels in cities, are often washed off streets, down storm drains, and into waterbodies. Combustion of fuels in automobiles and factories introduces hydrocarbons and metals into the environment. They eventually end up in the water through atmospheric deposition or runoff. Industrial facilities without the proper means to control runoff can also contribute toxic chemicals to the aquatic environment. The type of chemical that is released depends on the type of manufacturing done at a facility. Other chemicals, such as solvents, paints, cleaning solutions and others, originate from marinas and boating activities.

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Spilled oil that originates from cities and streets or that is poured down storm drains, can soak and kill aquatic organisms, such as these crabs. **Click on image** for larger view.

Despite efforts to control it, contaminated runoff still results in conditions unhealthy for humans and aquatic organisms alike, requiring authorities to close beaches and fisheries. **Click on image** for larger view.

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Return to Nonpoint Source Pollution: Pesticides and Toxic Chemicals

Spilled oil that originates from cities and streets or that is poured down storm drains, can soak and kill aquatic organisms, such as these crabs.

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Return to Nonpoint Source Pollution: Pesticides and Toxic Chemicals

Despite efforts to control it, contaminated runoff still results in conditions unhealthy for humans and aquatic organisms alike, requiring authorities to close beaches and fisheries.

Nonpoint Source Pollution

Pollutants from Nonpoint Sources: Bacteria, Viruses and Trash

Discarded plastics, metals and other types of trash can leach harmful chemicals into the environment. **Click on image** for larger view.

Bacteria and viruses are naturally present in the environment (Hill, 1997). Some pathogenic (disease-causing) microbes are associated with human or animal activities, however. Runoff from agricultural areas where manure is either generated or spread on fields can be a source of bacteria and viruses, some of which may be pathogenic, leading to outbreaks of disease. Urban areas can also be a source of pathogenic bacteria and viruses. As an example, outbreaks of cholera in urban areas have been blamed on inadequate sanitation.

The Norwalk virus has recently caused illness in a number of locations in the United States. This virus causes intestinal illness, and infects people when they come into contact with contaminated food or water. Eating raw shellfish contaminated with the virus is another way people contract this illness. Nonpoint source runoff from urban areas, or discharges from improperly maintained sanitary systems on boats, are also sources of the virus.

Discarded trash can become a component of nonpoint source pollution runoff. Plastics, metals and other types of trash often harm animals and plants. Plastics and metals degrade very slowly over time and can leach harmful chemicals into the environment. These materials can also contribute to the transmission of disease. In addition, trash simply degrades the beauty of an area.

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Litter plays a significant role in damaging our marine environment. Discarded plastics, metals and other types of trash not only degrade the aesthetic beauty of an area, they can leach harmful chemicals into the environment. They can also contribute to disease transmission.

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Nonpoint Source Pollution

Research, Monitoring and Assessment

Because nonpoint source pollution poses many threats to environmental and human health, scientists are working hard to effectively manage this problem. Research, monitoring and assessments of the environment are increasing their knowledge of the causes and effects of nonpoint source pollution, and leading to the development of strategies to reduce and control it.

NOAA's Mussel Watch Program monitors the level of chemicals in oysters, mussels and sediments.

Research

Computer modeling is one technique that scientists are using to better understand how nonpoint source pollution affects waterbodies. A model, or simulation, is a computer program that allows scientists to predict how an environmental "system" like a river, lake, or coastal waterbody may change as a result of varying physical or chemical conditions. Models can also predict the progression and severity of such conditions. With this knowledge, scientists can develop techniques to prevent harmful environmental conditions before they occur.

To develop models, scientists may concentrate on variables that are the most obvious indicators of nonpoint source pollution and potential eutrophication. For example: In a waterbody, nitrate-nitrogen levels above 1 part per million (ppm) and total phosphorus levels above 0.1 ppm can contribute to increased plant growth and eutrophication. Similarly, levels of dissolved oxygen below 1 or 2 ppm may indicate a that a waterbody is experiencing eutrophic conditions. At these low levels of oxygen, aquatic organisms may be starved for oxygen and die (LaMotte 1992).

Scientists will create a model that simulates these conditions, and can then forecast the potential effects of eutrophication, as well as where it might occur.

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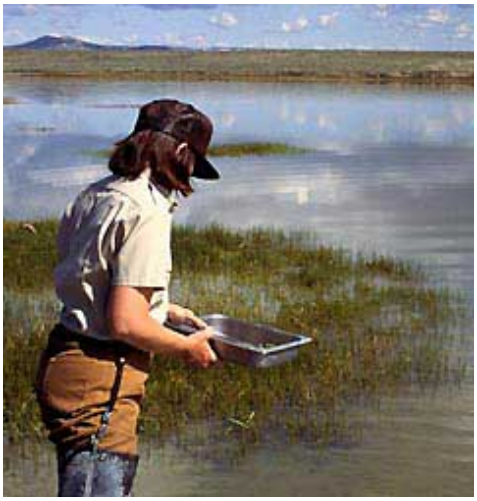
Monitoring

Research and the use of models provides scientists with important information that they can use to develop long-term monitoring programs. The data gathered from these monitoring efforts is then used to improve the accuracy of the original models.

NOAA's Mussel Watch Project is one example of a monitoring program. It is designed to watch the levels of chemicals in oysters, mussels, and sediments. The

project aims to predict trends in pollution across the country and determine which areas are at the greatest risk for contamination. Samples of mussels and oysters are collected every two years, and sediments are sampled once a decade to test for chemical contamination (NOAA, 1998).

The U.S. Geological Survey's National Water Quality Assessment (NAWQA) program is another example of a long-term monitoring project. Since 1991, NAWQA has been collecting and analyzing data at river basins and aquifers (layers of rock or soil that contain large amounts of water) across the country. Scientists monitor for nutrients (nitrogen, phosphorus, etc.) and pesticides that are frequently used in agricultural operations and suburban areas.



Scientists at NOAA, and other agencies, test for nutrients and pesticides that are used in nearby agricultural, urban and suburban areas. **Click on image** for larger view.

NOAA's National Estuarine Eutrophication Survey compiled data gathered from 138 estuaries in the United States (Bricker et al., 1999). The data revealed that more than 90 percent of U.S. estuaries exhibited eutrophic symptoms. More than half of the estuaries exhibited moderate to high levels of at least one eutrophic symptom, such as low oxygen levels, loss of submerged aquatic vegitation (SAV), or the presence of harmful algal blooms (HABs). Estuaries along the Gulf of Mexico and the Mid-Atlantic Coast showed the highest levels of eutrophic symptoms. These areas suffer the most intense agricultural use and urban runoff.

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Assessments

Research using computer models combined with long-term monitoring allows scientists to assess conditions, determine the relationships between nonpoint source pollution and its impacts, and recommend standards and strategies to control pollution.

Assessments are used to help plan control strategies. In 1998, the U.S. Environmental Protection Agency (EPA) published the National Strategy for the Development of Regional Nutrient Criteria. The strategy is an effort to develop specific criteria for nutrient levels in waterbodies, which will help states implement sound water quality standards.

Other control strategies include state coastal nonpoint pollution control programs, which are mandated under the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990. The CZARA requires coastal states and territories to develop and implement specific pollution control programs.

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Scientists at NOAA, and other agencies, such as the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency, sample sediments through various long-term monitoring programs. One program, the USGS National Water Quality Assessment program, has been collecting and analyzing river sediment data across the country since 1991. Scientists test for nutrients and pesticides that are used in nearby agricultural, urban and suburban areas.

Nonpoint Source Pollution

Controlling Nonpoint Source Pollution

While research, monitoring, and assessment look at the larger environmental effects of nonpoint source pollution, taking measures to stop pollution before it begins is also essential for controlling the problem. This is especially true in coastal communities. According to a NOAA Coastal Population Trends Report, about 153 million people lived in coastal areas in 2003. This is 53 percent of the total U.S. population. Between 1980 and 2003, the total coastal population increased by 28 percent, or 33 million people (Crossett et al., 2004.) If coastal populations continue to grow, the chances for more nonpoint source pollutants such as nutrients, sediments, pesticides, and other toxic chemicals to enter waterbodies via runoff increases.

Sediment fences such as this are used to control erosion, trap large materials, filter sediment from rainwater, and slow runoff. **Click on image** for larger view.

Even though the exact locations of nonpoint source pollution cannot be identified, scientists know that certain environments and operations produce a high volume of pollution. Experts have developed systems to reduce and even eliminate pollution from these places. Listed below are some strategies that urban and suburban areas, agricultural operations, forestry operations, and marinas use to decrease nonpoint source pollution.

Urban and Suburban Areas

Similar to sediment fences, retaining fences are used to prevent contaminants from entering aquatic environments. **Click on image** for larger view.

- *Buffer strips* are strips of grass located between and around impervious paving materials such as parking lots and sidewalks, and a body of water. The buffer strip absorbs soil, fertilizers, pesticides, and other pollutants before they can reach the water.
- *Retention ponds* capture runoff and stormwater. Sediments and contaminants settle out of the water when they are trapped in the retention pond.
- *Constructed wetlands* are a recent innovation in which an area is made into a wetland; the land is then used to slow runoff and absorb sediments and contaminants. The constructed wetland also provides habitat for wildlife.
- *Porous paving materials* are used in parking lots and highways. The porous pavement allows rainwater and stormwater to drain into the ground beneath it, reducing runoff.

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In some cases, there is also a stone reservoir underneath the pavement to allow filtration of the water before it reaches the groundwater.

- *Sediment fences*, or knee-high black fabric fences, are often used at construction sites to trap large materials, filter sediment out of rainwater, and slow runoff.
- *Grass planting and laying of straw* around construction sites help reduce runoff and associated nonpoint source pollution.

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Agricultural Operations

- *Buffer strips* are planted located between a farm field and a body of water. The buffer strip absorbs soil, fertilizers, pesticides, and other pollutants before they can reach the water.
- *Conservation tillage* involves leaving some crop residue from a previous harvest while planting a new crop. Less erosion occurs because the field is not plowed, and nutrients or pesticides are more likely to stay where they are applied.
- *Crop nutrient management* involves applying fertilizers sparingly to prevent excess nutrient runoff. Prior to the growing season, farmers test the fields to ensure that nutrients are applied only as needed.
- *Beneficial insects* can be used to control agricultural pests, reducing the need for pesticides. Common predators include ladybugs, praying mantises, and spiders, which feed on aphids, mites, and caterpillars. These natural predators help control infestations on valuable crops such as corn, soybeans, and tomatoes.

Forestry Operations

- The location and design of *roads and skid trails* (temporary pathways used to shuttle logs out of the forest) are carefully planned prior to any logging operations. Skid trails are designed to follow the contour of the land and reduce erosion.
- *Buffer strips* are maintained between logging operations and nearby streams, lakes or rivers.
- *Trees* are replanted after logging to allow for regrowth and less erosion.

Marinas

- *Shutoff valves* on fuel pumps on docks help limit spillage into the water.
- *Pump-out stations* at marinas allow boaters to safely empty their sanitary systems without dumping wastes into the water.
- *Trash* is placed in appropriate waste containers.

Pump-out stations at marinas such as this one allow boaters to empty their sanitary systems without contaminating the water**. Click on image** for larger view.

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Return to Controlling Nonpoint Source Pollution

Sediment fences such as this one are used in urban and suburban areas and construction sites to control erosion, trap large materials, filter sediment from rainwater, and slow runoff.

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Similar to sediment fences, retaining fences are used to prevent contaminants from entering aquatic environments. This retaining fence was set up as part of a salt marsh restoration program in Staten Island, New York in 1993. The fence prevented contaminants in the sediment from making their way into the Arthur Kill Waterway while the project was underway.

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Pump-out stations at marinas such as this one allow boaters to empty their sanitary systems without contaminating the water.

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Nonpoint Source Pollution

What You Can Do

Controlling and preventing nonpoint source pollution is every person's responsibility, including yours. There are many things all of us can do to reduce nonpoint source pollution, including:

One of the easiest-and most important-ways that people can reduce runoff is to plant trees, grass and shrubs in bare areas. **Click on image** for larger view.

- *Plant grass, trees and shrubs in bare areas.* This is one of the most important things you can do to reduce nonpoint source runoff. The grass, trees and shrubs will reduce and absorb runoff, and their roots will hold the soil together, reducing erosion.
- *Properly dispose of motor oil and household chemicals.* Never pour chemicals on the ground or in storm drains, where they will eventually make their way into a stream or river. Motor oils and household chemicals can harm, and even kill, aquatic life. Used motor oil should be taken to oil recycling facilities.
- *Use fertilizers and pesticides sparingly on lawns and gardens.* Excess fertilizer and pesticides can damage your plants. The excess often winds up in runoff and can lead to eutrophication in waterbodies. To reduce the use of pesticides, use beneficial insects such as ladybugs and praying mantises to control unwanted pests in the garden. Try a technique used in agriculture known as "scouting." Go out and survey your yard or garden to see what pests are present and then use pesticides only if natural predators cannot keep the pests in check.
- *Put trash in its place.* Keep it out of storm drains, where it will clog up the drain or end up in the nearest stream or lake.
- *Organize neighborhood cleanups.* Go on stream walks in your neighborhood, removing trash and debris as you go. It's fun, a good way to meet your neighbors, and you can learn a lot about the natural environment.
- *Recycle plastic, glass, and paper.* Less trash means less material in the waste stream, and reducing the waste stream is the goal of all measures to control nonpoint source pollution.

Neighborhood cleanup days are a good way to reduce trash in and around nearby waterbodies. **Click on image** for larger view.

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One of the easiest—and most important—ways that people can reduce runoff is to plant trees, grass and shrubs in bare areas. The added vegetation absorbs rainwater and holds soil together, thus reducing erosion as well.

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Neighborhood cleanup days are a good way to reduce trash in and around nearby waterbodies. It's also a good way to meet neighbors and develop a sense of a shared community.

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