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ABSTRACT

The Master Watershed Stewards (MWS) Program is a pilot project (developed through the cooperation of the Ohio State University Extension Logan and Hardin County Offices and the Indian Lake Watershed Project) offering the opportunity for communities to get involved at the local level to protect their water quality. The program grew out of the efforts of the Indian Lake Development Corporation in Ohio, a citizens action group made up of residents within the Indian Lake area concerned with improving and protecting Indian Lake. The purpose of MWS is to recruit and instruct a group of volunteers who will work on various water quality and pollution prevention and control projects in their own communities. The Ohio State University Master Gardeners Program was used as a model for the development of the MWS Program. Program materials cover the following topics: (1) "Issues and Ethics" (which includes an overview of the Indian Lake Watershed Project and discussions on water quality, legislation, and citizen roles); (2) "Lakes"; (3) "Streams"; (4) "Monitoring"; (5) "Wetlands"; (6) "Ground Water"; (7) "Agriculture"; and (8) "Yard and Garden." These topics address such issues as habitats, food webs, watershed management, floodplains, and pollutants. A resources section contains a list of resources for additional information, MWS program policies, and various forms to complete to become a Steward. (PVD)

Master Watershed Stewards

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Reference Sources:

Significant portions of material were adapted from the following resources:

Ohio State University Extension Master Gardener Program

The Washington State University Cooperative Extension Clallam County office and the Sequim Bay Water Quality Projects BAY WATCHERS Program.
WSU Extension
Clallam County Courthouse
223 East Fourth
Port Angeles, Washington 98362

Izaak Walton League of America Save Our Streams
707 Conservation Lane
Gaithersburg, MD 20878-2983
(301) 548-0150

Ohio's Scenic River Stream Quality Monitoring Citizen Action Program
Ohio Department of Natural Resources
Division of Natural Areas and Preserves
Scenic Rivers Program, Building 1889
Fountain Square Court
Columbus, Ohio 43224

This program was developed through the cooperation of The OSU Extension Logan and Hardin County offices and the Indian Lake Watershed Project.

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Acknowledgments:

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Master Watershed Stewards Program Introduction

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The Master Watershed Stewards (MWS) Program is a pilot project offering the opportunity for communities to get involved at the local level to protect their water quality. The purpose of MWS is to recruit and instruct a group of volunteers who will work on various water quality and pollution prevention and control projects located in their own communities.

This program grew out of the efforts of the Indian Lake Development Corporation (ILDC), a citizens action group made up of residents within the Indian Lake area concerned with improving and protecting Indian Lake. Because of their efforts the Indian Lake Hydrologic Unit Area was formed.

What is the Indian Lake Hydrologic Unit Area (HUA) and how did it originate? Addressing public concerns about the quality of our nations water resources, Congress passed the Federal Water Pollution Control Act of 1972, known commonly as the Clean Water Act. The act stated that "water shall be clean enough for swimming, fishing, and other recreational uses," and " there shall be no unlawful discharge of pollution into U.S. waters." Most governmental efforts were directed toward the control of point source pollution. Point source pollution is the introduction of an impurity into a surface-water body or aquifer at an easily identifiable distinct location through a direct route. Primary emphasis was placed on improving industrial and domestic waste water treatment.

By the mid-1980s government agencies indicated that substantial progress had been made to address and correct point source pollution. They also indicated that for substantial improvement of water quality to occur, nonpoint sources (NPS) of pollution must also be addressed. Nonpoint source pollution is the introduction of impurities into a surface-water body or aquifer, through a non-direct route and from sources that are "diffuse" in nature. Examples of NPS pollution include: automobile emissions, road dirt and grit, and runoff from parking lots; runoff and leachate from agricultural fields, barnyards, feedlots, home gardens, lawns and failing on-site waste water treatment systems; and runoff and leachate from construction, mining and logging operations.

In 1987 Congress amended the Clean Water Act of 1972. Section 319 directed states to assess and prioritize their most severe water quality problem areas and to develop nonpoint source management programs to solve these problems. The Indian Lake Watershed was identified as an area heavily impacted by NPS pollution. The term watershed, refers to a geographic area in which water, sediments, and dissolved materials drain to a common outlet - a point on a larger stream, a lake, an underlying aquifer, estuary or ocean. The Indian Lake Watershed ranked 7th among 93 watersheds statewide in the number of tons of cropland soil eroded and 6th overall for combined cropland erosion and erosion from all sources.

In 1989, the United States Department of Agriculture (USDA) initiated the Hydrologic Unit Area concept. The goal was to assist farmers and ranchers in voluntarily applying conservation practices that will help achieve water quality goals. Two USDA agencies, the Natural Resource Conservation Service (NRCS) formerly Soil Conservation Service and the Extension Service were given joint leadership in implementing the program. Nationally 74 HUA projects were established in the fiscal years 1990 and 1991 including Ohio's Indian Lake watershed and Big Darby Creek watershed.

A Hydrologic Unit is a watershed-area designation that delineates the hydrologic and geographic boundaries of a stream, river or lake basin. This organization helps water scientists, resource managers, regulatory personnel an policy makers to better coordinate activities across politcal boundaries. In Ohio, the major cooperating state and federal agencies include: The Ohio State University (OSU) Extension, Ohio Environmental Protection Agency (OEPA), Ohio Department of Natural Resources (ODNR), NRCS and the USDA Farm Service Agency (FSA) formerly ASCS.

The Master Watershed Stewards (MWS) program was developed through the cooperation of The OSU Extension Logan and Hardin County offices and the Indian Lake Watershed Project under a Clean Water Act Section 319 Nonpoint Source Reduction Grant. Extension is a natural agency to provide the necessary administrative support for an education and volunteer program. Extension was established by the Smith-Lever Act of 1914 to extend education and new research to the public. OSU's Master Gardeners Program has had a long history of success and was used as a model for the development of the MWS Program. Significant materials were adapted from The Washington State University Cooperative Extension Clallam County office and the Sequim Bay Water Quality Projects BAY WATCHERS program. Stream monitoring techniques and teaching materials were also developed utilizing the Izaak Walton League of America Save Our Streams and Ohio's Scenic River Stream Quality monitoring citizen action programs.

A series of informative, stimulating programs and discussions on important water quality issues have been compiled. The Indian Lake Watershed Project Team and Joint Board of Supervisors assisted in developing the list of topics and identifying potential instructors and educational materials. The most qualified people available to speak on the issues were requested to participate and have contributed their time, their staff and their resources to the MWS project.

The MWS course work is designed to get participants talking about facts and real information and concerns—not just fears and preconceptions. Qualified technical people have developed the programs to ensure that information is unbiased and accurate. At the end of the program, class participants should understand the major water quality problems, know what the water quality impacts are and have some ideas of what can be done by the public and where to go to get help. The people who attend the classes and pass an examination will become certified Master Watershed Stewards.

The MWS volunteers will be armed with resource information and have the Extension's network of trained research scientists, county agents and OSU to support them. Other agencies with authority to administer public laws and programs may be approached to assist the volunteers through the agencies' regular scope of work. Master Watershed Steward Volunteers will identify and carry out specific water quality projects that will benefit their community. For the pilot program, the volunteer's projects will focus on the Indian Lake Watershed.

Because this is a pilot program, the first classes of MWS are being asked to assist in evaluating the project as it progresses. The evaluations will be used to improve the program for future classes. As new information or classes become available, trained Master Watershed Stewards will be supplied the materials and will be invited to attend subsequent classes or workshops to update their knowledge. We hope that you all will freely voice your opinions. We need to know where we have succeeded and where we need improvement. We would also appreciate any ideas you may have that you think might result in a better program.

The future of the Master Watershed Stewards Program rests with the people who participate in it. A group of people, armed with knowledge, motivation, and supported by established institutions, can indeed make a difference.

I hope that you find the MWS Program challenging, stimulating and rewarding.

Gary L. Comer, Jr.
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Issues and Ethics

Water Quality in your Neighborhood

Issues and Ethics: Water Quality in Your Neighborhood

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Introduction

Ours is a water planet. Water covers three quarters of its surface, and makes up two-thirds of our bodies. It is so vital to life we can't live more than four days without it. If all the earth's water - an estimated 325 trillion gallons - were squeezed into a gallon jug and you poured off what was not drinkable (too salty, frozen or polluted) you'd be left with one drop. And even that might not pass U.S. water quality standards.

Indian Lake Watershed Project Overview

The Lake

Located in Logan County in west central Ohio, Indian Lake is approximately 5,343 acres in size. Construction on the reservoir began in 1851 and was completed in 1860. Because the lake was originally constructed as a feeder for the Miami-Erie Canal, it is a very shallow lake with an average depth of approximately 6 feet.

Since the turn of the century, Indian Lake has been used solely for recreational purposes. It is not used for public water supply or commercial fishing. The lake and park lands surrounding it are used for camping, fishing, swimming, boating and hiking. The park is in use year round.

A significant portion of the shoreline is in private ownership. Currently, the lake has more than 5,000 private boat docks. In addition, the lake area receives a large number of visitors from outside the lake area every year. Records indicate that over 1.3 million people visited the lake region in 1996. There were over 13,000 boats registered to Indian Lake in 1995.

The State of Ohio has designated Indian Lake for the following uses: Exceptional Warmwater Habitat, Public Water Supply, Agricultural Water Supply, Industrial Water Supply, Primary Contact (suitable for full-body contact recreation), and Bathing Water (waters that, during recreation season, are suitable for swimming where a lifeguard and/or bathhouse facilities are present). In addition, the lake is designated as a State Resource Water (this designation applies to surface waters within metropolitan park systems and to publicly owned lakes and reservoirs).

The Watershed

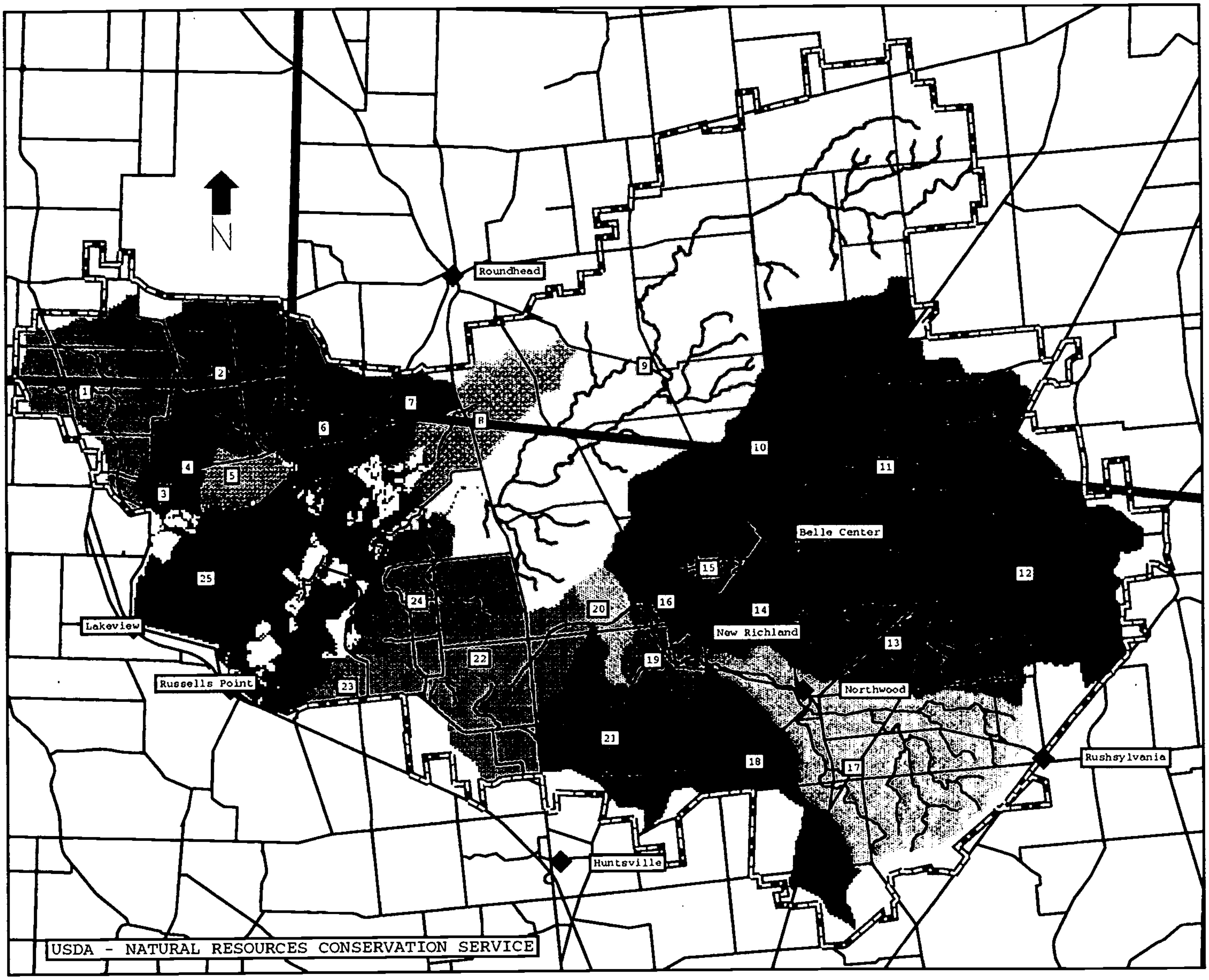
The Indian Lake Watershed covers approximately 62,312 acres in Logan, Hardin, and Auglaize counties. Four main tributaries drain into Indian Lake: Van Horn Creek, Blackhawk Run, North Fork of the Great Miami River, and South Fork of the Great Miami River. (See map next page).

Geology and Soils

The landscape of the Indian Lake Watershed was shaped by continental glaciation and running water. The watershed is located in the till plains of Ohio's central lowlands. The terrain is generally flat to gently rolling with slopes of 0-6 percent, with occasional steeper areas of 6-12 percent slope. Areas with slopes greater than 12 percent are rare. The steeper slopes are mostly in the headwaters of the South Fork subwatershed.

Much of the watershed consists of high lime glacial till of Illinoisan and Wisconsin age (50 to 100 feet of thickness) overlying Devonian

Indian Lake Watershed Project



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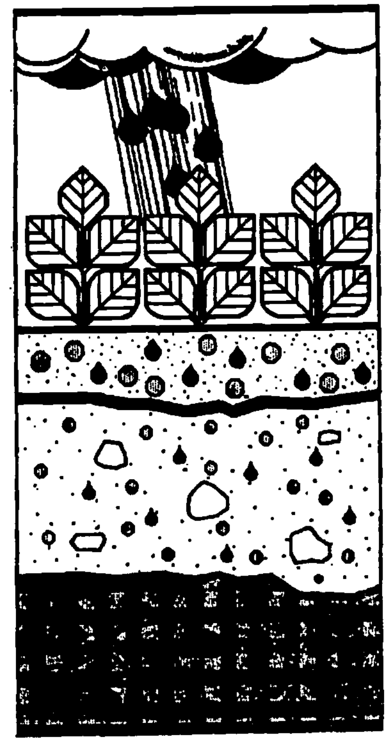
Indian Lake Hydrologic Unit Area
County Line
Roads
Primary Streams

AREA
1 Van Horn Creek -- 1,819 acs
2 Blackhawk Run -- 3,530 acs
3 Chippewa Drainage -- 263 acs
4 Chippewa Drainage -- 280 acs
5 Chippewa Drainage -- 508 acs
6 Beatty-Van Horn Ditch -- 1,206 acs
7 Baughman Ditch -- 480 acs
8 Banning Joint Co. Ditch -- 1,521 acs
9 North Fork Great Miami River -- 1,3785 acs
10 Liggitt Ditch -- 4,678 acs
11 Red Slough Ditch -- 4,960 acs
12 Upper South Fork Great Miami River -- 4,319 acs
13 tributary to S.F. Great Miami River -- 2,643 acs
14 S. Branch Red Slough Ditch -- 944 acs
15 Red Slough Ditch -- 299 acs
16 tributary to S.F. Great Miami River -- 985 acs
17 tributary to S.F. Great Miami River -- 4,769 acs
18 Gillen Ditch -- 1,944 acs
19 tributary to S.F. Great Miami River -- 688 acs
20 Middle South Fork Great Miami River -- 479 ac
21 Griffin-Fullerton Ditch -- 2,517 acs
22 Lower South Fork Great Miami River -- 2,919 acs
23 Dunns Pond -- 242 acs
24 Middle Branch Great Miami River -- 1,695 acs
25 Indian Lake -- 5,323 acs

dolomite of the lower Monroe formation. Because of the thickness of the glacial till, natural exposures of the bedrock are few in number and small in size. Where these outcrops occur, they are frequently the sites of quarrying operations.

The watershed's soils are derived mainly from high lime glacial till. The predominant topsoil texture in the watershed is silt loam. Eight major soil associations occur in the watershed. The two most extensive associations, the Blount-Morley and the St. Clair-Nappannee (together comprising 47 percent of the watershed area), have the highest slope and erosion classes in the watershed. The watershed's soils are typically silt loams with moderately slow subsoil permeability with a slight to moderate erosion hazard.



Ground Water

Indian Lake is located on the northern terminus of the Great Miami Valley aquifer system. The extensive aquifer system extends south from Indian Lake to Dayton and beyond. It supplies the groundwater needs of thousands of people in the region. In southeast Logan County, the buried valley aquifer is 1 to 2.5 miles in width and 70 to 230 feet in depth. It is a sand and gravel aquifer with interbedded silt and clay and occasional boulders.

The most significant source of recharge to the buried valley aquifer system is infiltration from surface water bodies overlying the aquifer, suggesting that Indian Lake may have a recharge function in the system. However, no groundwater budget has been calculated for Indian Lake.

Land Use

The four primary subwatersheds (North Fork, South Fork, Van Horn and Blackhawk) which comprise the Indian Lake Watershed are similar in the types and proportions of current land uses. Crop production is the dominant agricultural land use (principally corn and soybeans), followed by livestock pasturing (dairy operations). Together, these agricultural land uses comprise approximately 87 percent of land use in these four subwatersheds. There are no industrial land uses in the Indian Lake Watershed.

The largest area of urban land occurs in the South Fork subwatershed (845 acres), containing the towns of Belle Center, Yelverton, New Richland and Northwood.

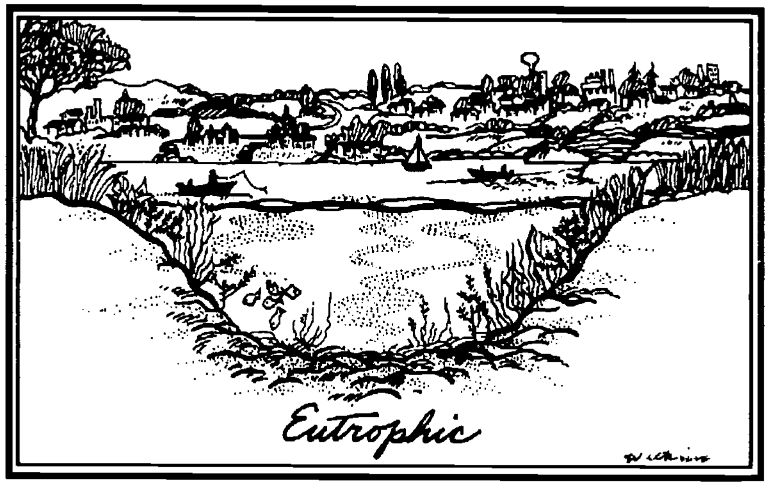
The villages of Lakeview and Russells Point are adjacent to the Indian Lake Watershed, comprise the next largest area of urban development (approximately 626 acres), and greatly affect the water quality with stormwater runoff, lawn care, urban construction and recreational use.

Forest cover in the watershed has been steadily declining in recent years. This is due mostly to clearing for agriculture, however, some forest has been cleared on the North side of the lake for development. Forest land currently accounts for less than 4 percent of the watershed acres.

The Problem

Nonpoint source pollution is the major cause of water quality degradation in the Indian Lake Watershed. Biological monitoring in the Indian Lake Watershed by Ohio EPA in 1988 indicated that essentially no tributary of the lake was fully attaining warmwater habitat aquatic life use designation for its entire length based on fish and macro-invertebrate criteria. Non-attainment appeared related to agricultural land use activities that resulted in habitat modification (channelization, removal of riparian cover, abnormal flow fluctuations, excessive sedimentation, and nutrient enrichment).

Because of the predominant clay soils in the watershed, operators have traditionally adopted conventional tillage practices which generally involves fall plowing, and leaving surface soils unprotected throughout the winter and spring months. These soils characteristically have a high rate of surface water runoff. The use of conventional tillage systems on moisture saturated soils can result in large amounts of soil being transported off agricultural fields. Sediment loading to Indian Lake has reduced the lake's volume by 35 percent and depth to only 3 feet in most areas. It is assumed, however, that increased use of no-till and conservation tillage within the watershed since project implementation has decreased sediment loading due to sheet and rill erosion by approximately 50 percent.



Streambank erosion persists as a significant source of sediment loading to Indian Lake. Information collected in 1989 for the National Resource Inventory (NRI) by NRCS and data from Ohio Capability Analysis Program (OCAP) estimated that 45% of the total soil erosion within the watershed was due to gully erosion, a majority of which was streambank erosion. This percentage has most likely increased while the proportion of sedimentation due to sheet and rill erosion has decreased.

Secchi disc measurements and Chlorophyll-A determinations conducted on the lake from 1990 to 1994 show that Indian Lake is hyper-eutrophic. Lily pads and other large aquatic flora have overtaken large areas of shallow water. Duckweed and filamentous algae choke near-shore areas during the summer months. It is believed that most of the excess nutrient loading is from application of fertilizer to surrounding cropland and lawns.

The Project

The Indian Lake Watershed Project, formerly known as the Indian Lake Hydrologic Unit Area Project, received its initial funding in 1990. The project, however, has its beginnings with the Indian Lake Development Corporation (ILDC), a lake association of Indian Lake residents organized in 1983 to improve Indian Lake and its surrounding area.

ILDC recognized a problem with the ongoing need to dredge the inlets of major tributaries where sediment accumulations were the greatest. Disposal areas for dredged materials were becoming overloaded, and the potential for the development of feasible, new disposal sites was lessening because of limited land availability, long pumping distances, and other environmental restrictions.

ILDC brought together several federal, state, and local agencies to discuss the problem, and a cooperative watershed approach was initiated. The Indian Lake Watershed Joint Board of Supervisors was formed consisting of one supervisor from each of the three Soil and Water Conservation Districts within the watershed, and representatives from local interests including agriculture, business, the local water dept., lake residents, and the Indian Lake State Park. The Joint Board receives and disperses funds, determines programming priorities and provides project direction.

An interagency implementation team consisting of individuals from NRCS, Division of Forestry, OSU Extension Service, Soil and Water Conservation Districts, and a Project Administrator contracted by the Joint Board provide technical support and implement programs.

The Programs

The Indian Lake Watershed Project provides a diverse array of incentive and education programs funded through various federal, state, and private sources in order to promote the adoption of Best Management Practices (BMPs) to reduce the sedimentation and eutrophication of Indian Lake and its tributaries. The following is a partial list of programs which have been or are currently being implemented in the watershed as of June 1996. A more complete list of programs is available in the "Indian Lake Watershed Project Long Range Management." Copies of the plan are available at local libraries, Ohio State University Extension office, and the Indian Lake Watershed Project office. (See Resource Agencies page).

Filter Strip Establishment

- 255 acres (42 miles with 50 foot average width)

Streambank Restoration

- 1580 feet applied

No-till Equipment Buydown

- 50 pieces of equipment

No-till Farming

- 80% of row crop and small grain acreage (6% prior to project implementation)

Integrated Crop Management

- 18 long-term agreements
- 3200 acres

Grassed Waterways

- 62.7 acres

Grade stabilization structures

- 36 structures

Critical area planting

- 4 acres

Tree Planting

- 17 acres

Pasture/Hayland Planting

- 1,625.9 acres

Precision Farming Systems

- 11 farms

- 5000 acres

Intensive Grazing Systems

- 40 acres

Livestock exclusion fencing

- 30,000 feet

Stream Monitoring

Education and Community Involvement

Stewardship Ethic

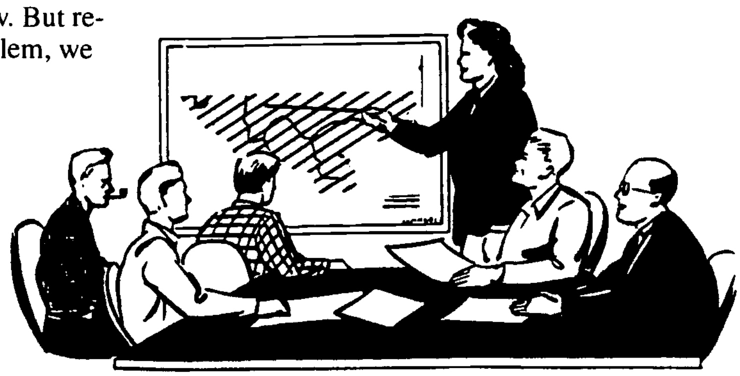
The Master Water shed Stewards (MWS) program is based on the concept that people will not knowingly do things that will pollute water. Yet everyday, as we go about living our daily lives, we do things that contribute to the water contamination.

You have joined the MWS program because you want to do something about water quality. No point in letting the news reports and magazine coverage drive you to despair; even the most "intractable" environmental problems march toward a solution when citizens get involved.

Few of us can do anything to keep million-barrel oil tankers on course through pristine waters. All of us can do something, every day, to ensure that fewer tankers are needed. None of us can stop the need for growth to facilitate increasing population. All of us can help reduce our own impact on the environment.

The volunteer program you are joining seeks to empower the individual to stop activities that contribute to water pollution. In other words, we want to foster a clean water ethic in our volunteers and, through them, in our communities. The program starts by providing background information about water and water pollution. By understanding the basics of hydrology, groundwater, geology and soils, stream, lake, and wetland ecology, agricultural practices, water quality monitoring techniques and other similar topics, you will understand how pollution occurs. Then you will learn what is being done to control pollution. Finally, you will be given tips about how you-as an individual and as a water quality volunteer can help protect and improve the water quality in our own community.

The 1990s have brought a new awareness that institutions alone can never solve the problems that culminate from the seemingly inconsequential actions of millions of individuals. Your trash, your neighbor's cows, his neighbor's septic system—all make the water less pure for the children of today and tomorrow. But remember: as much as we are the root of the problem, we are also the genesis of its solution.



We All Live Downstream

Sources of Water

Surface water

Surface water is water found above ground. This includes lakes, ponds, reservoirs streams, and wetlands. Surface water flows quickly downhill, following the pull of gravity. Surface water may be partially cleaned by exposure to sunlight and air, or by its journey through suitable habitat conditions.

Groundwater

Groundwater is percolated water stored in aquifers, large underground areas of soil and rock saturated with water. Groundwater flows very slowly. It isn't exposed to sun or air, which help clean it. It may take centuries to clean itself if it's polluted.

The Water Cycle

The water cycle (also called the hydrologic cycle) is an endless process of water circulation going on throughout the world. The sun's energy is at the top of the cycle. It transfers water from the seas and earth to the atmosphere in the form of water vapor. The soil and inland water bodies through evaporation and plants through transpiration add large amounts of water vapor in the atmosphere, but most of it comes from the oceans. Man, animals, and machines add small amounts of water by means of respiration and combustion.

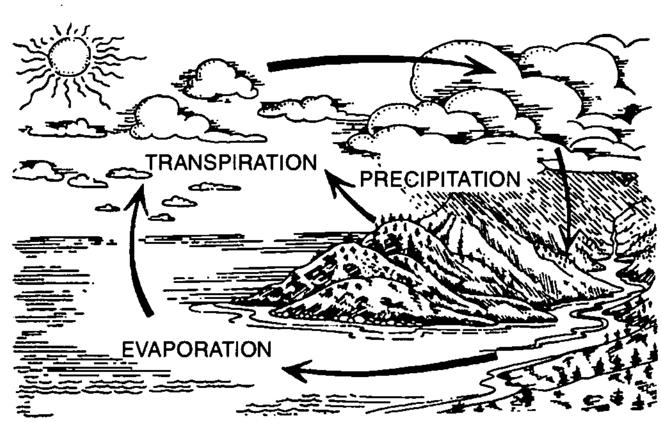
Air masses carry the water vapor across the earth, and the water vapor condenses into precipitation. Precipitation falls as rain, snow, sleet, hail. Some evaporates while falling and returns to the atmosphere. A small amount is intercepted and held by plants or by buildings, automobiles, and other structures and machines until it evaporates back into the atmosphere.

Most of the precipitation soaks into the soil; the part that doesn't runs to the sea by way of streams and rivers. Groundwater gets there more slowly. Some of the water that soaks into the soil is used by plants. Part of it percolates beyond the reach of plant roots to the water table, to underground reservoirs, and to springs and artesian wells.

Runoff on its way to the sea can be intercepted and stored for industrial or household use, and it can be diverted for irrigation.

Little water has been added or lost through the ages. The water cycle prevails in all places and at all times with neither beginning nor end.

Water covers nearly 75 percent of the earth; most is sea water. But sea water contains minerals and other substances, including those that make it salty, that are harmful to most land plants and animals. Still it is from the vast salty reservoirs, the seas and oceans, that most of our precipitation comes-no longer salty or mineral-laden.



The Water Cycle

Every year about 80,000 cubic miles of water evaporates from oceans

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and about 15,000 cubic miles from land sources. Since the amounts of water evaporated and precipitated are almost the same, about 95,000 cubic miles of water are moving between earth and sky at all times.

Storms at sea return to the oceans much of the water evaporated from the oceans, so land areas get only about 24,000 cubic miles of water as precipitation. Precipitation on the land averages 26 inches a year, but it is not evenly distributed. Some places get less than 1 inch annually and others more than 400 inches.

Water Budget for Ohio

Based on long-term weather records, Ohio receives an average of 38 inches of precipitation per year. Of these 38 inches, about 10 inches (26 percent) become runoff, which moves immediately to surface-water bodies like streams and lakes. Two inches are retained at the ground surface and evaporate back into the atmosphere in a relatively short period of time. Twenty-six of the 38 total inches enter the soil surface through infiltration. Twenty of these 26 inches go into soil storage and later are returned to the atmosphere by the combination of evaporation and transpiration (evapotranspiration). The remaining 6 inches of precipitation (16 percent of the total) have the potential to recharge the ground-water supply. Two of these 6 inches eventually move to springs, lakes, or streams as groundwater discharge. The remaining 4 inches either return to the atmosphere by evapotranspiration or are withdrawn to supply water needs.

The United States gets about 30 inches a year, or about 4,300 billion gallons a day. Total streamflow from surface and underground sources is about 8.5 inches a year, or about 1,200 billion gallons a day. This is the amount available for human use-homes, industry, irrigation, and recreation.

The difference between precipitation and streamflow 21.5 inches a year, or 3,100 billion gallons a day-is the amount returned to the atmosphere as vapor. It is roughly 70 percent of the total water supply. It includes the water used by plants.

Humans can exist on a gallon or so of water a day for drinking, cooking, and washing though we seldom do or have to. In medieval times, people probably used no more than 3 to 5 gallons a day. In the 19th century, especially in Western nations, people were using about 95 gallons a day. At present in the United States, a person uses about 1,500 gallons a day for needs and comforts including recreation, cooling, food production and industrial supply.

Humans can alter the water cycle but little, so our primary supply of water is firmly fixed. We can manage and conserve water as it becomes available-when it falls on the land. If we fail to do so, we lose the values that water has when used wisely.

Throughout the world the need for water continues to increase. Population growth brings demands for more water. Per capita use of water, especially in industrialized countries, is increasing rapidly. It is human management of the precipitation available to us that determines whether or not we have both the quantity and the quality of water to meet our needs.

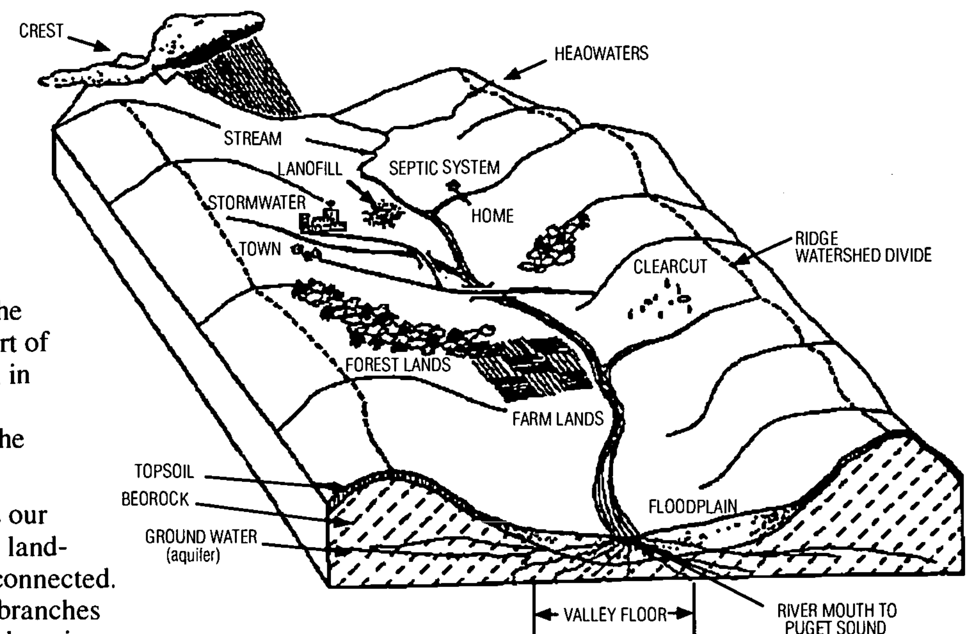
It is our obligation to return water to streams, lakes, and oceans as clean as possible and with the least waste.

What Is a Watershed?

The word means a parting, a shedding of waters. But a watershed is a gathering place, also.

A watershed is measured by the hilltops and ridges that are its boundaries. It is shaped by the hills, valleys and plains that are the landscape and is tempered by the forests, fields, lakes and marshes that are habitats for its creatures. Most of us know a watershed through its streams and rivers that connect forest with farm, farm with city and city with lake—and each of us changes the watershed day by day, bit by bit, as we go about the business of our lives.

A watershed, said Peter Warshall, has "walls of hills and mountains; a floor of river or lake; and roof of rain clouds." The rain erodes the walls into the watery floor and then evaporates back into the roof. Streams do not always rise in the mountains and flow to the sea. Rain falling on every square inch of land within a watershed contributes to streams as they wind their way downhill. (The rain may flow on the surface of the land, or it may soak into the ground and then flow to a stream, river or lake.)



The critical thing to remember about watersheds is that the rivers, the hills, and the bottom lands are all part of a system. Every activity on the land, in the water, or even in the air has the potential to affect the watershed system.

A change in the watershed affects our lives—a change that we make in the landscape affects the watershed. It's all connected. Nature's changes can be as quiet as branches building up behind a fallen log and changing the path of a stream. Or they can be as dramatic as a winter flood. Our actions, too, can be subtle or very dramatic; but they all affects someone or something. When we cut forests, clear land, lay concrete and asphalt, and build houses and towns we cause changes in the watershed. Those changes mean the water cycle works differently.

Rain striking the ground has fewer place to soak in gradually— runoff is faster and more violent...causing erosion and flooding. Water quality deteriorates as water drains from farms and cities carrying pesticides, animal waste, oil and heavy metals into our groundwater, streams, lakes, and, eventually, oceans.

The activities of your neighbor up the hill will affect what the rain carries into your yard. And what you pour or spread on the ground, what ends up in your septic system or driveway, affects what ends up downstream from you, in the nearest stream or river, in the groundwater, or in Indian Lake. The watershed, the water cycle and our lives are all connected. Any action, anywhere affects the land, the water and, ultimately, us. We all live downstream.

Defining Water Quality

Beneficial Uses

An abundant supply of good, clean water must support a variety of beneficial uses. These include drinking water for domestic use and stock watering; industrial, commercial, agricultural, and fish and wildlife maintenance and enhancement; recreation; generation of electrical power; and preservation of environmental and aesthetic values. Drinking water is the beneficial use that usually requires the highest quality water to protect human health.

The quality of water required for each beneficial use often differs. Yet the quality of any body of surface or groundwater is a function of natural influences and human activities. Several beneficial uses may exist for one body of water. Ohio's surface and groundwater standards protect water supplies for the beneficial use that requires the highest quality water. These standards are consistent with public health and public enjoyment of Ohio's waters. The standards also ensure the propagation and protection of fish and wildlife.

Why Water Quality Varies

Characteristics

Water has unique physical, chemical, and biological characteristics that can determine its quality.

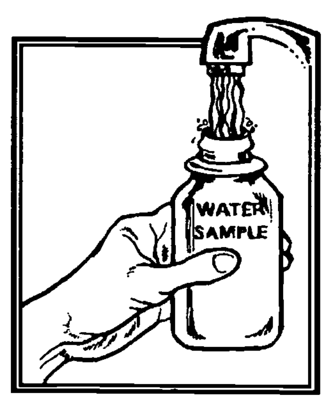
Physically

Water exists in three forms: solid ice, liquid water and gaseous water vapor. Liquid water put under pressure does not compress significantly. However, as it expands when frozen, it may cause water supply pipes to break. Water (including surface and groundwater) always flows downhill, from a high point to a lower point. Water molecules evaporate into water vapor from liquid water. This process is called vaporization. Water also may change directly from solid ice to a vapor. This is a unique process called sublimation. As water changes into vapor, it leaves behind any dissolved or suspended solids. These materials then concentrate in the remaining water. This is only a concern if too much dissolved or solid material becomes concentrated in the water left behind. That water then may become degraded to a point where it cannot support the necessary beneficial uses.

Chemically

Water is a deceptively simple substance. Two atoms of hydrogen and one of oxygen combine to form the molecule H_2O. In its pure form water is a colorless, tasteless liquid. It is neither acid nor alkaline. Water molecules do not split to form charged particles called ions. Yet water behaves as if it were an ion. Water has a positive charge on one end or pole of the molecule and a negative charge on the other. Because of this bipolar behavior, water is the universal solvent.

Water gathers a little of everything it contacts. Sea water contains nearly every substance known. Fresh water also may contain many substances, but in smaller amounts. In addition to dissolved material, water also carries many suspended particles. Naturally occurring dissolved chemicals and suspended particles make pure water a rare commodity in nature.



Pure water, though safe, is not very good for drinking. It does not taste good to most people. Many of the naturally dissolved minerals and salts give water its flavor and are necessary for life and health. In fact, good drinking water has about 200 ppm of these minerals and salts. However, not everything dissolved in water is healthy for people.

Biologically

Water is the cornerstone of life. Wherever water occurs, except in the deepest aquifers, life exists. All life depends on water.

Each person is made up of about two-thirds water. Adults require at least two quarts of water in some form each day to sustain life. Losing just 10 percent of the body's water would be fatal. Nearly all the water in the body is exchanged for new about every four months. However, not all contaminants swallowed with the daily intake of water are excreted and some may accumulate in the body.

Water Quality Indicators and Nonpoint Pollution

While "pure" water is unnatural, clean water is cherished. Most people regard water quality as important in their own minds. However, disagreements often occur over what constitutes good water quality. Let's look at a few measurable water quality indicators and how they contribute to nonpoint pollution.

Fecal coliform bacteria

Fecal coliforms live in the intestinal tract of warm-blooded animals. They are not necessarily "pathogenic," or disease causing, but their presence in water indicates the presence of animal wastes and the possible presence of disease-causing bacteria or viruses. Nonpoint sources of fecal coliforms include failed on-site waste disposal systems, waste from animals grazing near streams or shorelines, and overflows from combined sewage/stormwater systems.

Turbidity

Turbidity is cloudiness in water caused by suspended material including clay, silt, plankton, colored soluble organics, and fine organic and inorganic particles. During rainstorms, eroded soils are suspended in surface runoff as water flows down watersheds toward the sea. If there is protective ground cover, rain sinks into the ground and is released slowly through springs and seeps, with little runoff or flooding. If the cover is stripped away, falling rain and overland flow sweep up loose material and carry it along. Suspended soil settles to the bottom of streams, and bottom-dwelling plants and animals are smothered. Light needed by plants to produce oxygen is reduced.

Dissolved oxygen

Dissolved oxygen is important to assure that plants and animals have sufficient oxygen for respiration. Oxygen reduction in surface water is usually associated with organic waste which, when dumped into surface waters, causes an explosion of bacteria, fungi, and other organisms that use the waste as food. Like all living things, these "decomposers" demand oxygen. As dissolved oxygen is removed from the water, animals living there are stressed, and at critical levels, must leave or die.

Inorganic nutrients

Fertilizers are composed of nutrients that stimulate plant growth in water as well as on the land. If excessive amounts are used or if they are applied during rainy periods, they may wash into streams and creeks. "Eutrophication" is caused by excessive growth of plants, called "nuisance algae," because they are sometimes toxic, deplete oxygen, and may impart a foul smell and taste to the water. Because of the unique quality of each body of water, there are no numerical criteria for most forms of inorganic nutrients, but standards require that concentrations be kept below that which may harm aquatic life or threaten public health.

Temperature

High water temperatures can cause stress to animals, particularly cold water fish such as perch and walleye. If trees, brush and other sources of shade are removed from streambanks, the water will warm up; thus, logging, land clearing, or agriculture may cause unnecessary destruction of aquatic habitats.

Nonregulatory Definitions of Water Quality

Water has other uses besides drinking, swimming and fishing. Home water uses include cooking, bathing and laundry. Outside the home, water uses include watering home and garden plants, irrigating crops, food processing, industry, and power generation. Some beneficial uses may require certain water quality indicators to be purer than drinking water standards.

Bathing and laundry

The primary water quality problem for bathing and laundry is hardness. Dissolved salts of calcium and magnesium cause hard water—usually bicarbonate salts, these may be chloride, sulfate or nitrate salts.

Water hardness is measured in grains. One grain of calcium bicarbonate equals 17.1 ppm by weight. The American Society of Agricultural Engineers' water hardness classification system has four classes:

Class	Grains per gallon	ppm Total Hardness
Soft	0 to 3.5	0 to 60
Moderate	3.5 to 7	61 to 120
Hard	7 to 10.5	121 to 180
Very hard	more than 10.5	> 180

Hard water reduces the cleaning efficiency of both soap and detergents. It reacts with soap to form suds and soap scum on bathroom fixtures. Hard water reacts with detergent in laundry or dishwashing to form solids that precipitate out of solution. These solids collect between the fibers in clothing, making them stiff. Collected solids can wear clothes out faster. Hard water may also discolor clothes. Hard water solids also collect in washing machines and water heaters, causing excessive wear.

The addition of phosphate to detergents prevents solids from forming. Unfortunately, phosphate returning to surface water through sewers, direct discharge, and septic systems usually degrade lake and stream quality.

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Phosphate is the limiting factor in plant growth in most lakes. Enough nitrogen usually is present in lakes for plant growth. Excess phosphate in lakes promotes algal blooms. One pound of phosphate may promote the growth of half a ton of algae. Algal blooms make the water murky. When light cannot reach plants at the bottom of the lake, the plant dies. Bacteria in the lake digest the dead plants, but use up oxygen in the water in the process. Without oxygen, fish die because they cannot breathe. More bacteria consume more oxygen and the lake dies. This process is known as eutrophication.

Phosphates are difficult to remove at waste treatment plants. Use nonphosphate detergents whenever possible.

Water softeners treat hard water by exchanging sodium for the salts of calcium and magnesium. Home softened water prevents many of the household problems mentioned earlier. However, people who have sodium restricted diets should use unsoftened water for drinking and cooking.

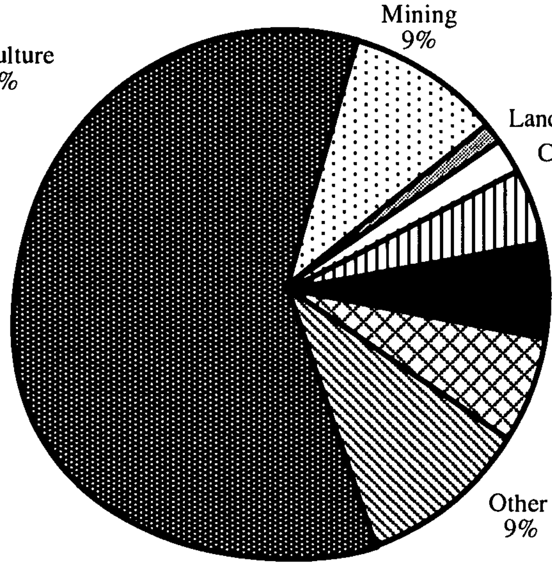
The Many Faces of Pollution

What is Pollution?

"The contamination of soil, water, or the atmosphere by the discharge of noxious substances." American Heritage Dictionary

"Any alteration in the physical, chemical, or biological components of air, water, or soil that threatens life." Daniel D. Chiras, Environmental Science.

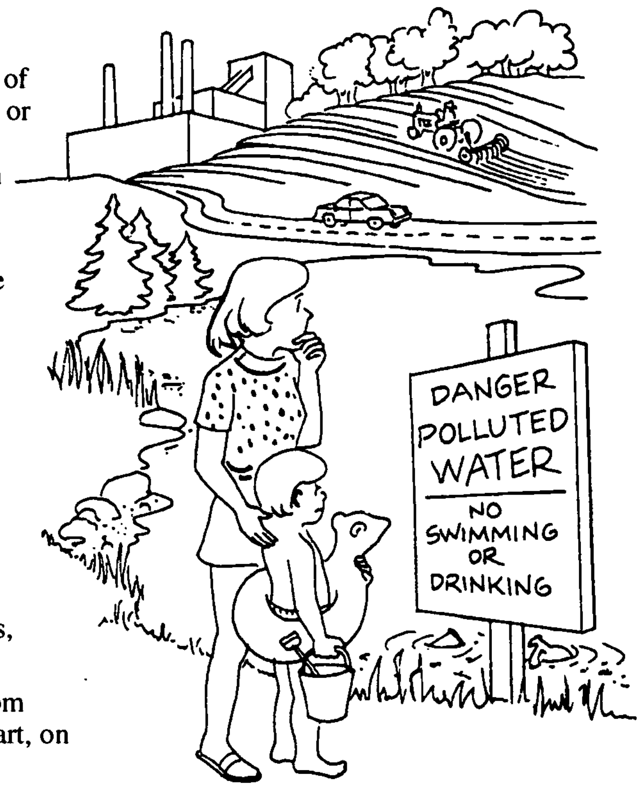
"Too much of something in the wrong place." James G. Septh, Earth '88, National Geographic Society.



What is Water Quality?

The Federal Water Pollution Control Act, commonly called the Clean Water Act since 1977, emphasizes that water quality standards should: include provisions for restoring and maintaining the chemical, physical and biological integrity of surface waters of the United States; provide, wherever attainable, water quality for the protection of fish, shellfish, wildlife and recreational waters; and consider the use and value of surface waters for public water supplies, propagation of fish and wildlife, recreation, agriculture and industrial purposes, and navigation.

Sources of Pollution



Water quality programs are usually based on the source of pollution. If pollution comes from a specific source, outlet or pipe, it is called "point source pollution." Point sources of pollution are fairly easily managed and permits are written to control and monitor contaminants entering the water.

If contaminates dribble, drip, or ooze into our water resources in a manner that makes it difficult to determine the source of the contamination, it is called "nonpoint source pollution." Not only are the sources difficult to identify; they are difficult to regulate.

Nonpoint sources of pollution share several general characteristics:

1. Nonpoint sources generally cannot be monitored at their point of origin, and their exact source is often difficult or impossible to trace.
2. Nonpoint source pollution is cumulative. It results from many actions by many different people, animals, or businesses, and is often spread over wide areas.
3. The extent of nonpoint source pollution may vary from place to place and from year to year, depending, in part, on the geography, geology, and weather of a region.
4. Control of nonpoint source pollution requires more than structural solutions. Effective control requires the use of best management practices, combined with public education, economic incentives, and in some cases, regulations.

Some of the contributions from nonpoint sources are unavoidable such as nutrient loss from croplands that occurs even with the most careful cultivation practices, the natural leaching of chemicals from weathered soils.

The majority of contributions, however, stem from human activity. Failing on-site sewage disposal systems, the improper use and disposal of pesticides and other common household chemicals, and erosion at construction sites are just a few of the ways our activities can generate significant amounts of nonpoint source pollution.

Sources of Nonpoint Pollution

Some of the major point and nonpoint sources of contamination follow. It is evident that no one source discharges only one contaminant. Instead, pollution from the various sources is usually made up of complex mixtures of contaminants.

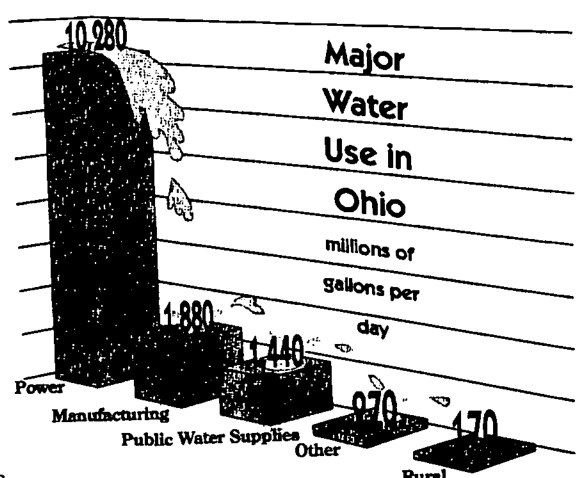
1. Atmospheric sources include gaseous and particulate lead and hydrocarbon exhausts from automobiles; gases and particles from factory and power plant chimneys; and combustion products from wood stoves and vehicles. These enter the water directly or are carried by runoff.
2. Forestry and logging contribute contaminants from soils that are eroded off roads and clearcuts, herbicides, and insecticides, and also cause aquatic habitat degradation.
3. Runoff from commercial and domestic agriculture carries fertilizers, pesticides, soil particles eroded from cropland and shorelands, and nutrients and pathogens from animal waste.

4. Runoff from suburban and rural residential areas carries wastes from lawns and gardens, pets, cars, on-site sewage disposal systems, and household paints and chemicals.
5. Landfills can contaminant surface water and ground water with virtually every material used and disposed of in society.
6. Highways are significant sources of hydrocarbons, metals, and contaminated particles that wash off into roadside ditches and stormdrains.
7. Surface runoff from urbanized areas contains a mixture of contaminants (including pathogens, toxic metals and organics, nutrients, and sediments) from streets and motor vehicles, commercial and industrial activities, and human and animal inhabitants.
8. Dredging and dredged material disposal redistributes contaminated particles in the Lake.
9. Recreational boating contributes petroleum products, bottom paints, sewage, and refuse spillage directly to the Lake.
10. Combined sewer overflows combine surface stormwater runoff from urban and suburban areas with sewage and industrial wastewater and discharge some of it directly to the environment without treatment.
11. Industries discharge a wide range of contaminants including toxic metals and complex organic and inorganic compounds depending on the particular industry.
12. Municipal sewage treatment plants discharge large volumes of treated wastewater that contains a complex mixture of contaminants including pathogens, nutrients, oils and greases, toxic organic chemicals and metals, and sediments.

Conflicting Uses of Water Resources

One problem in creating a water quality ethic is that people place value according to what is important to them. When we try to decide how to prevent or control water pollution, the many human activities associated with one or more components of the environment must be evaluated and some balance or order created. Various activities to be weighed include residential, industrial, commercial, recreational, educational, cultural, waste disposal and defense.

Resources are used for each of these activities. Construction of residential homes would obviously require the use of trees from the forests and industrial activity may require additional fresh water to produce its products. Expanded urban and suburban activity may impact agricultural areas and wetlands. Both require the use of shoreline and water. Water-related recreation is one of the great attractions of Indian Lake.



Source: *Water Quality Standards Handbook*, U.S. EPA Office of Water Regulations and Standards, Washington, D.C., Dec. 1983.

Conflicts arise as the human population increases and different interest groups vie to use resources. Because natural resources are limited commodities, trade-offs must be considered. Short term gains versus long term losses is also a consideration. For example, the development of shoreline property may bring economic gain, but cost the destruction of valuable fish and wildlife habitat and adversely impact water quality. Are we willing to accept the long term losses for the obvious gains in the short term?

Consider the trade-offs involved in growth management. An argument for development might be the stimulation that it provides to the economy and the expansion of the tax base for the community. On the other hand, the risks associated with such rapid development are often not anticipated.

When making decisions about conflicting uses, we often have to decide which resources are best used to what end. Questions that should be asked in making these decisions include the following:

1. Does the resource in question have local, regional, or national significance?
2. Does the resource offer the potential for more than one major land or water use?
3. Is the resource renewable or non-renewable?
4. What is the nature and extent of the impact on use of that resource?
5. What are the short-term and long-term costs and benefits?

A critical judgement that must be made concerns the degree of environmental degradation that is acceptable and how it can be minimized. These are complex issues which have no simple or universal answers, dependent as they are on fluctuating economics and individual values.

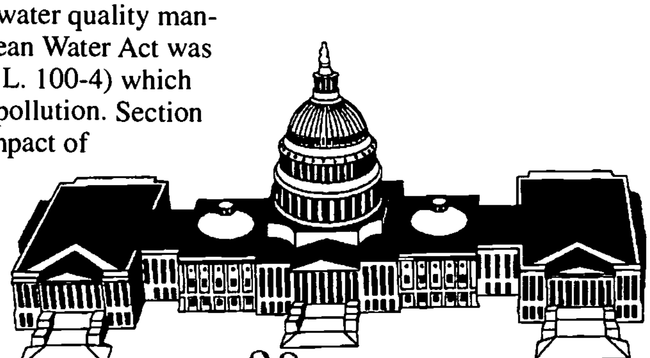
Personal decisions are an important variable in the overall analysis. Something as simple as choosing to responsibly recycle glass, paper and aluminum products will reduce the problem of solid waste disposal, at the same time conserving energy used in the production of these products. Similarly, disposing of oil, solvents, pesticides and other toxic chemicals in a safe and approved way will assure that these contaminants will not enter and further damage the environment.

Legislating Clean Water

Because water pollution is a pervasive environmental problem, cleaning it up and keeping it clean concerns everyone. It involves a complexity of scientific, technological, economic and political factors that cut across state, national, and international borders.

Federal Water Quality Programs

National attention to nonpoint pollution surfaced in 1972, when Congress enacted the Clean Water Act (P.L. 92-500). Section 208 of this federal statute directed states to conduct planning for water quality management including nonpoint pollution control. The Clean Water Act was later reauthorized as the Water Quality Act of 1987 (P.L. 100-4) which contains a new provision addressing nonpoint source pollution. Section 319 of the 1987 act requires each state to assess the impact of nonpoint pollution on its waters and to develop a management program for controlling nonpoint sources.



Pollution sources

Point source pollution: Point sources of water pollution are stringently controlled. Discharges from most point sources now are within state water quality standards. Monitoring is ongoing and sources which violate their discharge permits are subject to fines, and in extreme cases, the discharger may be forced to shut down.

Nonpoint source pollution: Nonpoint pollution, because of its very nature, is difficult to control. "Dischargers" may be businesses, municipalities, or private individuals. For this reason, education and a series of special programs appears to offer the best hope of reducing the pollution stream.

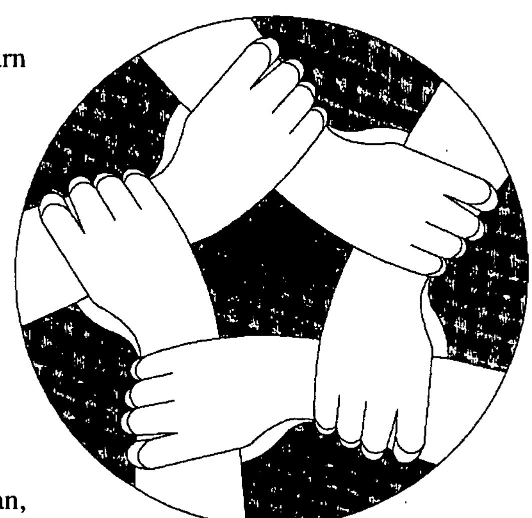
Watershed Management Strategies

Watershed management is a fairly new concept. It grows out of understanding the water cycle and the linkages between people, pollutant sources, water quality, and other natural resource inputs. Watershed management reflects the realization that pollutants cross political boundaries and are best controlled through cooperative efforts among the various jurisdictions. Watershed management recognizes that each basin is different.

Although the state administers some water quality programs that are wide-spread, the basic responsibility for planning and managing pollution is assigned to local jurisdictions, such as soil and water districts, and health departments.

Citizen Roles

1. Make a commitment to change your lifestyle to reduce the amount of pollution you add to your watershed.
2. Join organizations such as the one offering this class and learn all you can about the issues.
3. Volunteer to serve on a watershed committee, a planning committee, a growth management committee, a conservation district board of supervisors or other public service opportunity that contributes to making public policy or providing citizen oversight.
4. Attend public hearings and meetings and make your opinions known.
5. Sign up to receive notices of future meetings.
6. Read available historical information for the area and the locals newspapers.
7. Become familiar with your local watershed management plan, zoning, land use planning, and urge your local government agencies to implement its recommendations.
8. Share your knowledge with your friends, neighbors, clubs and community. Invite a representative from the planning department or watershed management committee to speak to your neighborhood associations, service club, PTA, or grange.



9. Identify an action from your local watershed management plan and help plan and organize a project that will address the action. Then get community support and funding and do your part toward improving water quality.
10. Become involved with scouts, 4-H, or other youth groups to teach stewardship of land and water resources.
11. Participate in or organize community tree plantings, hazardous waste cleanup, Adopt-A-Stream/ Highway programs, wildlife habitat restoration projects and similar activities which physically improve our environment.

Lakes

The World Beneath the Waves

Gems of the Landscape

Lakes, ponds, and reservoirs contribute much to the ways that we think about aquatic ecosystems. Most of us, in one way or another, have enjoyed lakes or ponds. We may have fished from their banks, swum in their depths, boated on their waves, or just relished a scenic view at sunset or from a passing car. But, how many of us have actually thought about what happens on and under the waves? How much do we know about the creatures that live within these bodies of water or about the processes that allow these creatures to survive? We may have questions like: Why don't lakes freeze solid during the winter? How do fishery managers set catch limits? Why should we care about what takes place miles away from the lake? This chapter will answer these questions and many more. Throughout this section, you will see the words 'lake,' 'pond,' and 'reservoir' used interchangeably. Although these systems are unique in their own ways, most of the processes discussed here occur in some degree in each of these ecosystems.

Lakes: The World Beneath the Waves

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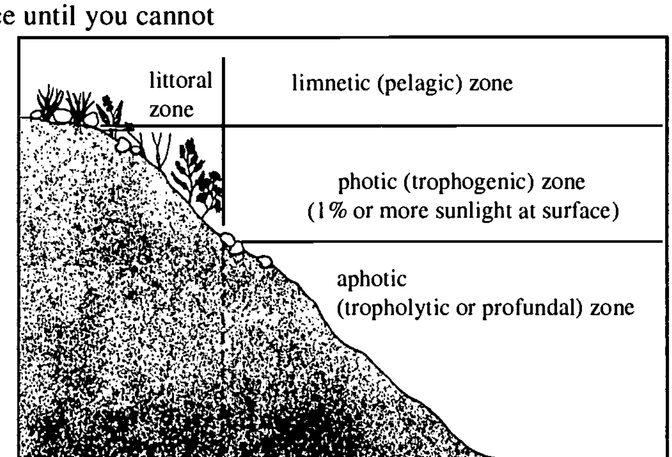
A Lake is a Lake...Isn't it?

As mentioned earlier, there are three major types of "lakes" - lakes, ponds, and reservoirs. In the most general sense, ponds are bodies of water up to nine to ten acres in size. Lakes are larger, often measuring hundreds of acres in size, and reservoirs are defined as artificial, or human-made, lakes. As you continue reading this chapter, some more differences between these aquatic ecosystems and many of the processes and functions of them will be defined and explained.

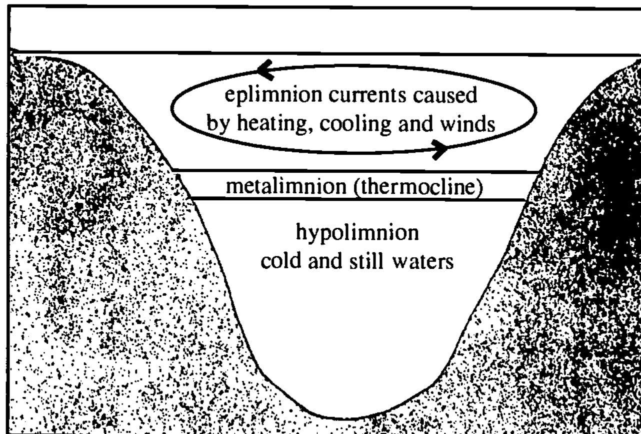
Lake Zones

To more fully understand lake ecosystems, one must first understand the basic regions of lakes. Imagine yourself sitting in a boat along the shore of a lake. As you look down into the water, you see aquatic plants, fish, aquatic insects, and the lake bottom. This shallow area of a lake is called the littoral zone. The lake bottom itself is known as the benthic zone. This zone may consist of mud, leaf debris, gravel, large rocks, or any combination of these. Now, push your boat away from shore while looking down into the water. As you get farther from shore, you will notice that the aquatic plants are becoming more scarce until you cannot see any plants at all. The zone ranging from the waters' surface to the depth at which plants cannot grow is referred to as the photic zone. This is marked by how deep sunlight can penetrate into the water. The region below the photic zone is called the aphotic zone, or the area without sunlight. You have just reached the end of the littoral zone and have entered the pelagic zone, or open water. This zone covers the entire section of a lake or pond that does not contain any aquatic plants. Some lakes and ponds are so shallow that they do not have a pelagic zone. The entire body of water can support aquatic plant growth.



Zones of a lake as determined by sunlight penetration

Lakes can be divided into two basic types based on the layering of the water temperature. If the temperature of the water is essentially the same from top to bottom, the lake is referred to a being unstratified, or not layered. If there is a noticeable difference between the temperature at the bottom and at the top of the lake, it is called stratified. When a lake is stratified, three separate regions can be identified based on the temperature of the water. Once again, envision yourself in your boat. Now, dive out of the boat into the water. If the lake you're in is stratified, the region near the surface is known as the epilimnion. This zone is heated or cooled by heat from the sun or by the winds blowing across its surface. If you swim toward the bottom of the lake, you will pass through a region of the lake in which the temperature becomes noticeably colder. The zone of transition from warmer water to cooler water is referred to as the metalimnion, or thermocline. The colder zone near the bottom of the lake is the hypolimnion. The overall structure of the water in a lake is often referred to as the water column.

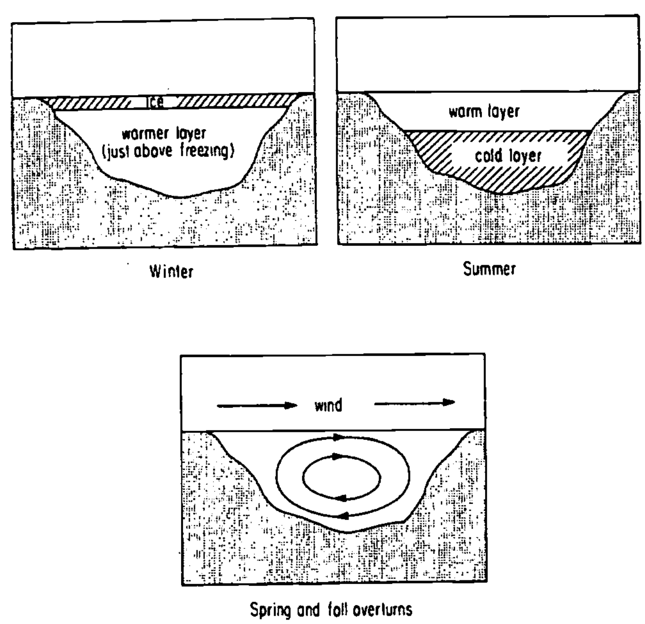


Thermal layers in a lake

This layering of the water occurs because water becomes more dense and is heavier as the temperature drops. However, when the water temperature drops below 39°F (4°C), it becomes less dense and is lighter. At this point, water has reached its maximum density and is in its heaviest state. This is why entire lakes and ponds don't freeze in the winter. The layer of ice on the surface is actually lighter than the slightly warmer water below it.

Turnover

In the spring, when the temperatures begin to rise, lakes and ponds go through a process known as turnover or upwelling. When the ice at the surface starts to melt, it becomes warmer. As it does this, it reaches the point of maximum density and begins to sink. This causes the water at the bottom of the lake to rise to the surface, bringing with it many of the nutrients and materials that have been sitting on the lake's bottom during the winter. This process continues to mix until the water temperature is basically uniform throughout the lake. This process is usually repeated during the fall, but in the opposite way. In the fall, the water is mixed when the upper layer becomes colder, and more dense, than the water below it. However, not all lakes experience this upwelling in the same way. Some only mix the upper layer, or epilimnion, of the lake. Some only mix once a year, and some don't mix at all. You may have observed this process yourself. Turnover is usually noticeable when a lot of nutrients and materials that have been on the lake's bottom can be seen at the surface. This often gives the lake a "dirty" look.



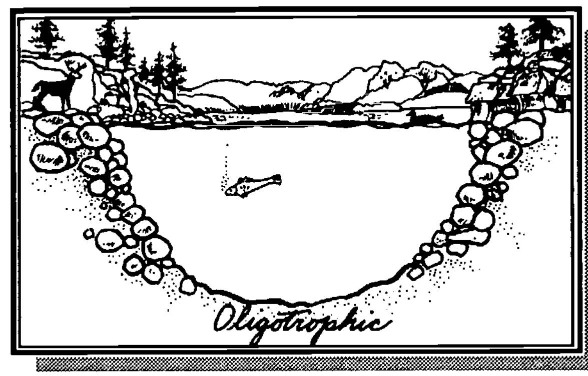
The pond through the seasons. Thermal stratification occurs during the sinter and summer in temperate regions. Spring and fall are times of thermal mixing.

Aging

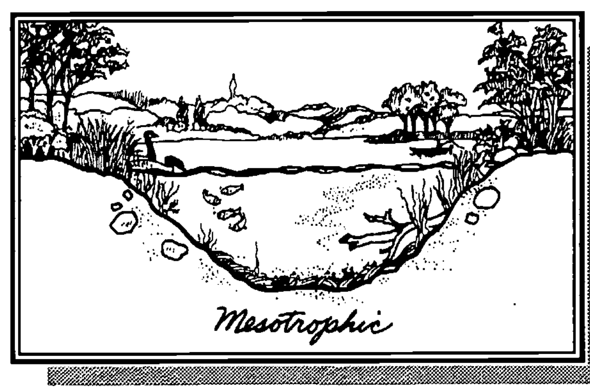
As with all of the other components and systems on this planet, lakes and ponds age and change over time. As this occurs, they often progress from one form of system to another. Lakes and ponds are generally grouped into three types: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic Lakes

Oligotrophic lakes are often thought to be sterile or lifeless bodies of water. Granted, these lakes are often not highly productive, but, they do contain forms of life that may be found in no other system.



If you have ever marveled at a lake with water so clear you could see several feet down, if not more, you were probably looking at an oligotrophic lake. A major force that determines whether a lake is oligotrophic or eutrophic is the material that composes the basin in which the lake forms. If the basin is formed primarily from a mineral-poor substance, such as granite, the lake will probably be oligotrophic. Many of the lakes in the mountainous regions of the world are examples of oligotrophic lakes. The water in these lakes is clear because there are too few minerals and nutrients entering the lake to fuel highly productive ecosystems. These lakes are often very deep and may reach depths of several hundred feet.

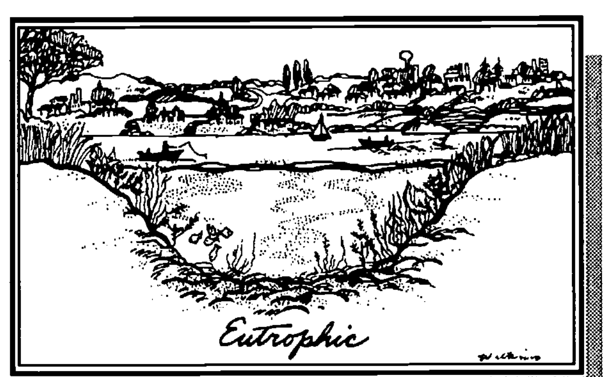


Mesotrophic Lakes

Mesotrophic lakes are unique in that they are the transition stage between oligotrophy and eutrophy. These lakes may either support lowly productive ecosystems, highly productive ecosystems, or something in the middle. Also, the depth of these lakes can be quite variable.

Eutrophic Lakes

The third type of lake is referred to as a eutrophic lake. These lakes balance the low productivity of oligotrophic lakes by being highly productive. Eutrophic lakes often form in basins composed of limestone, clay, or other mineral and nutrient-rich materials. Ponds, artificial reservoirs, and impoundments fall mainly into this category. These lakes are often very shallow, thus allowing sunlight to extend farther into the water, fueling mass growths of aquatic plants.



Many eutrophic lakes occur naturally, but some lakes become eutrophic because of the disruption of the system by humans. This is referred to as cultural eutrophication. Cultural eutrophication occurs when humans alter the natural nutrient flow of aquatic ecosystems. This happens when an increase in nutrients, especially from residential and agricultural fertilizers, are added to the system. The results of this addition are

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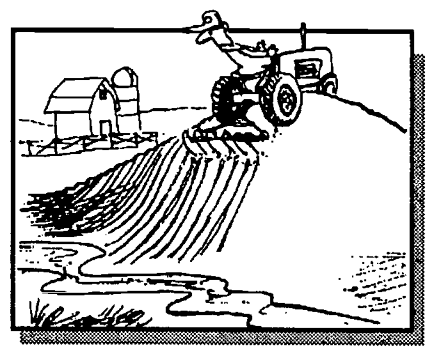
an increase in aquatic plant growth, an increase in the growth of algae, and possible die-offs of other aquatic organisms.

Organism die-offs occur when the large masses of aquatic plants begin to die and decompose. As they decompose, these plants use up oxygen that is vital for the survival of aquatic organisms. The most notable example of this was the condition of Lake Erie in the 1960s. During this time, large amounts of fertilizers and other nutrients were washed into the lake with each rainfall. This caused the local populations of many aquatic plant species to expand to previously unheard-of levels. Consequently, the shallow areas of the lake became choked by these massive plant populations. As these plants began to die off, the process of their decomposition used up all the oxygen in many parts of the lake. This caused nearly all the local fish populations to die as well. This led to the description of Lake Erie as a "dead lake." In fact, the lake was actually too alive. This degree of eutrophication is often referred to as hypereutrophication.

Another method of cultural eutrophication occurs when large amounts of sediment are washed into lakes through streams and rainfall. Although this also occurs naturally, the process of sedimentation can be greatly sped up by human developments. The main sources of this increase in sedimentation are poor agricultural and developmental practices. For example, if a farmer plows to the edge of a stream or lake, much of the soil along this area will be washed into the nearest body of water. Human-caused sedimentation creates problems as it speeds up the natural aging process of lakes. This process also makes the lakes shallower and allows for much greater growths of aquatic plants that can result in the same problems that plagued Lake Erie in the 1960s. As a means of controlling this human-made condition, many management agencies choose to dredge, or scoop, the excess sediment from the lakes. Although this is effective at removing the sediment, dredging only serves to manage the symptom and not the problem.

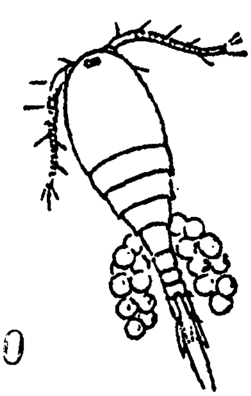


Food Webs and Trophic Levels

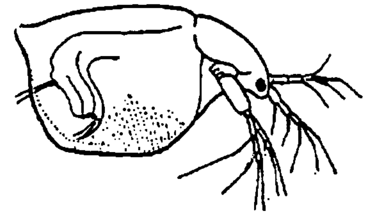
In all ecosystems, including aquatic ones, the organisms are classed into several categories based on what they eat, what eats them, and what function they perform in the system. These various levels are referred to as trophic levels. These levels make up the food chain, food pyramid, or food web. The term food web is more appropriate as all the components of the system are interconnected. Thus, no organism functions at only one level; each performs many different functions.

Plankton

At the base of the lake food web are the various nutrients and minerals that drive the entire system. These include nitrogen and phosphorous, which provide for plant growth, and other minerals released by the lake basin. The next components of the food web are organisms collectively called phytoplankton. These are very small plantlike organisms that can be seen best through a microscope. However, some can be viewed by the naked eye. These organisms depend on sunlight, just as plants do, to fuel their growth. Just as plants grow toward the light, phy-

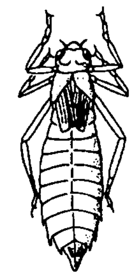


toplanktonic organisms migrate up and down the water column to stay in the photic, or lighted, zone.



The next organisms in the food web are collectively known as zooplankton. These are tiny animals that feed on phytoplankton. They also migrate throughout the water column in search of their prey. These organisms, although small, are very important members of the aquatic food web. Since these organisms form the "base" of the food web, many other organisms depend on them for food.

Macroinvertebrates

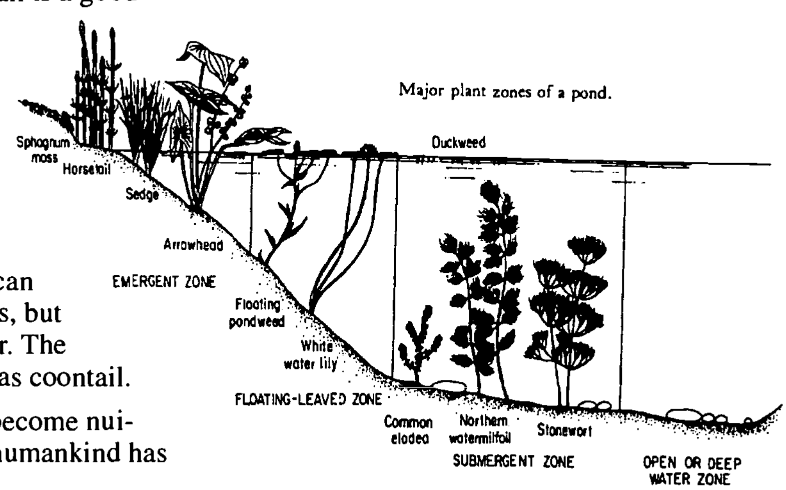


The next "step" of the food pyramid is made of organisms known as macroinvertebrates. These are primarily aquatic insects and crustaceans, such as dragonflies, crayfish, and water pennies. Macroinvertebrates are creatures without internal skeletons that spend at least one stage of their life cycle in the water. A prime example of this is the dragonfly. Although the adult dragonfly is terrestrial, their eggs are laid on plants growing along the shore and the larvae, or immature stages, develop in the water. These organisms feed on zooplankton, aquatic plants, algae, and other macroinvertebrates. Some even feed on small fish and amphibians. Many of these animals live in the benthos region of a lake. Benthos, more commonly known as muck, is the layer of nutrients and debris lying on the lake bottom. The organisms found in this region can be collected and sampled using an instrument called a dredge. A sampling dredge is simply a small, weighted scoop that is used to collected a mass of debris and organisms from the lake bottom.

Aquatic Plants

Plants make up a very important part of aquatic ecosystems. Some of the more common aquatic plants are cattails, water lilies, and coontail. They provide food for many species of fish, macroinvertebrates, amphibians, and other organisms. Plants also provide places for animals to breed, lay their eggs, hide from predators, and ambush their prey.

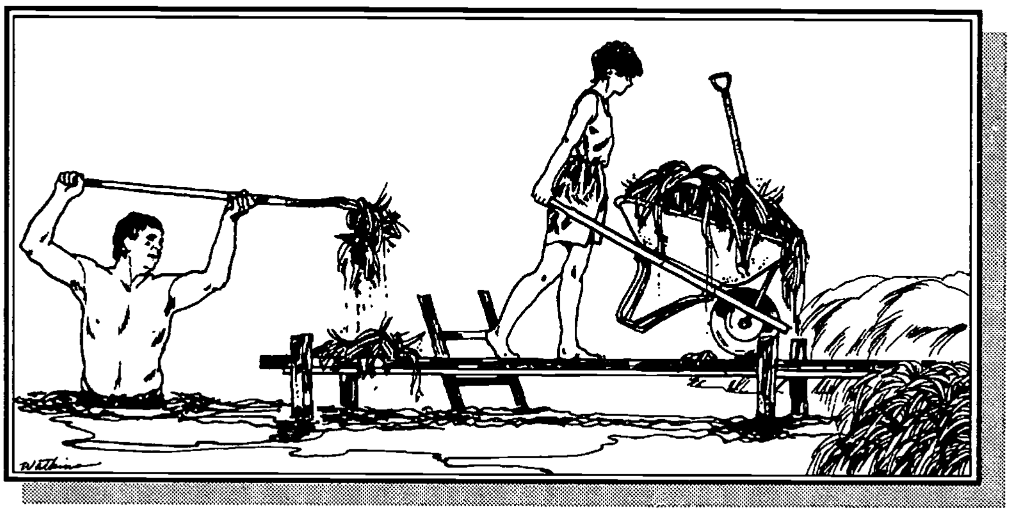
Aquatic plants are classed into three categories, based on where and how they grow: emergent, floating-leaved, and submergent. Emergent plants typically grow near the shores of lakes, ponds, wetlands, and streams. The leaves of these plants are often long and narrow and extend above the surface of the water. The cattail is a good example of an emergent plant species. Floating-leaved plants grow farther from shore than do the emergent plants. They often have long stems with leaves that are flat and float on the surface of the water. Water lilies and duckweed are examples of floating-leaved plants. The submergent plants grow as far away from shore and in the deepest water that sunlight can reach. Their leaves can be a variety of shapes, but rarely extend beyond the surface of the water. The most common submergent is known simply as coontail.



Major plant zones of a pond.

As was described above, plants can also become nuisances if they grow too thick. Accordingly, humankind has developed many ways to try to control aquatic plants. The most common method is the application of aquatic herbicides such as copper sulfate. However, the addition of chemicals to an ecosystem can create many problems. If too much of the aquatic plant population is killed, the balance of the ecosystem could be affected and could have disastrous results. Without plant cover, small and juvenile fish could become easy prey for larger fish and reduce the fish population. Also, the decomposition of the masses of plants could result in a similar problem that faced Lake Erie as described above.

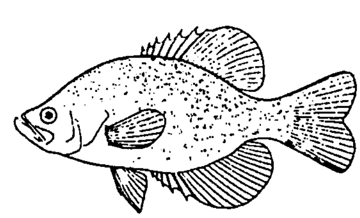
Another way to remove unwanted plants from aquatic ecosystems is to physically remove them. This can be done by simply cutting the plants down and taking the harvested plants out of the lake. Many commercial products are available to do this including rakes that are tied onto a rope and thrown from shore. Many private businesses have formed to deal with this problem. They often use a machine that resembles a large, floating lawn mower that cuts the vegetation out and stores it in a bin to be disposed of later. Once again, there are possible consequences to this harvesting as many aquatic plants can grow from small pieces of their original form. Thus, the harvesters can actually spread the plants to areas that may not have had a problem before.



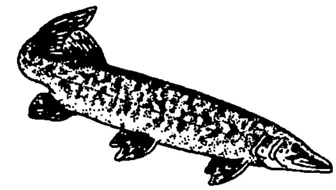
One of the most effective methods of controlling unwanted plant growth is through the introduction of animal species that will eat the plants. The most common biological control is a fish known as a grass carp, or white amur. This fish grows to large sizes and feeds primarily on submerged aquatic plants. However, care must be taken when introducing an organism that isn't native to an ecosystem as it may do more than might be predicted. Consequently, many states do not allow these fish to be introduced or may only allow fish that are sterile to be stocked.

Fish

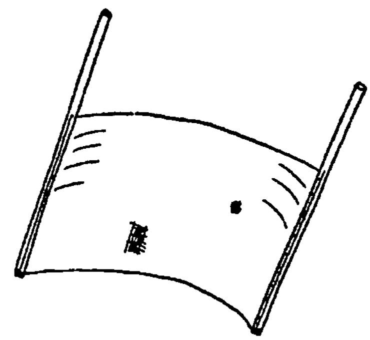
Many different types of fish can be found in lake ecosystems. As compared to those found in streams (even the same species) fish found in lakes are generally larger. Fish communities often form a food web in themselves. Small and juvenile fish, which feed on plankton and small macroinvertebrates, are in turn eaten by larger fish which are then preyed upon by even larger fish. The types of fish found in lakes range from minnows and shiners, also called forage fish, to sunfish, like bluegills and crappie, to the top predators, bass and northern pike. Scavengers, such as catfish and carp, also make up an integral part of



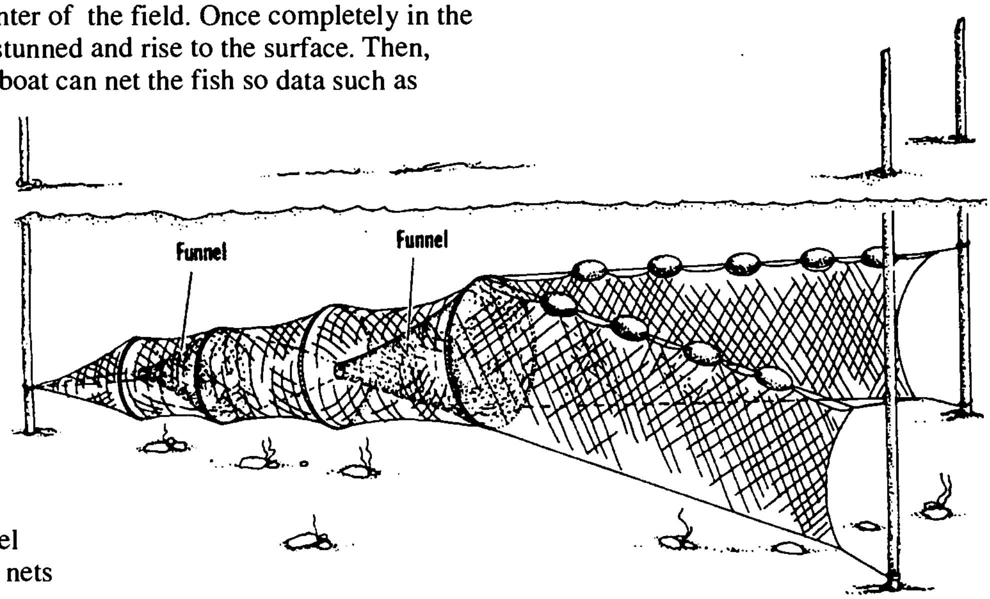
the fish community. Fish, such as bass and sunfish, are found in the shallow littoral zone of lakes where a lot of vegetation and structure exists in which they can hide and hunt. Others, like steelhead and muskie, coast throughout the open waters of the lake.



Many fish species, such as bass, pike, some sunfish, and catfish, are called game fish by anglers and fisheries managers. These fish are those that are actively pursued by anglers and are managed by fisheries biologists. The populations of these fish are manipulated and controlled to provide an optimum, sustainable fishery for the future. One of the ways that fisheries biologists manage fish populations is through the establishment of size and harvest limits for certain fish in certain areas. In this way, they can control the sizes, numbers, and ages of the fish in the system.



Fisheries biologists obtain data about fish populations in many ways. These sampling methods are divided into two categories: active and passive sampling. Active sampling includes methods by which biologists actively search out the fish and capture them. This type of sampling involves the use of seines, trawls, and even selective angling. Seines and trawls are nets of various sizes and shapes that are pulled by people or by boats, respectively. The most popular and effective method is known as electrofishing. Electrofishing involves the use of direct current (DC) flowing between metal nodes connected to a generator on a boat to stun the fish. Fish that are near or within the electrical field are involuntarily attracted to the center of the field. Once completely in the field, the fish are momentarily stunned and rise to the surface. Then, biologists on the electrofishing boat can net the fish so data such as lengths, weights, and health can be obtained. After the data have been taken, unless specimens are needed, the fish are released back into the system.



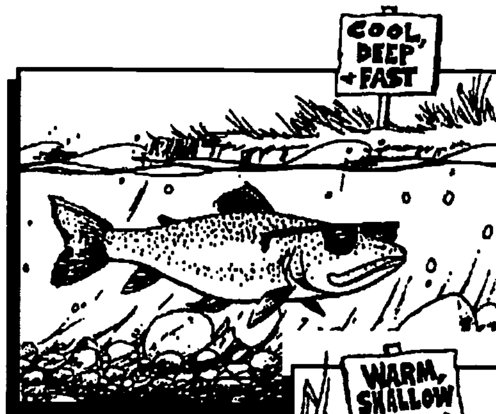
Passive sampling relies on the fish to enter and become trapped in different styles of nets. These nets are often quite long and are constructed of a series of chambers that prevent the fish from escaping. Hoop nets, gill nets, and trammel nets are examples of this. Hoop nets are nets placed on circular, D-shaped, or square frames that have a long netted panel, called a lead, attached to the mouth of the net. These nets are placed along the shore such that the lead begins at the shoreline and the body of the net extends out into the body of water. Thus, fish traveling along the shoreline come up against the lead that directs them into the net. As the fish move further into the net, they pass through funnel-shaped chambers that prevent them from returning through the opening of the net. Gill and trammel nets are large sheets of netting that capture and entangle fish as they try to swim through the nets. This type of net must be checked regularly to ensure the health and condition of the fish.

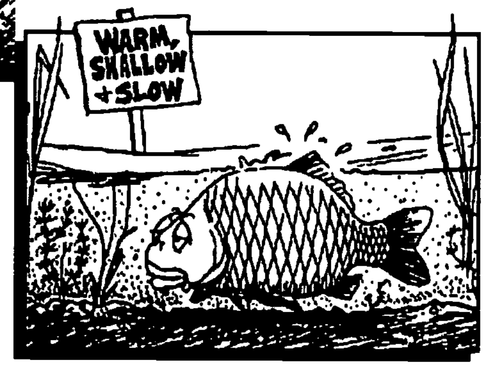
Another useful tool used by fisheries managers is the creel survey. A creel survey is a method by which biologists travel throughout a lake and along its shores getting information and opinions from the anglers.

In this way, managers can get information such as fishing success, types of fish caught, whether the fish were kept or released, etc. directly from the people fishing.

Water Quality Monitoring

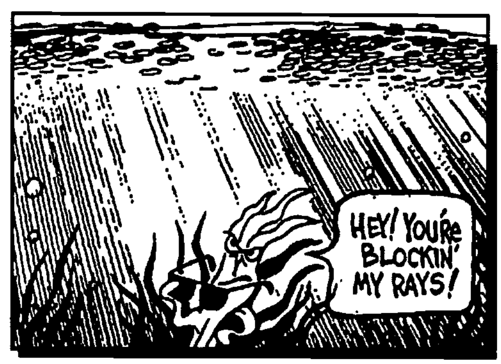
There are many ways to monitor the water quality of lakes and ponds. One of the easiest methods is to take water samples and analyze some of the chemicals and properties of the water. The primary measurements gained from this type of monitoring are pH values and dissolved oxygen (DO) levels. Levels of pH indicate how acidic or basic the water is. The range of pH is from 0 to 14 with 0 being very acidic, 14 being very basic, and 7 being neutral. Dissolved oxygen levels are very important as nearly all aquatic life depends on dissolved oxygen to breathe. If these levels approach zero, the water is referred to as being anoxic, or without oxygen. Water that has been trapped near the lake bottom by the stratification of the lake often becomes anoxic. This happens frequently if there are large amounts of decomposing vegetation and debris, also called detritus, that use up oxygen.

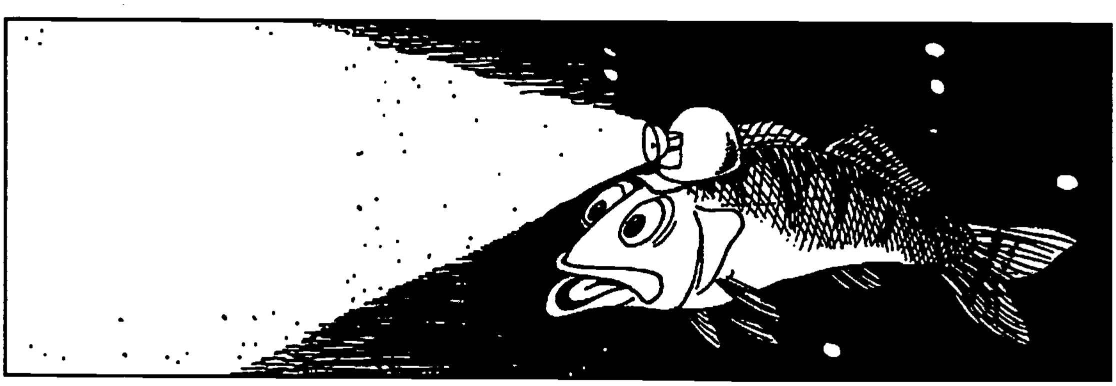




Another important measurement used for water quality monitoring is water temperature. As described earlier, water becomes more dense the closer it becomes to 39°F (4°C). Temperature and DO levels have a unique relationship. As water becomes colder, it can bond with more oxygen. Thus, colder water can "hold" more oxygen than warmer water can. This is vital for fish because as the water gets colder, the metabolic rates of the fish slow down and the fish need less oxygen. Because of this, many fish survive better in cooler water than in warmer water.

Turbidity is also a useful measurement of water quality. Turbidity is defined as how cloudy, or turbid, the water is. Sediment, plankton blooms, and/or algae blooms can increase turbidity. This affects the survival of many fish because some fish hunt for their prey by sight and if the water is too cloudy, they will be unable





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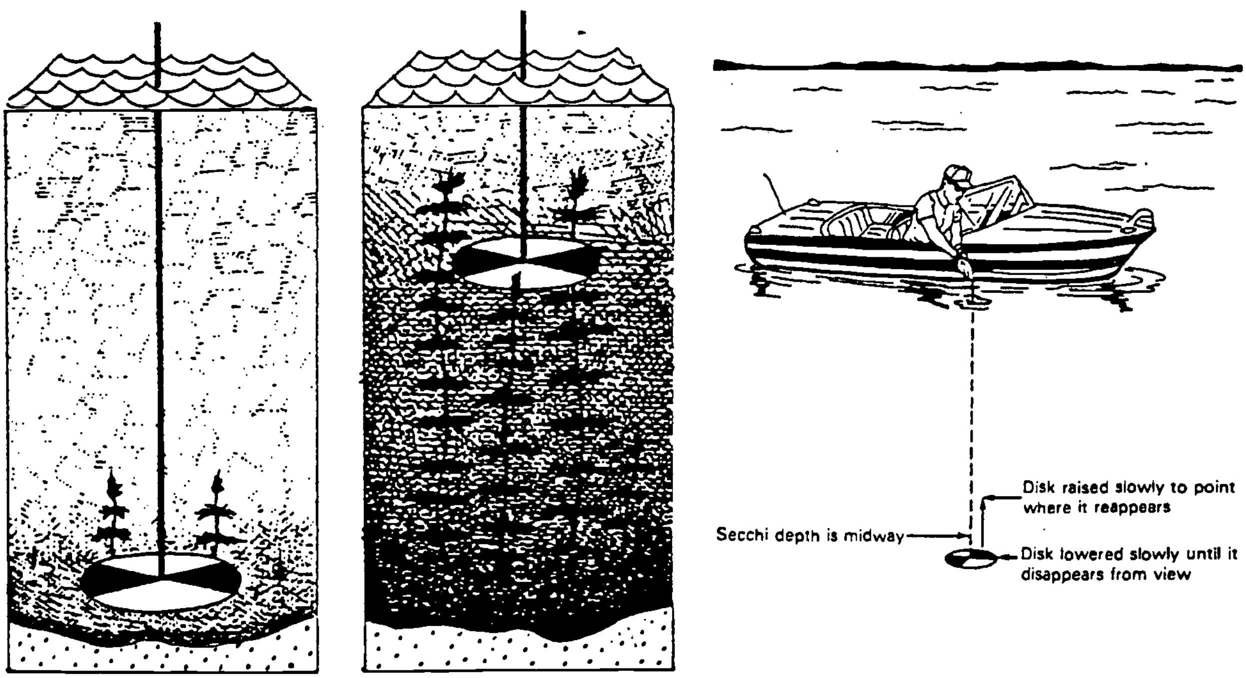
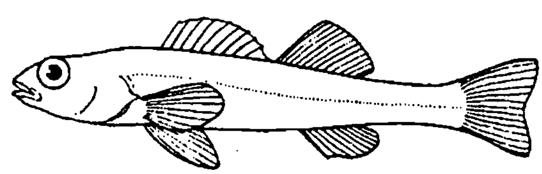
to find food. High turbidity also decreases the penetration of sunlight into the water column and inhibits plant and phytoplankton growth. This, in turn, can affect the entire food web. Turbidity is measured using an instrument called a Secchi disc. A Secchi disc is simply a round, weighted disc that is divided into four sections that are alternately painted black and white. The Secchi disc is then attached to a rope, that has marked length increments, and lowered into the water until it just disappears from view. Then, the rope is measured from the surface of the water to the point where it disappears from view. This depth is the depth to which sunlight can penetrate. Secchi depth may range from a few inches to several yards.

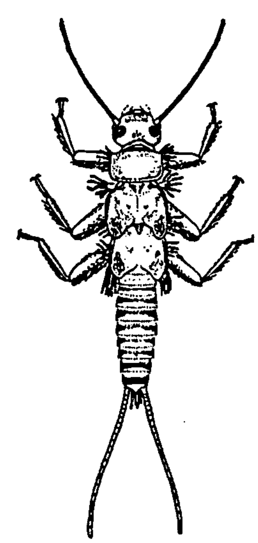
MEASURING WATER CLARITY WITH A SECCHI DISC



A clear lake　　*A turbid lake*



The most recent form of monitoring is the use of biological indicators. Many species and types of organisms can tolerate very specific levels of pollutants and disturbances. By sampling the populations of fish and macroinvertebrates, biologists can determine the health of an aquatic ecosystem. This method of monitoring is very valuable as it can show the quality of the water over time. Chemical testing only shows the quality of the water at the exact time the sample was taken. However, biological monitoring shows what the water quality has been over a time spanning days, weeks, or years. For example, if a fish that is intolerant of pollution is found in a system, then the water quality must be relatively good. However, if the species used to be found in a particular system, but isn't anymore, then something must have happened to remove it from the area. This method of assessment can also be done using macroinvertebrate populations instead of fish populations.



Lake Management

There are two basic ways to manage the overall trophic structure of a lake or pond. The first method is called top-down management. Top-down management is the manipulation of the populations of the top predators in a system to affect the populations of all the other organisms in the system. For example, the addition of bass to a system will decrease the populations of sunfish and minnows, which will allow for the increase of zooplankton levels. This increase in zooplankton populations will decrease the levels of phytoplankton in the ecosystem. This can also be done in an alternate way by decreasing the population levels of top predators. Thus, the prey species will increase and zooplankton will decrease, and so on down the food chain.

The other method of management is bottom-up management. This is the opposite of the top-down approach. By manipulating the nutrient levels in the lake, managers can affect the populations of the top predators. If, for example, extra nutrients, such as fertilizers were added to a lake, the populations of plants and phytoplankton would increase. Thus, zooplankton populations would increase because of the additional food supply. Forage fish populations would also rise and result in a larger population of top predators. By increasing the nutrient levels, managers are effectively increasing the food supply to every "step" in the food pyramid.

Lake Watershed Management

Protecting The Watershed Can Improve Water Quality

A lake is the reflection of its watershed (the land that drains — eventually — into it) and the everyday actions that take place in the watershed. The importance of the relationship between a lake and its watershed cannot be overstated when addressing water-quality issues. A high-quality lake, valued for water supply, recreation and aesthetic appeal, can benefit all watershed residents (and nonresidents alike) by providing a healthy place to play and/or enjoy a quiet sunset. In other words, a high-quality lake improves the quality of the community's life.

The lake-watershed "system" is a functioning unit with interacting biological, physical, chemical and human components. If a lake suffers from problems such as extensive weed growth or algal scum, fish kills, or filling in with sediments, often the cause of the problem can be linked to a source or sources within the watershed.

The characteristics of lake-watershed interaction depend on a number of variables. Some variables include the ratio of drainage area to lake area, how the land is used, the climate, soils and geography, as well as existing conservation measures. The interplay between these and other variables varies from region to region and even from lake to lake. That's why each lake and its watershed are a unique

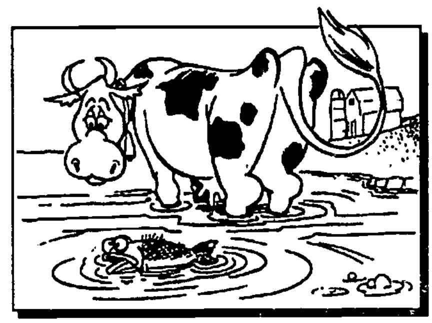
system. Understanding the characteristics of a particular lake and its associated watershed is essential for developing the most appropriate management strategies for achieving water quality goals.

What Threatens Lakes?

To understand how to manage a lake and its watershed to improve water quality you must also be able to understand how activities in or around the lake and or on the watershed can threaten the lakes health.

Major Threats To Lakes

The major threats to lake water quality in the United States are:



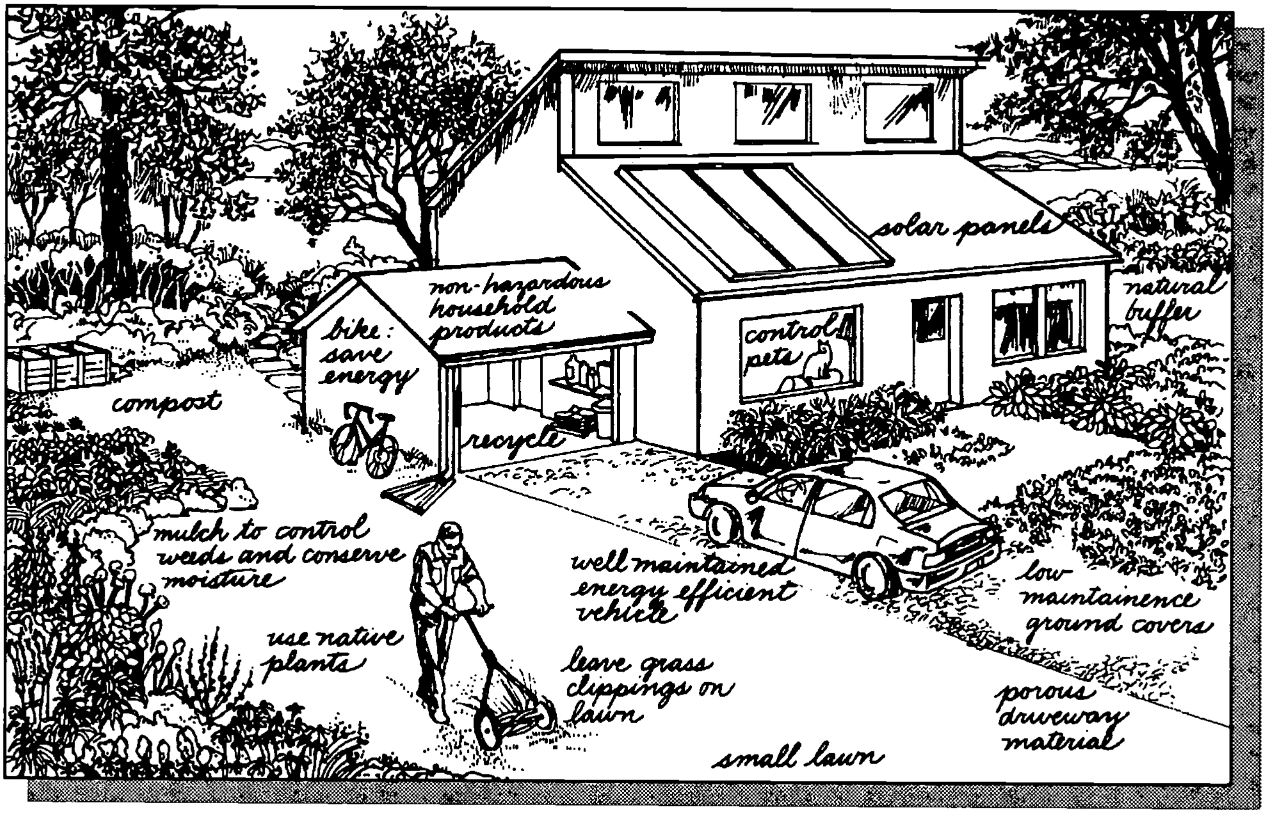
- An over abundance of nutrients. Excessive nutrients can lead extreme algal blooms and plant growth which ultimately lead to depletion of the oxygen supply for fish and other aquatic organisms.
- Organic wastes. When organic wastes assimilate they cause a lack of oxygen needed for aquatic organisms to survive.
- Excess sedimentation. Sediment carried by "runoff" can fill lakes and destroy habitat for plants and animals, clog fish gills, smother eggs of fish and other aquatic organisms, as well as impair recreation such as swimming and boating access.
- Heavy Metals and other organic chemicals such as polychlorinated biphenyls (PCBs) can contaminate fish and other wildlife effecting there survival or rendering them unfit for consumption by humans and other animals.

Sources of Pollution

Although sources of pollutants like sediment and nutrients can exist in the lake itself, the primary sources of pollutants can be found in the watershed. Some sources include:

- Agriculture practices can lead to pollutants like nitrogen, phosphorous, sediment, pesticides and organic matter entering the lake.
- Runoff from pavement and lawns. Runoff in some areas can carry pollutants such as oil, metals, bacteria (including E-coli), nutrients, and transports them through storm sewer systems.
- Municipal sewage treatment plants in some cases can combine sewage with storm water in what is called a Combined Sewer Overflow (CSOs). This can lead to nutrients, organic wastes, toxic household substances and other types of pollution.
- Septic systems also contribute to lake pollution when they leak into shallow groundwater. This can also increase nutrient loads, bacteria and organic wastes.
- Destruction of shoreline vegetation by construction, wave action, and other activities, also increases chances of degrading lake water quality as well as plant and wildlife habitat.

- Air pollution that is carried to the ground via rain, is a major threat in some areas of the country. Some types are referred to as acid rain.
- Urbanization of agricultural or forested land increases hard surfaces like roads, parking lots, and rooftops. This increases the velocity of runoff reaching the lake and causes streambank erosion, turbidity, and degraded wildlife habitats. Urban runoff also carries oil, bacteria, nutrients, sediment, and metals into lakes.



Activities That Impact Water Quality

Many of polluting activities such as building and road construction, commercial farming, and point source pollutants such as factory discharges have environmental requirements they must meet. That's why it's the smaller scale nonpoint sources of pollution that can be the most detrimental to a lake's health. Examples include:

Household Activities:

- Leaking septic systems can contribute to nutrients and bacteria getting into nearby waterways, streams and eventually, the lake. Some nutrients can also be carried through the shallow aquifer and reach spring fed pond or lakes. Failing septics can prevent a lake's use for drinking water or recreational activities. Excessive algal blooms may be one indication of a problem.

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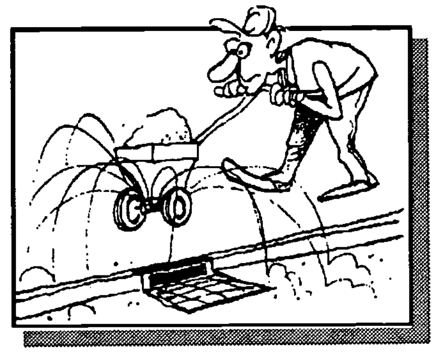
- Using detergents containing phosphorous to wash boats, cars, and pets in locations where waste water can run off into the lake adding unneeded nutrients.
- Over fertilizing your lawns and gardens, or fertilizing at the lakeshore can also contribute excess nutrients to the lake, potentially affecting drinking water and recreational activities. Green lawns can cause green lakes.
- Clearing vegetation near and on the lake shore removes a natural buffering system which can help absorb nutrients and sediment runoff.

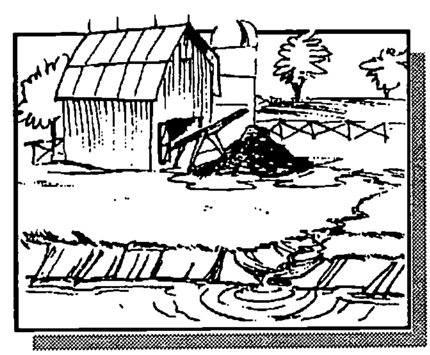


Boating Activities:

- Use of powerful large horsepower boat motors in shallow areas can churn up nutrient laden sediments to support algae growth and destroy aquatic life.
- Poorly maintained power boat engines can leak fuel, oil and grease into water bodies.
- Improperly cleaning boats before entering different lakes can introduce exotic species of plants and animals which can also affect lakes by impairing recreational activities and/or destroying plant and wildlife habitats.

Farm Activities:

- "Clean" cropping practices that leave the fields clean in the fall also leave soil vulnerable to snow, wind and rain. Nutrients and some herbicides attach to soil particles and are transported with it, to the nearest water body.
- Mixing and loading herbicides near wells or tile lines can leak chemicals into the shallow groundwater which, ultimately, resurfaces in springs or tributaries which carry it into the lake.
- Improper animal waste management and storage. Animal waste is a valuable source of fertilizer when used properly. Improper storage or land application can contribute nutrients and bacteria to nearby waterways, streams and eventually into the lake which can prevent the lake's use for drinking water and recreation.



Although it may seem that one house, one boat, or one farm alone cannot harm a lake, the cumulative impacts of hundreds of boats, homes, and farms can add up to poor water quality. Every action you take affects lake water quality.

What Can I Do?

For those of you fortunate enough to live near a lake, pond, or reservoir, there are many ways that you can protect your local water body. One of the best things you can do to protect lakes, ponds, and reservoirs is to adopt "Best Management Practices." Best Management Practices (BMPs) are actions you can take or encourage others to take to reduce impacts on the environment.

Some BMPs are clearly aimed at residents who already live or farm seasonally or year round on shoreland property. Shorelands include any land area adjacent to bodies of water receiving runoff from that land area including lakes, streams, ditches etc.

Even if you do not live directly on a shoreline, the way you manage household wastewater and property can have a significant impact on water quality downstream. Pathways that carry contaminants may not always be obvious. Drain tiles, ditches, storm sewers, paved roads, and shallow groundwater can all carry pollutants from residential, industrial, and agricultural areas into lakes, rivers, or wetlands.

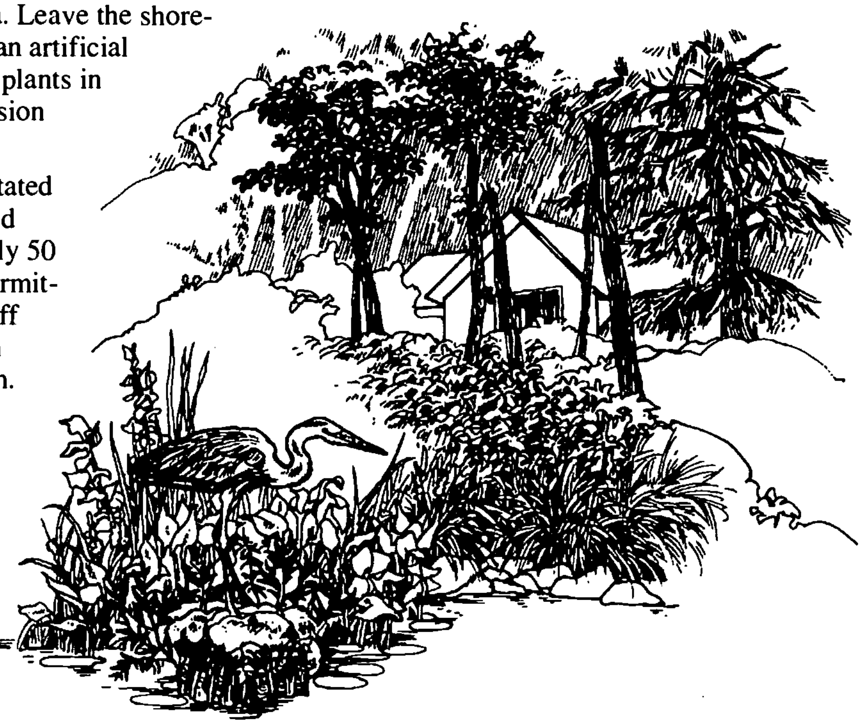
Fertilizers and chemicals applied to lawns or crops can wash down driveways or ditches and end up in surface water. Improper disposal of household waste or industrial chemicals can add toxics to our lakes. Poor land use and construction practices result in erosion, increasing the load of sediments entering our waters. These adverse impacts on surface and ground water not only affect water quality for human use, but also damage wildlife and fish habitat and other natural resources.

The following section includes Shoreland BMPs that you can adopt or encourage others to adopt. Remember everyone lives in a watershed of some lake or stream, even if they don't live directly on the waterfront. Everyone has the right and responsibility to preserve those waters for present and future generations to enjoy.

Shoreland Best Management Practices

Keep the Shore Natural

- In many cases, the best management for shorelands may be retaining the natural characteristics of the area. Leave the shoreline in its natural condition; don't build an artificial beach. Leave existing rocks and aquatic plants in place to break waves. (They prevent erosion and stabilize the shoreline).
- Leave at least 100 feet of naturally vegetated areas (buffer strips) along lake shores and river banks and at least 25 feet, preferably 50 feet or more, along road ditches and intermittent streams. Buffer strips intercept runoff and filter sediment and phosphorus from water before it reaches the lake or stream. Check local and state zoning ordinances regarding minimum buffer strip widths.
- Plant deep-rooted, woody vegetation along lake shores, streambeds and road ditches, if the natural buffer has been removed. (Plant roots stabilize the shoreline, prevent erosion and take up nutrients carried by water before they reach the lake.)

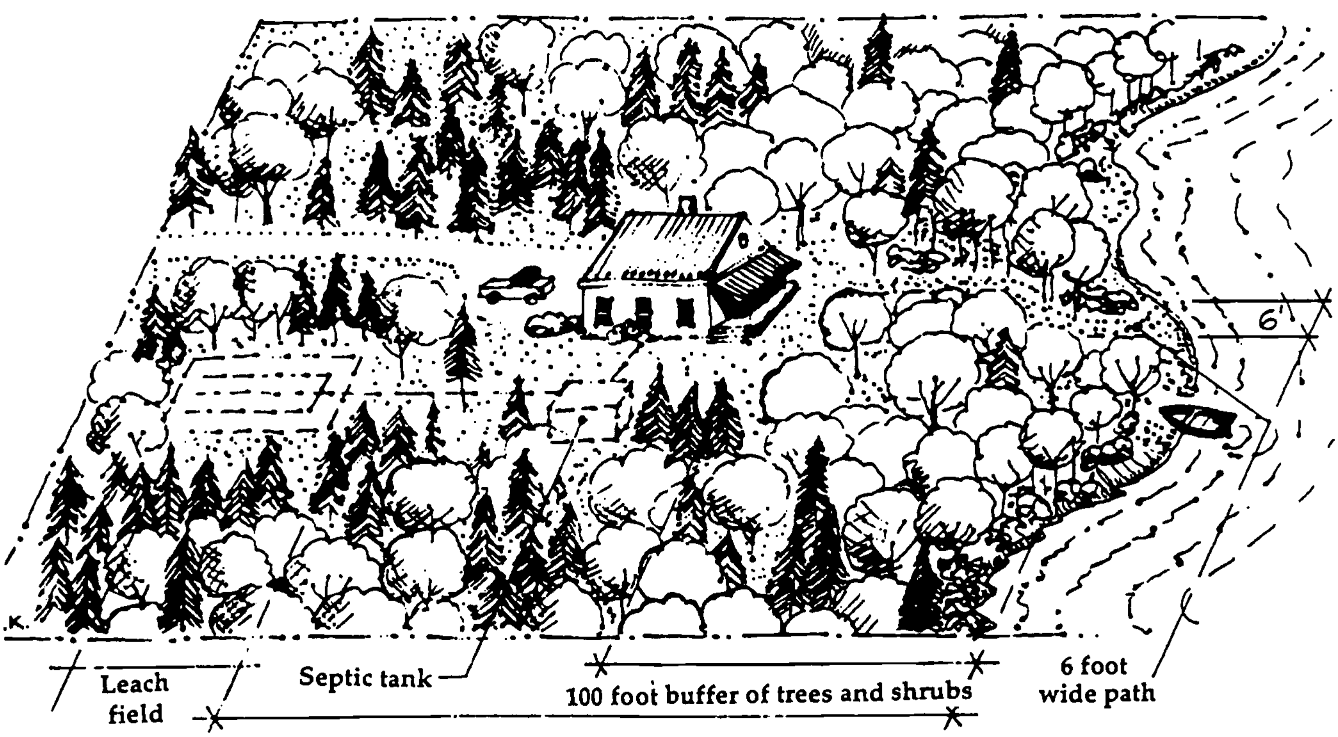


- Use temporary docks, which are put in and removed seasonally. Avoid creosoted or pressure-treated wood. Cedar is a better option and is very durable.

- Don't build a permanent dock; a permanent dock will disturb bottom habitat, alter wave patterns and cause erosion where non occurred before.
- Use a public beach, boat launch, or marina for access to the lake. By concentrating recreational uses in one area, you protect the shoreline habitat elsewhere.

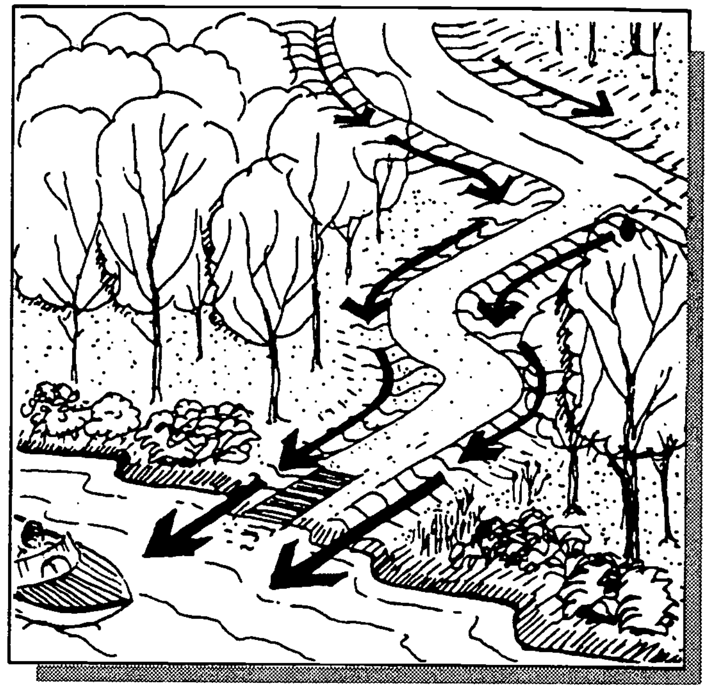
Develop Shoreland Areas Responsibly

- Find a builder who follows good soil protection practices. Minimize the area disturbed and use liberal amounts of hay and other mulches to prevent erosion. Erosion control is the most important technique.
- All disturbed areas should be mulched within one week and should be seeded or mulched within one week of final grading.
- On erodible soils or on slopes, also use filter fabric fences or hay bale dams to control erosion that does take place.
- Follow local and state lake protection laws and obtain necessary permits. Both you and the builder may be legally responsible. Information about laws is available from your town office and state environmental agencies.
- Build on flat or gently sloping land. Steep slopes (over 20%) mean a greater likelihood of erosion and runoff problems.
- Preserve existing ground features. Natural depressions allow water to puddle and soak in, instead of running off.
- Avoid constructing ditches that run directly into lakes and streams. Detain runoff in depressions or divert flower to flat, wooded areas. Flowing water carries sediment and phosphorus. Detaining or dispersing water allows it to seep in the soil where sediment and phosphorus are filtered out.



Build Responsibly

- Design and build new roads and driveways with culverts, drainage diversions, ditches and roadside buffers to deal with runoff from major storms. Ask your county Soil and Water Conservation District for help.
- Work with your town to adopt town road standards that will reduce phosphorus runoff.
- Avoid construction on steep slopes (greater than 20%). On lesser slopes, use water bars and diversions. Do not allow roads with slopes greater than 10%.
- Improve poor roads and driveways by diverting storm water off them into roadside ditches that are vegetated or stone-lined and that are U-shaped — not V-shaped.
- Divert water flowing in roadside ditches that have long sloping runs into flat wooded areas where phosphorus and soil are filtered out. Use frequent ditch turnouts to slow the water flow.
- Retain or plant buffer strips along roads and uphill from ditches to intercept nutrient-rich runoff before it gets into the ditch.
- Organize volunteers to go out during or right after a heavy rainstorm to identify and trace sources of erosion. Determine which streams and rivulets are brown with silt and find out where erosion is worst. Then work with landowners to correct the problems. For assistance, check with your state environmental agency's lakes program, your county Extension Office, Soil and Water Conservation District, or your state coalition of lake associations.



Reduce Hazardous Material Use

- Store hazardous materials in contained, safe areas. Containment prevents contamination of water supplies and lake water by undetected leaks.
- Dispose of paint thinner or chemical products responsible — not on the ground or down the drain. These products cannot be removed by natural processes. Instead:
- Let latex paint air dry in a well-ventilated place until it hardens, then put it in your garbage. This will help prevent toxic waste leaking into a landfill.
- Allow used paint thinner and solvents to settle, then pour off the clear liquid and reuse. The sludge should be air-dried and put in the garbage.
- Never dispose of any motor oil or other petroleum products on driveways or roads.

- Most oils and petroleum products are high in phosphorus and contain other toxic material. Motor oil can be recycled: take it to a service station that collects used motor oil.

Garden With Care

- Keep your lawn, garden and other cleared areas small. Enjoy the natural beauty and privacy of the site; maximize the opportunity for phosphorus-rich storm water to soak into the ground.
- Don't rake leaves or other forest floor debris. They help trap and filter water and prevent erosion.

- Use fertilizers only if a soil test indicates the need. Then, follow these guidelines: apply small amounts over a period of weeks and never apply fertilizer before or right after a heavy rain. Liquid fertilizer may be best to prevent runoff excess phosphorus, if properly applied.
- Choose natural alternatives to herbicides or pesticides for your garden and lawn; and redesign your garden using local plants so that it will require less maintenance. Herbicides and pesticides are poisonous and easily carried by runoff water into lakes and drinking water supplies.
- Choose non-phosphate detergents, or use plain water when washing a car or other large item. Don't let the detergent and rinse water get into the lake or streams.

Practice Responsible Boating

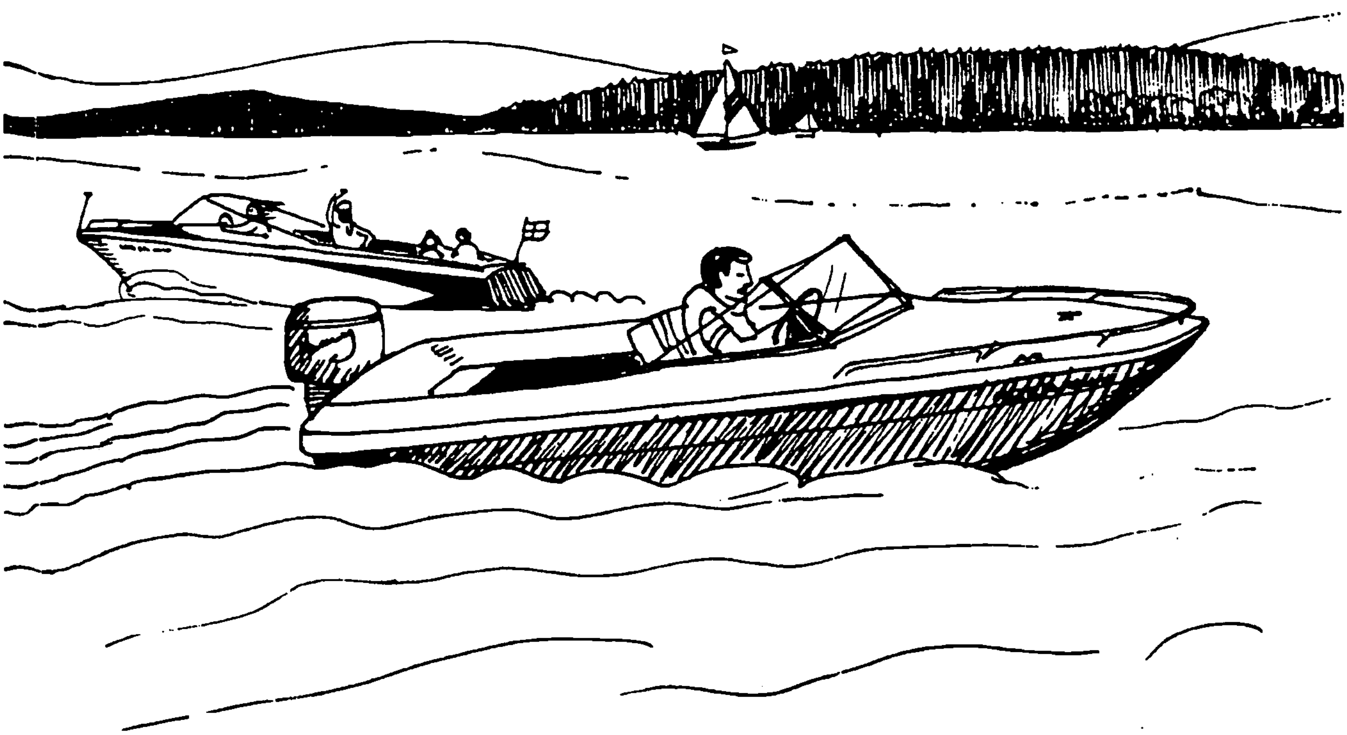
When buying a boat:

- Choose a boat that fits the size and depth of the lake. This applies to both length and horsepower. Avoid boats with V-shaped hulls; they create large wakes and chop up vegetation.
- Buy an engine with good fuel-burning efficiency. Make sure the engine and boat complement each other.
- Use correct gasoline/oil mixtures. Use lead-free gas.
- Be careful when handling gas to avoid spills. Fix leaks.
- Make sure the engine has current air emission controls which prevent smelly clouds of exhaust from escaping. Have frequent tune-ups.
- Keep your muffler in good condition. Exhaust pipes should be below the water line.

When driving a boat:

- Drive at safe, fuel-efficient speeds.
- Watch your wake and slow down if it gets too big; large wakes erode the shoreline and damage wildlife habitat.

- Do not operate motorized watercraft within 200 feet of any shoreline (including islands) at greater than no wake speed.
- Operate motorized watercraft away from shallow areas. Motors churn up bottom vegetation and habitat, scare nesting birds off their nests and resuspend phosphorus-rich sediments.
- Keep a trash bag handy and make sure nothing is thrown into the lake. Never leave cut fishing line or plastic materials in the water.
- Dispose of boat sewage and waste water by keeping it in a sealed holding tank and pumping it out at a marina. In most states, overboard discharge of sewage and waste water is illegal.
- Obtain a copy of your state's boating laws and know the "rules of the road".
- Operate jet skis, wet bikes, surf jets and similar vehicles responsibly and safely.
- Minimize the use of your motor boat. Choose canoeing, sailing and rowing as alternatives.



Avoid Farmland Erosion

- Preserve the integrity of that grassy or tree-lined strip along shorelines, often called a riparian zone or greenway. This strip of vegetation serves as a filter to stop excess nutrients and other pollutants from entering waterways. A filter strip 50 feet wide can stop up to 90 percent of the sediment in surface runoff from flowing into lakes and streams. These areas also provide great habitat for many types of wildlife.

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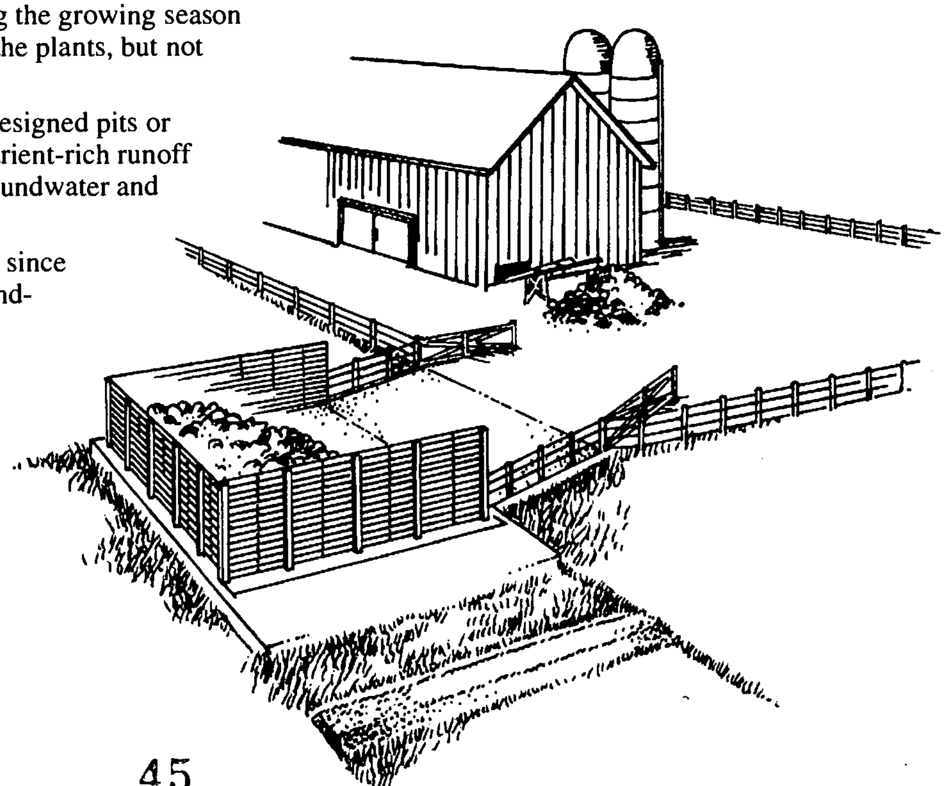
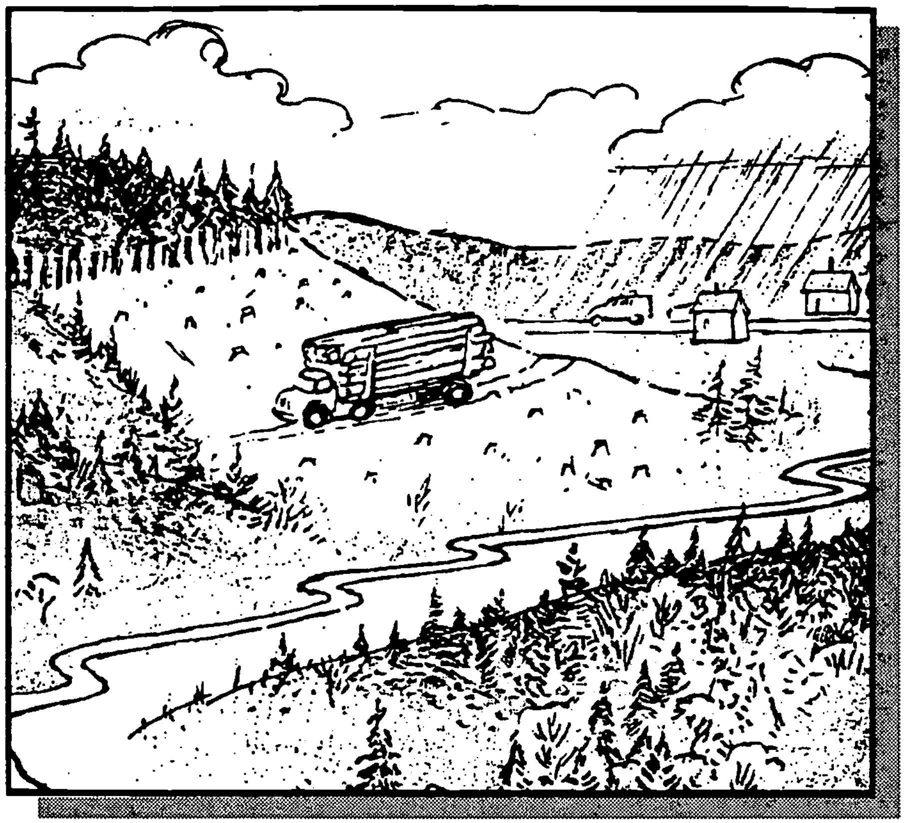
- Utilize Conservation tillage practices where appropriate, to reduce the potential for erosion; these practices break up large expanses of tilled soil and slow the flow of storm water.
- Plant winter cover crops to reduce erosion. The roots stabilize the soil during runoff.
- Apply fertilizer only during the growing season when it can be utilized by the plants, but not before a storm.
- Store manure in properly designed pits or stacking sites to reduce nutrient-rich runoff which can contaminate groundwater and lakes.
- Avoid the use of pesticides since they can contaminate ground-water, rivers, lakes and streams.
- Use best management practices; consult your county Extension Office, Soil and Water Conservation District, or your state environmental agency's Nonpoint Source Pollution Coordinator.



Avoid Erosion on Logging Jobs

- Cut only small openings. Large openings remove the protective forest canopy and can increase erosion.
- Leave broad strips of wooded land next to streams (at least 75 feet) and along the lake shore (at least 100 feet): check local and state zoning requirements for specific cutting limitations.
- Incorporate culverts, water-bars, and dips into logging roads and skid trails to prevent erosion. Use switchbacks on steep slopes. Revegitate logging areas.
- Keep slash (unwanted branches and wood debris) out of streams and ponds. It interferes with fish and wildlife and can cause erosion of stream banks.
- Check with your town and state environmental agencies to find out if you need a permit for crossing streams or wetlands on your property. Not all crossings require permits and some crossings can be permitted without review. Both the contractor and the property owner may be legally responsible for obtaining permits.



- Avoid working in extremely wet areas and during the "rainy season." The soil's ability to hold and filter water can be destroyed by heavy equipment.
- After the operation, revegitate all exposed soil areas in skid trails, yarding areas, etc.
- Consult your county Soil and Water Conservation District, your state forest service or your state environmental agency's Nonpoint Source Program.

This concludes the lakes section of the manual. Although most of the examples given were from lakes, nearly all of these processes and situations occur in ponds and reservoirs as well. Remember, almost everything that goes on or comes from the land eventually finds its way into lakes, ponds, reservoirs and streams; it is all interconnected.

Streams

The Rivers in your Backyard

Introduction

Watersheds

Watersheds are complex systems and each one responds differently to interference. Much of what happens to a stream occurs outside its immediate channel but within the watershed. Because of their sensitive balance, streams are indicators of events that occur within the watershed; activities in a watershed have the potential to affect not only the nearest stream, but the downstream water bodies as well. Water may take many paths from the time it forms as precipitation in the sky until it flows back into the ocean. The path it takes will determine the quality of the water and its fitness for drinking, recreation, industry, farming and habitat.

Streams within a watershed originate from rain water, springs, and snow melt. As water flows overland or through soils, it recharges surface and ground water supplies. This process may also filter out impurities such as sediments, oil and grease, and bacteria. The concentration of these impurities, the speed and amount of water, materials the water flows over or through, and how steep the land is all contribute to the ability of a natural system to regenerate itself and maintain good water quality. The increase in human activity has significantly changed the natural process by altering the land's cover and increasing the concentrations of pollutants.

Stream Health

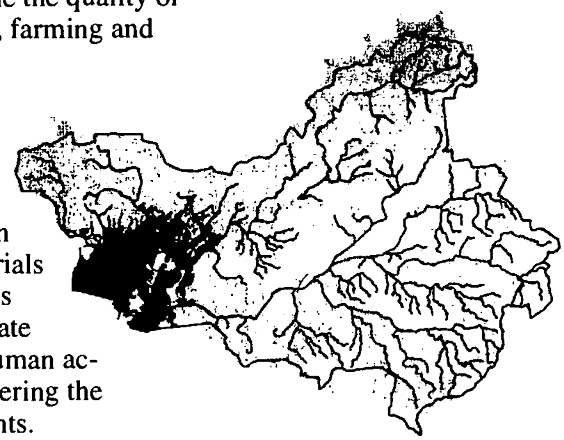
Healthy streams provide a nurturing habitat that includes living and feeding areas for fish and wildlife. They also improve our quality of life by providing recreation opportunities, natural open space, and an ever-changing outdoor classroom for ongoing education. Stream corridors are sensitive ecosystems that serve three major functions:

- Networks of streams provide spawning and rearing grounds for fish.
- Streams and streamside vegetation provide food and habitat for invertebrates (e.g., insects), fish and a wide variety of wildlife species. Root systems of vegetation also stabilize streambanks, guarding against erosion.
- Small streams and wetlands help retain flood waters by absorbing rain water in their meandering courses and associated sponge-like soils.

The healthier the stream systems, the better these functions are performed.

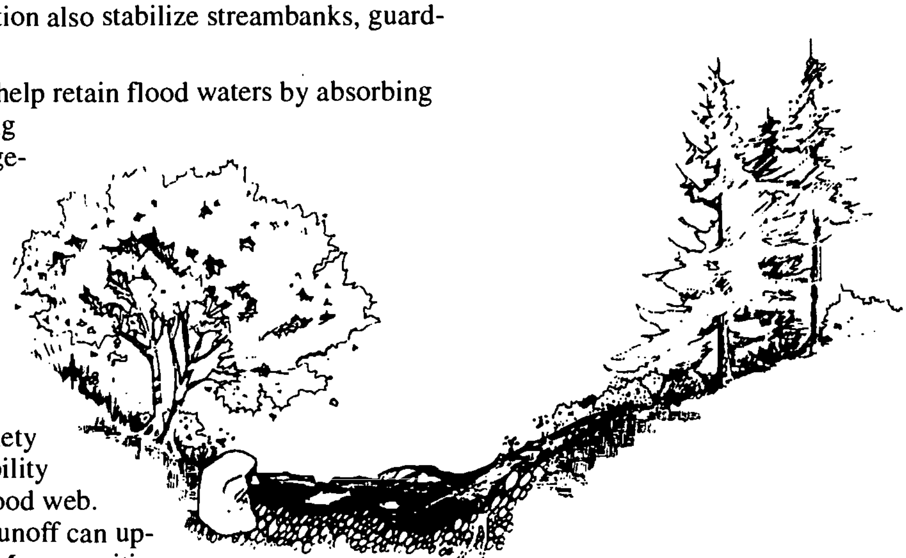
A healthy stream community will have a wide variety of plant and animal species both in the stream and on the banks. This variety of flora and fauna encourages stability and forms a complex ecological food web. Pollution and excess stormwater runoff can upset the balance of the ecosystem. More sensitive,

Streams: The Rivers in Your Back Yard



Indian Lake Watershed

Prepared By:
Gary L. Comer
Extension Agent, Water Quality
Ohio State University Extension
Indian Lake Watershed Project



less tolerant species are killed by the increase in nonpoint source pollution, resulting in less stable, less complex ecosystems with fewer varieties of the more tolerant species.

Measures of Stream Health

The quality of water determines livability for aquatic organisms and usability for ourselves. Pollution affects livability and usability and can be detected using four key measures of stream health.

> **Measures of Stream Health**
>
> *Water quality*
>
> *Stream corridor/habitat quality*
>
> *Aquatic insect populations*
>
> *Fish populations*

Water quality

Several parameters are used to determine water quality. Heavy metals, toxicants, suspended solids, fecal coliform, dissolved oxygen, nutrients, pH, conductivity, and temperature are all measures of water quality. Each parameter will be within a certain range if the quality of water is good.

Stream corridor/habitat quality

Good quality habitat stream corridors (also known as Riparian Corridors) have a variety of plant types that stabilize soil, reducing erosion, filter out sediments and pollutants, provide food and refuge for fish and wildlife, and provide shade that keeps water temperatures cool. A balanced stream corridor will also have a variety of animals that interact and make up a complex food web.

Aquatic insect populations

In the clean water necessary to support abundant and diverse aquatic life, there may be many species of bottom-dwelling insects. Insect species like mayfly nymph and midge larvae consume simple plants like algae and the decaying remnants of larger plants. These insects and the larger insects that eat them provide food for fish. These complex food webs are very stable because of the checks and balances that occur when many predators and many prey live in the stream.

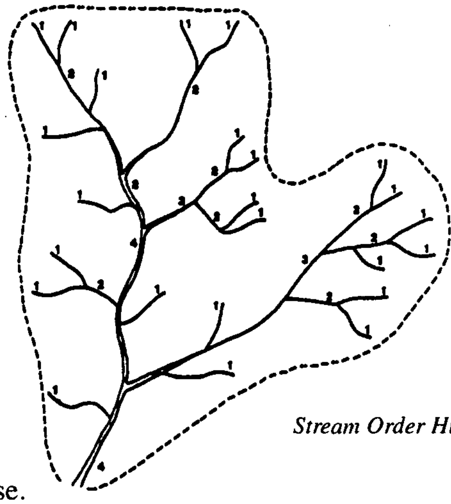
Fish populations

The presence of a wide variety of fish species and habitats in a small stream is often regarded as an indicator of excellent water quality because they are particularly susceptible to environmental changes. Some harmful changes that effect fish populations include increases in water temperature, reduction of vegetation, silt, high water flows, pollution, and flow control structures such as dams and reservoirs.

Small Streams

Most people living in Ohio and throughout the Midwest are aware that some of the major streams and rivers are imperilled by pollution. What they fail to realize is that one of the contributing factors to the overall decline is the degradation of small streams and "insignificant" drainages. . . the streams in our backyards. We view water quality in terms of pristine wilderness streams, over looking the loss and polluting of small urban creeks that are being filled, channelized, covered with parking lots, or relocated to make way for development, or used as waste areas for litter or herbicides.

These are the same streams (first order streams) that are tributaries to the larger streams (second order streams) that are tributaries to the small rivers (third order streams) that are tributaries to the major rivers (fourth order streams). No stream or ditch is too small to be important. Even smaller streams often belong to water networks that provide critical habitat for many rare or endangered species and other aquatic life. They also provide a constant supply of water to larger downstream rivers, lakes, and marine estuaries.



Stream Order Hierachy

A single stream may appear insignificant as wildlife habitat. But since there are many small streams in Ohio, they account for a large portion of fish and wildlife habitat. Healthy streams are valuable but fragile. They are easily damaged by poor logging practices, pollution, and by the growth of cities and towns. Small streams are vital to water quality and wildlife. Small streams must be saved from abuse.

Protecting and securing relatively undisturbed headwaters of first order streams with high biodiversity may be the only hope of restoration of many of America's streams. These systems contain fauna populations which my be used to seed habitats that become restored or improved downstream.

What Makes a Good Stream?

Riparian Areas

Riparian areas are important and valuable ecosystem supporting entire communities of life. Riparian areas are the green ribbons of life found on the edges of water courses (streams, lakes, ponds, etc.). Conditions there support plant communities that grow best when their root systems are near the level of high ground water. These zones range in width from narrow ribbons in desert and mountain settings to wide bands on the plains and lowlands. Some biologists extend the definition to include standing and even sub-surface water.

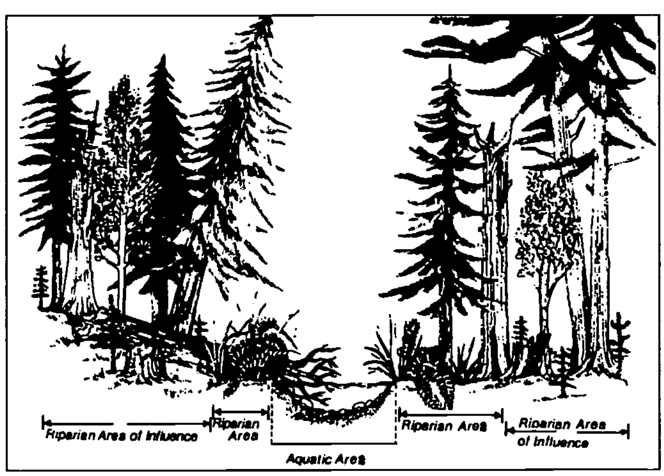
Plants along the streambed influence the entire stream ecosystem. Riparian zones have several unique properties. A riparian area is linear, has a water transport channel and flood plain, and is interrelated with upstream and downstream ecosystems.

Riparian habitat is a combination of three areas. Each is distinctive and contributes to the entire ecosystem.

Aquatic Area: The aquatic area of streams, lakes and wetlands is generally wet. During dry periods, aquatic areas have little or no water flow. Any side channels or oxbows containing freshwater ponds are included in the area.

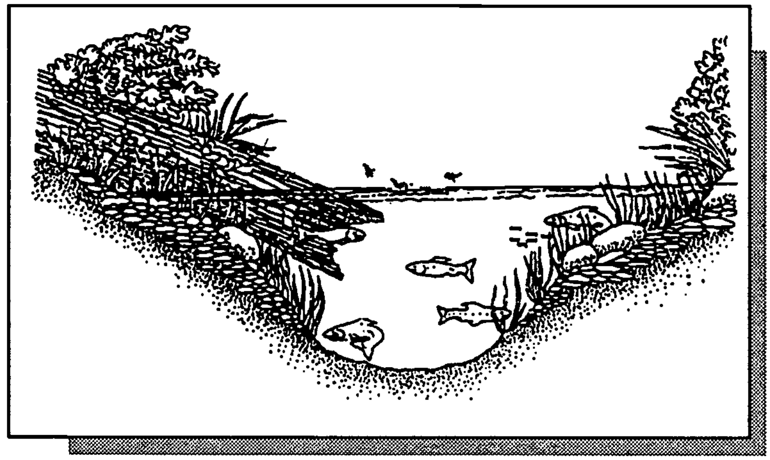
Riparian Area: The riparian area is a terrestrial zone where annual and intermittent water, a high water table, and wet soils influence vegetation and microclimate.

Area of Influence: This is a transition area between a riparian area and upland cover. An area of influence has soil moisture and is characterized by a noticeable change in plant composition and abun-



dance. Trees in this area contribute shade, leaves, woody debris and insects to a stream. In Ohio, the area of influence includes ground cover, shrubs, and understory trees on the floodplains, and canopy trees in the upland areas away from the immediate banks. This stair stepping area of vegetation provides a variety of wildlife habitat.

Role of Riparian Vegetation



Riparian vegetation provides cover for aquatic and terrestrial animals. Shade created by the riparian vegetation moderates water and air temperatures. This vegetation limits water contamination, slows water velocities and filters and collects large amounts of sediment and debris. Uncontrolled sediments can kill fish and macroinvertebrates, and destroy critical aquatic habitats.

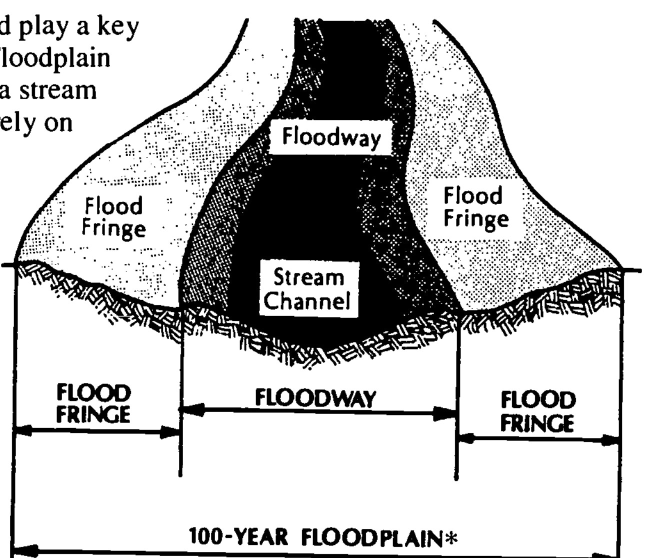
Stream food webs depend on organic debris for nutrients. In small headwater streams, a large percentage of the energy for organisms comes from the vegetation along the stream, and only a small percent from photosynthesis. The leaves, needles, cones, twigs, wood and bark dropped into a stream are a storehouse of readily available organic material that is processed by aquatic organisms and returned to the system as nutrients and energy.

A diverse population of insects depends on this varied food base. Much of the debris is retained and processed in the headwaters by bacteria, fungi, insects, and abrasion, with very little leaving the system until it has been at least partially processed.

Riparian areas have a high number of edges (habitat transitions) within a very small area. The large number of plant and animal species found in these areas reflects habitat diversity. Since they follow streams, riparian areas are linear, increasing the amount and importance of edge effect. Extensive edge and resulting habitat diversity yield an abundance of food and support a greater diversity of wildlife than nearly any other terrestrial habitat.

Floodplains

Floodplains are an important part of a riparian area and play a key role in ecosystem health throughout the stream system. Floodplain vegetation that shades or directly contributes material to a stream is considered part of the riparian area. Stream channels rely on natural flooding patterns. Frequency of flooding and groundwater supply are the major factors controlling the growth of floodplain trees. Floodplains and backwaters act as reservoirs to hold surplus runoff until peak floods are past. This controls and reduces downstream flooding. Floodplains also spread the impact of a flood over a larger area as vegetation helps collect debris and sediment.



*probability of flooding once every 100 years

Composition of riparian plant communities depends on the water pattern (fast or slow moving or dry or wet periods). Both wet and dry phases are necessary in this area to complete the stream's nutrient cycle and food chain. Flooding is critical to the exchange of nutrients and energy between the stream and the riparian area.

When healthy, vegetated banks in the riparian area act as natural sponges. They help maintain soil structure, allow increased infiltration, and reduce bank erosion. Vegetated streambanks also contribute to ground water recharge. Good cover slows the flow and increases percolation into underground aquifers. Stored water is then available during drier periods to maintain and improve minimum flow levels. A major benefit of this aquifer recharge is maintenance of year-round streamflow.

Riparian vegetation uses large amounts of water in transpiration. Often, vegetation needs the most water during the period of lowest streamflow. At these times, vegetation may actually reduce streamflow.

Water Dynamics

Structures in streams, whether fallen logs, boulders, root wads, or artificial placements, provide habitat diversity and help meet the needs of many aquatic organisms. To understand how these structures function, the basics of stream hydraulics need to be understood. The principal forces acting on water in a stream channel are gravity and friction. Gravity propels water downstream, and friction between the water, streambed, and banks resists this flow.

Water velocity is influenced by:

- Steepness of slope.
- Size of substrate materials.
- Type and amount of riparian area and stream vegetation.
- Shape, depth and frequency of pools and riffles.
- Meanders of the stream.
- Obstructions.

As velocity increases, these factors provide more resistance to flow. This causes eddies, chutes and waterfalls that can dislodge and move objects downstream.

There are three basic stream forms:

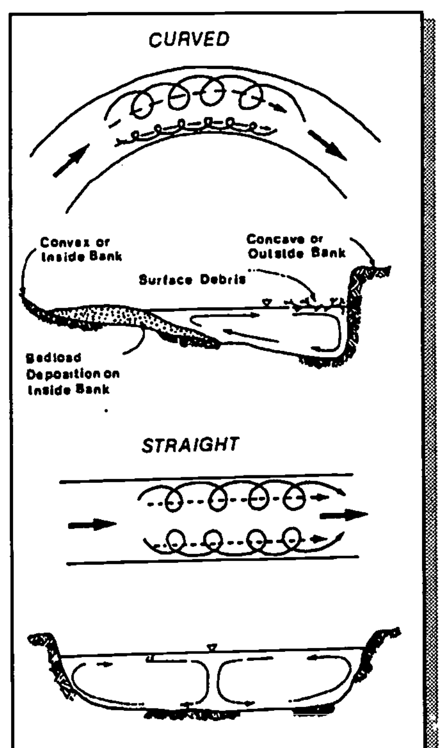
1. Straight—relatively straight or nonmeandering channels,
2. Braided—channels that meet and redivide, and
3. Meandering—single channels with "S" shaped channel patterns.

A stream will naturally meander whenever possible. In larger streams, a line of maximum velocity, called the *thalweg*, wanders back and forth across a channel in response to streambed configuration. Thalwegs are generally found near the center of a water column because of friction with the streambed and surface tension.

Water spiral

Friction between water and streambanks causes water to move in a corkscrew fashion down the channel. This corkscrew, or helical flow, is called a *water spiral*. As changes occur in the stream channel (straight or curved, high or low gradient, or as a result of instream structures), the water spiral will change.

A water spiral slows and becomes smaller as it moves along the inside of a curve in a stream channel. As velocity decreases, suspended material carried by the current drops out of the flow and settles along the bend. This change in velocity forms gravel bars and deposits spawning gravel.



Water spiral

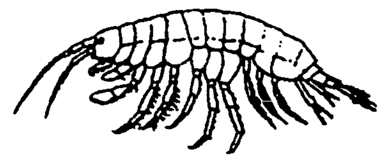
A water spiral enlarges and accelerates as it moves around the outside of a curve or an obstruction, such as a boulder. The force of the water is dispersed over a larger area. Thus, increased velocity scours or digs pools during high flows. These pools provide excellent feeding and rearing habitat for fish during low flow periods.

Stream Data

Water Quantity

The quantity of water directly affects plants and animals that live in a stream and humans that use it. Volume and velocity are key dimensions of water quantity. These change with the season and are influenced by human actions, soil movement from erosion and landslides, and vegetation changes from fire, logging, grazing, disease and windstorms.

The volume of water affects composition of the streambed by moving and depositing sediments and debris. Fast-moving water carries more and larger material. The channel of a rapidly moving stream will have larger material, but a slowly moving stream will have a bed covered with mud and silt.



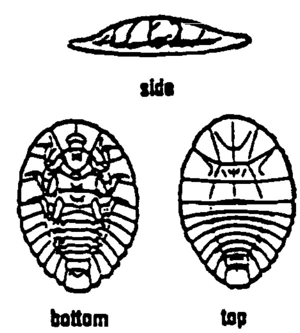
Scud:
Order Amphipoda

Velocity

Flow velocity is one of the main factors that determines the character of a stream. Velocity directly influences:

- Dissolved oxygen (DO) concentration through aeration at the surface.
- Water temperature through evaporation.
- Composition of the streambed.
- Amount of nutrients available to organisms.

Velocity is a measure of how fast water moves. Velocity is calculated in feet per second (velocity = ft/sec.). The substrate also influences streamflow. A factor of 0.9 is used for smooth mud, silt or bedrock streambeds, and 0.8 for rubble, gravel or plant-covered streambeds. Streamflow (or discharge) is calculated in cubic feet per second (cfs). (Average width X average depth X velocity X bottom factor = streamflow in cfs.)

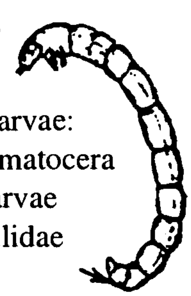


Water Penny: Order Coleoptera

Adaptations to velocity

The rate at which a stream flows determines which plants and animals can live there. Plants adapted to fast water have strong, spreading roots for secure attachment. Their thin flexible stems offer little resistance to the current and have less chance of breaking. Algae adapted to fast flowing water have filaments that "stream" in the direction of the current.

Animals have a variety of adaptations. Clams and mussels burrow into the bottom avoiding the current. Blackfly larvae and limpets attach to rocks with sucker-like structures and use streamlined shapes to avoid being swept away. Water pennies have a streamlined, flattened shape. Snails adhere to the bottom with a broad foot. Fish and other organisms move to pockets of slower water.



Midge Fly Larvae:
Suborder Nematocera
Black Fly Larvae
Family Simulidae

Streambed

The bottom composition of a streambed determines the types of habitats and aquatic life found in a stream. Generally, the steeper the gradient and harder the rock layers, the faster and more narrow the stream will be. Gently sloping gradients and "S" shaped curves characterize a slow moving stream. Different types of streams will have specific substrates, habitat types and aquatic organisms.

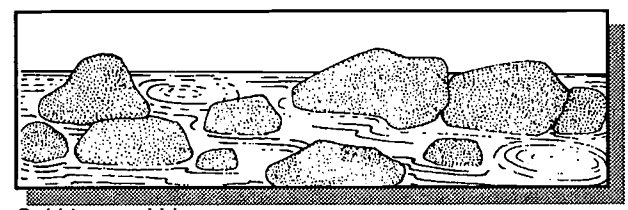
Substrate

The *streambed* is the part of a stream over which water moves. *Substrate* is the mineral or inorganic material that forms a streambed.

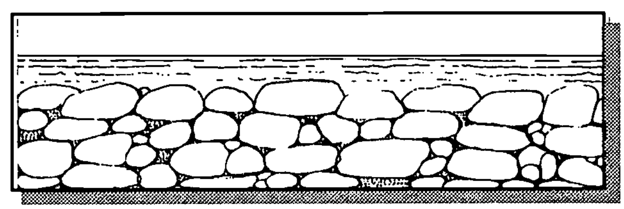
Substrate Types

- Boulders are 12 inches or more in size and are the largest substrate materials. Movement of water around boulders scours small pools in which fish rear and rest.
- Rubble or cobble stabilizes the bottom of streams and provides habitat for fish rearing. Most fish food is produced in cobbled areas. Cobble ranges from 3 to 12 inches.
- Gravel is 0.2 to 3 inches in size, (somewhere between peas and oranges in size). It provides habitat for spawning, egg incubation, and homes for aquatic invertebrates. Gravel must remain clean and porous so circulating water can bring enough oxygen to embryonic fish and invertebrates. Different species of fish and invertebrates require different size, depth and volume of gravel to complete their life cycles.
- Fine sediments are less than 0.2 inch. "Large" fine particles can trap newly hatched fish in the redds and "small" fine particles decrease water percolation through spawning gavels. High sediment loads slow plant growth and reduce available food, oxygen and light.

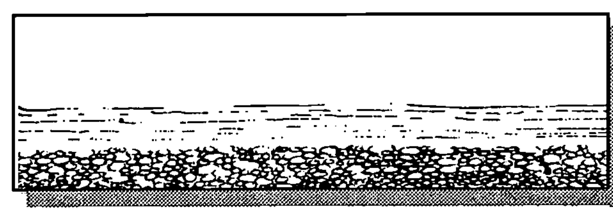
Boulders



Rubble or cobble



Gravel



The substrate types create certain configurations in a streambed. These configurations form specific habitat types. Stream width, depth, velocity, and flow also contribute to habitat diversity within a stream. This diversity provides for specific needs of aquatic organisms and fish.

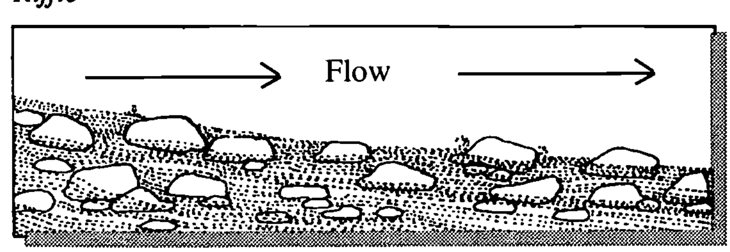
Stream Habitats

Riffles

Riffles are portions of a stream that are relatively shallow, fast and steep. They often have bedrock, cobbles, and sometimes boulders. As water rushes over these areas, the choppiness of the surface reflects the roughness of the bottom.

The sun shines through shallow riffle water and encourages algae to grow on the tops of rocks. The gravel and cobble bottom of a riffle

Riffle



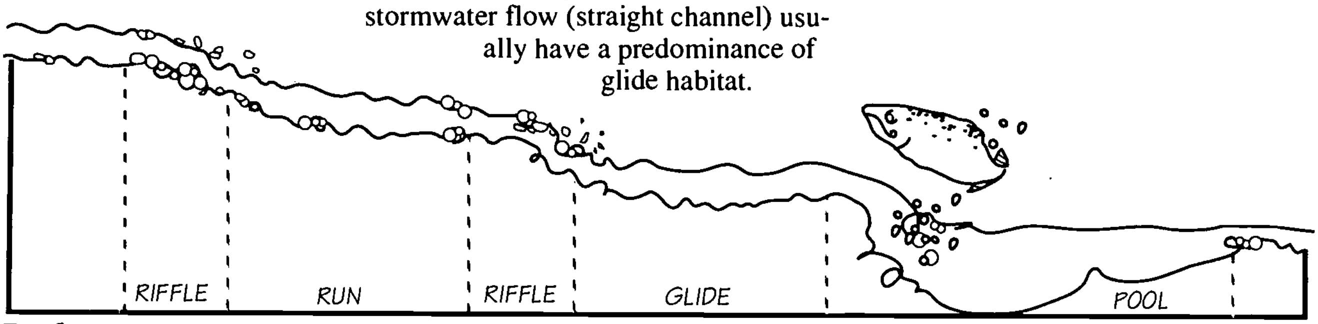
provides nooks and crannies for insect larvae to live and feed. A rough cobble bottom slows water just above it, providing breaks, holding places and shelter for fish. Some organic material is scoured from the rocks and sent downstream to be used as food by aquatic organisms.

Runs

A Run is a stretch of mostly fast smooth current, deeper than a riffle (more than 20 inches) that usually follows a riffle moving downstream. Runs may have rocky or silt bottoms and provide food and habitat for aquatic life.

Glides

The part of a stream characterized by slow moving (although faster than pools) somewhat shallow depth and often with a silt bottom is typically referred to as a glide. Glides maya be found above or below pools. Modified streams maintained for agricultural or urban stormwater flow (straight channel) usually have a predominance of glide habitat.



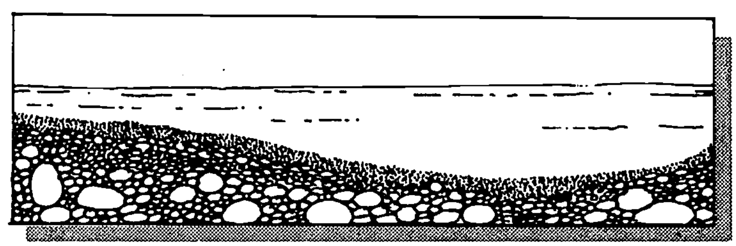
Pools

Pools are areas of deeper and slower waters often above and below riffles. Pools are important feeding and resting areas for fish. They are generally formed around stream bends or obstructions such as logs, root wads or boulders.

Pools contain three distinct areas: head, body and tailout. Each part of a pool meets different fish needs. Turbulent water at the head collects food carried from upstream and provides cover and an area with a higher dissolved oxygen concentration.

Slow water in the body of a pool indicates a reduced gradient. Organic material washes downstream, settles in pools, decomposes, and produces carbon dioxide and nutrients needed by plants in riffles. Drifting fine organic particles provide food for invertebrates. Fish wait in pools for drifting insects.

Pool



Gravel collects in pool tailouts. Fish use little energy to stay in this area and many wait here for food to pass by. Fish often use pool tailout areas with adequate flow as spawning beds.

Lateral habitats

Lateral habitats along the edges of streams are areas of quieter, shallow water. Boulders, root wads or logs can form small pools (pocket water or eddies). Fine sediments and gravels are found here. Accumulations of organic materials provide rich food sources for invertebrates. These areas provide important rearing habitat for young fish. Sculpins and crayfish wait for prey in pools near boulders or root wads.

Water Temperature

Water temperature is one of the most important factors for survival of aquatic life. Most aquatic organisms become the temperature of the water that surrounds them. Their metabolic rates are controlled by water temperature. This metabolic activity is most efficient within a limited range of temperatures. If temperatures are too high or too low, productivity can decrease or metabolic function cease. The organism can die. These extremes, or lethal limits, vary for different species.

Lethal limits

Within the lethal limits there is an ideal range of temperatures, in this range, an organism is more efficient, and the species has a greater chance of success. Various species of fish have adjusted to upper and lower levels of an optimum temperature range. Spawning, hatching and rearing temperature ranges vary from species to species. Invertebrate populations are also affected by water temperature. In this way, temperature determines the character and composition of a stream community.

Plant cover's role

With the exceptions of hot springs and thermal pollution, solar radiation is the cause of increased water temperatures. Shade from riparian vegetation plays a major role in keeping streams cool. During midsummer, adequate shade will keep a stream 7 degrees to 12 degrees cooler than one exposed to direct sunlight. Even the shade from debris in the water will help keep temperatures low. If there is enough debris, temperatures can be 3 degrees to 8 degrees F cooler than if there was no shade. Once water has warmed, it does not cool rapidly, even if it flows into a shady stretch.

It is important to recognize that water temperatures change from day to night and that cool-water areas exist in a stream.

Warmer temperatures encourage the growth of life forms that adversely affect fish and human health. Pathogens such as bacteria, as well as several parasitic organisms, thrive in warmer waters.

Air temperature, surface area

As water in a stream mixes with air through exposure and turbulence at the surface, water is influenced by the air temperature. This mixing action can also increase the evaporation rate.

The greater the surface area of a body of water, the greater its exposure to both solar radiation and air. Because of its increased surface area a wide, shallow stream will heat more rapidly than a deep, narrow stream.

Streambed, streamflow, orientation and sediments

Color and composition of a streambed also affect how rapidly stream temperature rises. A dark bedrock channel will gain and pass to the stream more solar radiation than a lighter-colored channel. Similarly, solid rock absorbs more heat than gravel.

The streamflow, or volume of water in a stream, influences temperature. The larger a body of water, the slower it will heat. Rivers and large streams have more constant temperatures than smaller streams.

The direction a stream flows also affects how much solar radiation it will collect. Because of the angle of the sun's rays, southerly flowing streams receive more direct sunlight than streams flowing north. Eastward or westward flowing streams receive shading from adjacent ridges, trees and riparian vegetation.

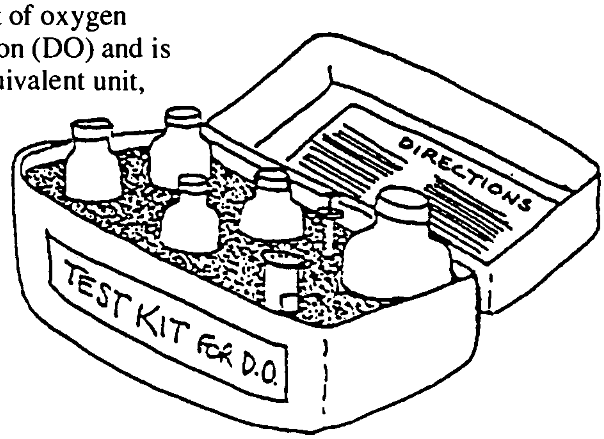
Sediments suspended in water can absorb, block or reflect some of the sun's energy depending on their color and position in the water. Particles on or near the surface can have a beneficial influence through reflection, but those with a dark color increase the total energy absorbed from the sun.

Effects of thermal pollution

Thermal pollution occurs when heated water is discharged into cooler streams or rivers. This heated water generally has been used to cool power plants or industrial processes and can be as much as 20 degrees F warmer than the water into which it is discharged. This increase in temperature can have drastic effects on downstream aquatic ecosystems.

Dissolved Oxygen

Dissolved oxygen is as essential to life in water as it is to life on land. Oxygen availability determines whether an aquatic organism will survive and affects its growth and development. The amount of oxygen found in water is called the dissolved oxygen concentration (DO) and is measured in milligrams per liter of water (mg/l) or an equivalent unit, parts per million of oxygen to water (ppm).



DO levels are affected by:

- Altitude.
- Water agitation.
- Water temperature.
- Types and numbers of plants.
- Light penetration.
- Amounts of dissolved or suspended solids.

As water low in oxygen comes into contact with air, it absorbs oxygen from the atmosphere. The turbulence of running water and the mixing of air and water in waterfalls and rapids add significant amounts of oxygen to water.

Fish species living in a particular reach of stream may indicate the amount of DO present. Common carp are tolerant species and survive DO levels as low as 0.8 ppm. On the opposite end of the sale are rainbow trout which require a minimum of 6.0 ppm DO.

Effects of temperature on dissolved oxygen

Temperature directly affects the amount of oxygen in water—the colder the water, the more oxygen it can hold. Bodies of water with little shading can experience a drop in DO levels. The area immediately downstream from the entry of warm water can be altered drastically. Thermal pollution generally occurs in larger streams. However, dilution will temper these effects as warm water mixes with colder water downstream.

At higher altitude (elevation), the dissolved oxygen saturation point is lower than under the same conditions at lower altitude.

When aeration is high, DO levels can temporarily be higher than the saturation level. This extra oxygen is not stored in the water.

Photosynthesis, oxidation and decomposition

Oxygen can also be added to water as a result of plant photosynthesis. During the day, plants can produce oxygen faster than it can be used by aquatic animals. This surplus is temporarily available throughout the night for plant and animal respiration. Depending on individual stream conditions, high daytime DO levels and low nighttime DO levels can occur.

Photosynthesis can be inhibited by sediments. Suspended sediments make water look murky or cloudy and block or reflect much of the sunlight that would otherwise be available for photosynthesis. Sediments can also settle onto the leaves of plants, further blocking their efficiency as oxygen producers.

The chemical oxidation and decomposition of dissolved, suspended and deposited sediments remove oxygen from the water. The amount of oxygen needed for these processes is called biochemical oxygen demand (BOD) and is oxygen that is unavailable for aquatic life. If the quantity of these sediments is large, remaining oxygen can be insufficient to support many forms of aquatic life.

Most DO problems in streams occur when temperatures are at their highest and flows at their lowest. Macroinvertebrate and fish are especially at risk during this time.

Maintaining productive DO levels

To maintain productive DO levels in a stream, shade should be provided to keep water temperatures cool. The presence of instream structures such as boulders, log root structures, etc. ensures mixing of water and air. Materials that can increase BOD, such as manure from feedlots or untreated municipal waste, should not be introduced.

pH

The concentration of hydrogen ions in a solution is called pH and determines whether a solution is acid or alkaline. A pH value shows the intensity of acid or alkaline conditions. In general, acidity is a measure of a substance's ability to neutralize bases, and alkalinity is a measure of a substance's ability to neutralize acids.

The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic so a change of one pH unit means a tenfold change in acid or alkaline concentration. A change from 7 to 6 represents 10 times the concentration, 7 to 5, 100 times, and so on.

Most organisms have a narrow pH range in which they can live. While some fish can tolerate a range of 5 to 9, others cannot tolerate a change of even one pH unit. Because of this narrow range of tolerance, pH, limits where many organisms can live and the composition of a community.

While pure distilled water has a pH of about 7, any minerals dissolved in water can change the pH. These minerals can be dissolved from a streambed, the soil in a watershed, sediments washed into a stream, or the atmosphere.

Where many soils have a high alkaline content, pH levels of some water bodies can rise above 10. Forest soils tend to be slightly acid and many lakes or streams in forested regions can approach a pH of 6.

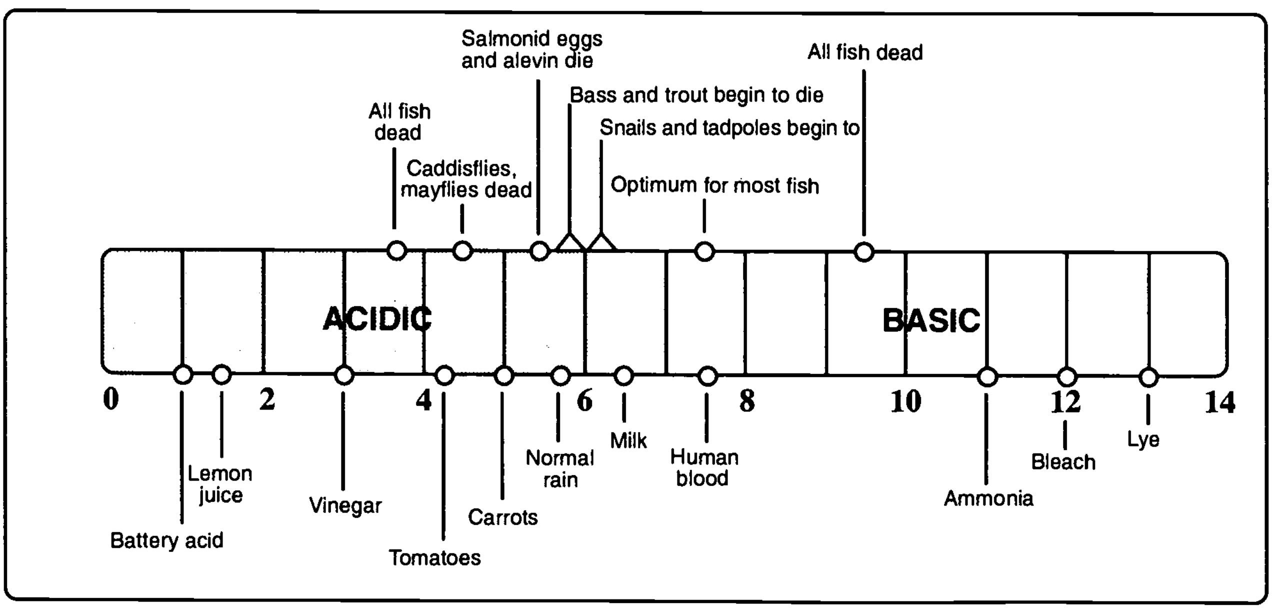
When rain falls through the atmosphere, the gases it contacts come into solution. As rain absorbs carbon dioxide it becomes slightly acidic, but reaches a natural lower limit of pH 5.6.

Air pollution, primarily from automobile exhaust and fossil fuel burning, has increased concentrations of sulfur and nitrogen oxides in the air. These fall with rain as weak sulfuric and nitric acids causing an "acid rain." Currently in portions of the eastern United States, the mean pH for rainfall is 4.3, approximately ten times more acidic than normal. Rainfall measuring just under pH 2.0 fell on Wheeling, West Virginia, in 1978. This was approximately 5,000 times the acidity of normal rainfall and is the most acidic rainfall on record. Because rain can fall a considerable distance from a pollution source, acid rain is a regional and global problem.

Increased acidity has caused pH to exceed lethal levels for fish in many lakes. A U.S. government study estimated that 55 percent of the lakes and 42 percent of stream miles in the eastern United States are currently being subjected to acidic depositions, which will eventually lead to their deterioration. In addition, acid build-up in soils can have detrimental effects on forests and crops, and hinders natural nutrient recycling processes.

Factors that determine the pH of a body of water can be far removed from a particular site, making it difficult to directly manage the pH. Because pH is a limiting factor, it is important to have a measurement to determine which organisms can survive and prosper. This measurement also serves as a baseline measurement and can assist in the monitoring of future changes.

pH Scale



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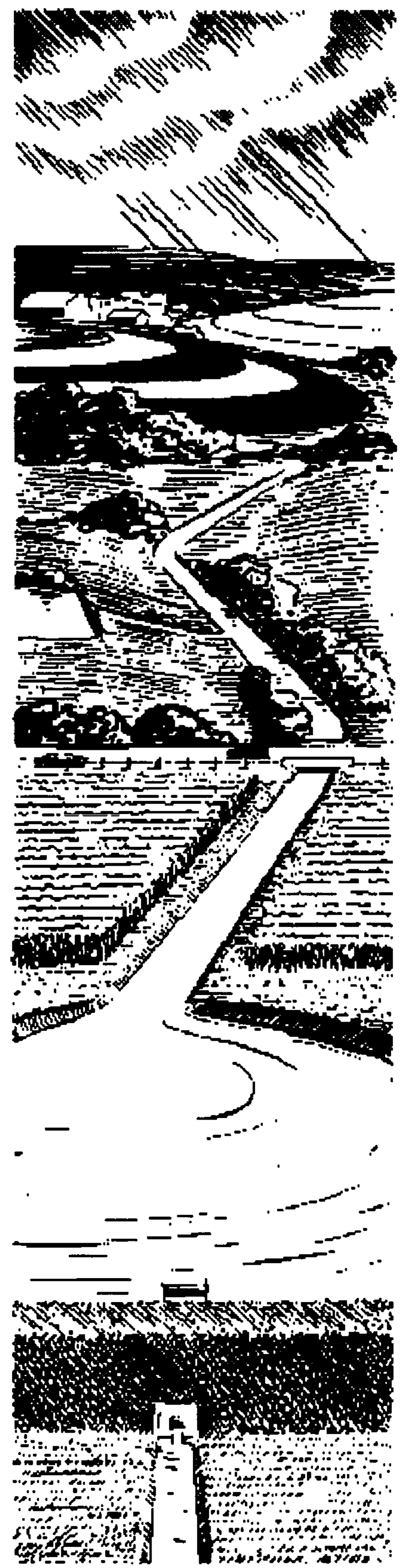
Sediments

As long as there has been water, it has carried solid particles called sediments. Sediments occur naturally as products of weathering and erosion. Wind, water or frost action on rock surfaces result in gradual breakdown of large, solid rock pieces to finest sand. Nutrients necessary to life are transported as sediments, using rivers and streams as drainage outlets.

Ecosystems depend on sediments for their health, but excessive amounts are harmful. Erosion and sediment transport are natural phenomena that can improve as well as degrade habitats within a watershed. Water erodes gravel banks to provide a continuing source of gravel for a stream, shifts gravel bars, and forms or deepens pools, all of which benefit spawning and rearing fish. However, erosion of fine-textured soils such as clays, silts, and fine sand can reduce habitat quality by compacting gravel or lowering water quality.



Sediment types

There are several types of sediments. Bedload sediments are too heavy to be constantly suspended. They are rolled and bounced along the bottom of a stream. The size of a particle of bedload sediment will vary with the volume and speed of the water. Spawning gravel is often transported as bedload sediment during high winter streamflow. Periodic fluctuations in the amount of sediment and bedload being transported naturally occur.

Suspended sediments are those carried in suspension. Rapidly flowing water can carry more suspended sediments than slow-moving water.

A gradient of deposition exists and is determined by streamflow velocity and volume and sediment size. Heavier sediments settle out first, followed by successively lighter materials. As velocity decreases, from the center of the stream out toward its edges, or in slow water areas, the finest sediments settle to the bottom, no longer suspended by the action of water.

Total suspended sediment (TSS) is a measure of how much sediment a stream is carrying. Suspended sediments can give water a murky or cloudy appearance by reducing light penetration. Turbidity is the term used to describe and measure the degree to which light is blocked.

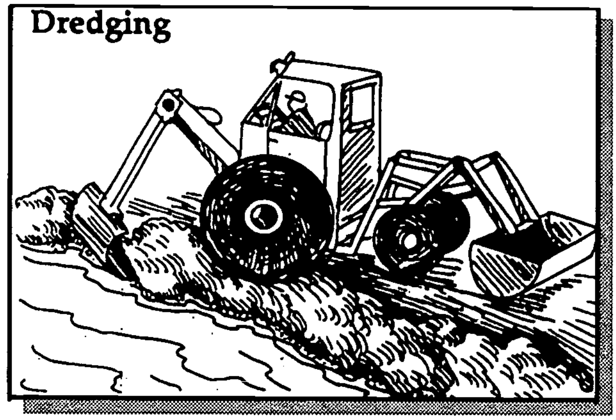
Helpful and harmful sediments

Sediments dissolved in water can be beneficial or harmful to the aquatic community. Some are nutrients essential to life. Others can be minerals or salts that change water pH or are poisonous to life. The measure of solids dissolved in water is called total dissolved solids (TDS). TDS levels higher than 500 ppm make water unfit for human consumption.

Suspended sediments can block or reflect sunlight before it reaches aquatic plants. Heavier sediments can cover leaves, inhibiting photosynthesis, or even bury plants or other substrates.

Sediments affect insect life in a body of water. Large amounts of sediments can smother some species. A change in the bottom material and the type, number, and health of plants changes the habitat, and, therefore, the species composition of the insect community.

Today, even though industrial and municipal wastes receive more attention, sediments are the nation's primary water pollutant. Erosion is the source of most sediments. Agriculture is responsible for more erosion than any other single activity, but road construction and use, timber harvest, forest fires and other sources contribute. Heavy concentrations of sediments increase the cost of municipal water treatment, can be harmful or fatal to aquatic life, and are indicators of excessive erosion.



Fish are also adversely affected by high sediment levels. Very high concentrations of suspended sediments can irritate and actually clog gill filaments, causing fish to suffocate.

Bedload sediments deposited in the channel change the composition of gravel beds used for spawning. This can reduce the amount of oxygen available to the eggs by blocking water circulation, trap fry in the gravel, or reduce the amount of suitable spawning habitat. Changes in plant and insect composition can also reduce amount and types of food needed during different stages of development.

Importance of Vegetation

Excessive sedimentation and the problems it causes can be controlled by reducing erosion. Surface runoff is the primary cause of erosion and can be prevented with adequate plant cover during periods of runoff. Plants and the organic material they add to soil lessen the force of falling rain, add structure to the soil, and increase the soil's ability to absorb and hold water. When surface runoff does take place, leaves and stems of plants trap much debris and sediment that would otherwise be carried into streams.

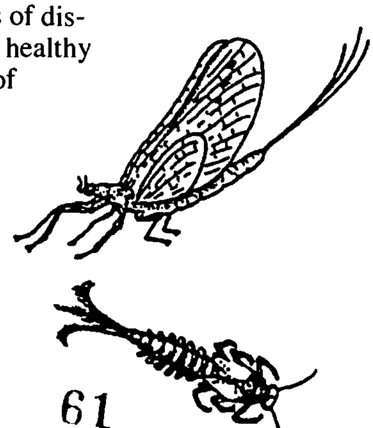
As a stream meanders across a floodplain, it moves sediments and deepens its channel. Riparian vegetation is especially important in the control of these sediments. Plants along streams help prevent bank erosion.

If these plants are lost, a devastating chain of events can begin. The banks become eroded, undercut, and frequently collapse, destroying more plants and exposing more soil to weathering and erosion. Sedimentation increases. Heavy flows scour the channel, moving even greater quantities of sediments. The stream channel continues to downcut, interfering with the redeposition of sediments. This lowers the water table and decreases water retention in the area around the stream. Decreased water retention in the area around a stream means higher flows that will accelerate erosion.

During the summer months, a wide, shallow stream, shaded only by its deep cutbanks, will be warm and have limited quantities of dissolved oxygen. At this point, it is no longer a productive or healthy stream. Control of excessive sedimentation and the health of streams depend on vegetation, especially in riparian areas.

Aquatic Organisms

A healthy stream is a highly diversified ecosystem. Its complex food chain ranges from microscopic diatoms and algae to large fish, birds and mammals.

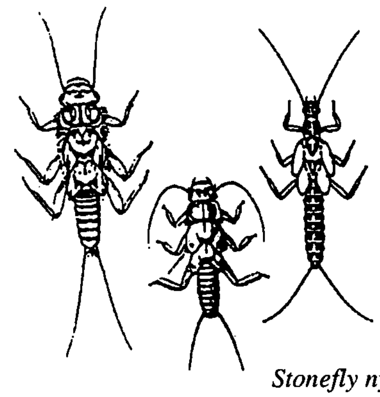


Mayfly adult and nymph

The diversity of species, particularly aquatic organisms, and their numbers are important to any stream study for two reasons:

1. As indicators of water quality in the stream.
2. As parts of various food chains, including fish and birds.

A wide variety of organisms inhabit water. The size and diversity of a population depend on the quality of available water. Fish occupy an important position in the aquatic food chain and obtain their food supply from several sources.



Stonefly nymphs

The amount of food available in a stream is determined by the characteristics discussed in previous sections. When producers are plentiful, consumers also flourish. Diatoms coating a rock feed primary consumers such as mayflies. They, in turn, feed higher-order consumers like stoneflies and fish.

Overhanging vegetation supplies a variety of terrestrial insects to the menu. Many aquatic insects use streamside vegetation during emergence and adult stages of their life cycle.

Some aquatic insects leave their positions among boulders and gravel in riffles and are carried downstream short distances before reattaching to the stream bottom. When insects are moving in a water column, as drift or during emergence, they are most vulnerable to being eaten.

Benthic (bottom) organisms are found on stones or in mud or vegetation. Organisms in fast water have many specialized methods for obtaining food. To gather food in a water column, they grasp it quickly or filter it from the water while remaining stationary. Others gather food on the bottom.

Plankton can be producers or consumers and float or swim freely throughout a stream. Few organisms can live in rapid sections of streams without being swept downstream by the current. Consequently, plankton are abundant in slower waters or large streams and rivers.

Food processing

In autumn, forest floors are piled high with leaves. But in spring, the Earth's load is lightened; the leafy carpet has worn thin and seems to disappear with the melting snow. Where have the leaves gone? Those that stay where they fall are decomposed, for the most part, by soil invertebrates and microbes. But many of the "disappearing leaves" are carried down hill slopes into small, heavily canopied forest streams.

Most leaves and other organic materials blown by the wind, washed from the surrounding landscape, or fallen directly from overhanging limbs into watercourses do not get very far. They are trapped by rocks, logs and branches close to where they entered the water. They become part of the food or energy base of the stream.

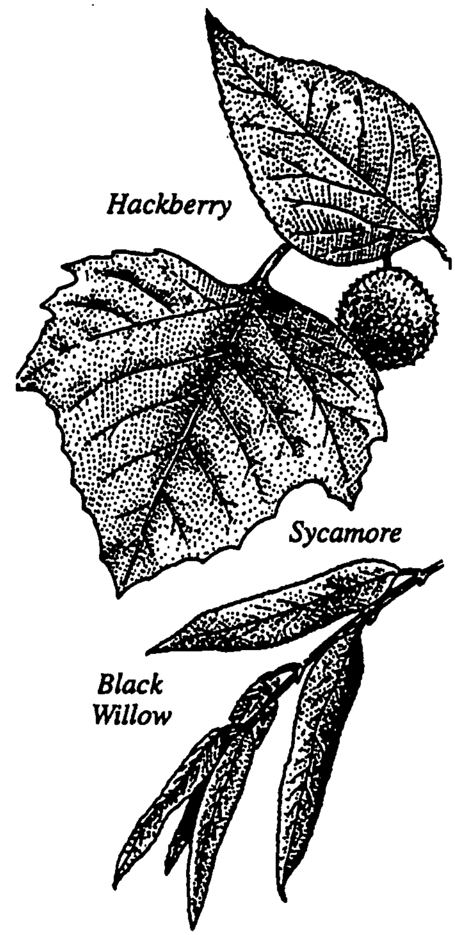
Some of this material settles out in pools and backwaters. Leaves that get buried will decompose anaerobically. Because anaerobic processes are much slower than aerobic ones, buried leaves remain intact longer. These leaves can be recognized by their black color. Eventually the buried leaves are re-exposed, and decomposition continues aerobically, much as if they had never been buried.

Riparian habitat management for wildlife

Riparian habitat is the land and vegetation that is situated along the bank of a stream or river. Such an area is often referred to as a flood-plain, streamside habitat, or bottomland forest. Because the topography is flat, it is subject to frequent seasonal flooding.

Plants commonly associated with riparian habitat include deciduous trees such as silver maple, red maple, sycamore, elm, cottonwood, box elder, buckeye, hackberry, willow and river birch. Shrub in the under-story layer of riparian woodlands include elderberry, bladdernut, wahoo, common alder, buttonbush, spicebush, silky dogwood, and red-osier dogwood. The ground cover is composed of flowering plants such as scouring rush, white snakeroot, waterleaf, jewelweed, nettles, and wingstem.

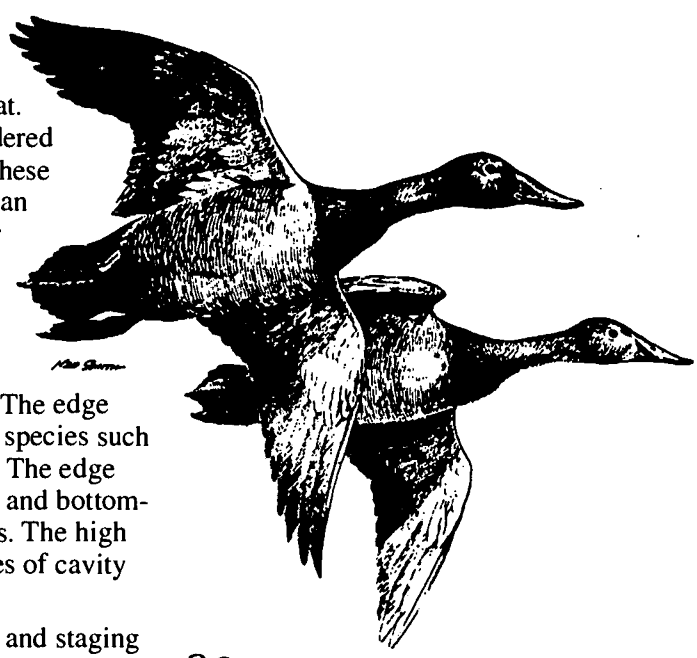
Riparian habitats are constantly shifting and changing in physical structure and plant composition due to the sometimes extreme forces exerted upon them by the fluctuating water levels of adjacent streams. As a result, riparian habitats can also be identified by the mixture of live and dead vegetation, especially the predominance of standing dead trees and ground cover debris such as logs and natural litter.



The values of riparian habitat

Riparian habitat is one of the richest and most diverse habitat types in Ohio. Even though its dominant plant community is woodland, it usually contains a patchwork of smaller microhabitats such as buttonbush thickets, seasonal spring pools, sedge meadows, and cattail marshes. This mosaic of habitats, together with the surface water and abundant soil moisture, makes riparian land especially appealing to wildlife.

Riparian habitats offer many benefits to wildlife. They provide excellent travel corridors for safe movement between habitat types and promote the dispersal of wildlife populations. This benefit is particularly important to quail in western Ohio, because quail are somewhat limited in their ability to move to, seek out, and exploit surrounding available habitat. Habitats suitable for quail in western Ohio could be considered island oases in a vast cropland desert. Quail cannot reach these uninhabited islands without protected passageways. Riparian lands can provide these critical connecting access links for quail and other wildlife.



Riparian lands also supply an abundance of edge habitat that is spread out over a large area, making cover more accessible to wildlife. Riparian lands present two types of edges, each of which serves the needs of specific wildlife. The edge between the stream channel and vegetated bank is used by species such as the kingfisher, bank swallow, and prothonotary warbler. The edge formed by the merging of upland habitat, such as cropland and bottomland forest, is used by bobwhite quail and cottontail rabbits. The high density of trees with nesting cavities attracts several species of cavity nesters such as the pileated woodpecker and wood duck.

Riparian areas also serve as significant resting, feeding, and staging areas for waterfowl and other migrating birds. In some regions of Ohio, riparian habitat offers the only available habitat for migrating birds.

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Management of riparian habitat

Management of riparian areas involves protection, restoration, or both. It is extremely important that existing riparian habitats receive protection. An estimated two million acres of riparian habitat has been destroyed in Ohio since settlement. Like wetlands, riparian lands have been misunderstood and abused by the human community.

What caused the destruction of these riparian lands? Conversion to agricultural uses (cropland and pasture) has been the most damaging to riparian resources. Stream channel modification to improve cropland drainage by removing silt from the substrate and eliminating meanders is a major agricultural practice that has severely degraded both stream and streamside habitat. Industrial and residential development has also played a role.

Protection

Protection of riparian habitat is the first and best approach because it is less difficult and less costly to protect habitat than to rebuild degraded habitat. To provide quality habitat for riparian wildlife, a strip 125 feet or wider of riparian vegetation (preferably trees and shrubs) should be set aside and preserved along the water course. A minimum of 75 feet must be protected if water quality is to be maintained well enough to support a healthy aquatic community. A good rule of thumb is to maintain a protective buffer of 2 1/2 - 3 times the natural stream width.

Protection may also require restricting livestock use of riparian land and eliminating logging operations.

Restoration and enhancement

It is also important to try to regain some of what we have lost. This means restoring riparian sites that have been totally or partially destroyed. Habitat restoration is the repair of damaged riparian habitats so they may once again produce and support significant wildlife populations. Habitat enhancement is the creation of better or more suitable habitat within a land area. Habitat enhancement may not always mean more wildlife, but may mean an increase in other values related to overall watershed health.

Various techniques exist for restoring and enhancing stream habitat. In order for any habitat restoration or enhancement work to be successful, it must meet two criteria. It should be placed where it will best aid creation of the desired habitat condition and it should be designed to last for a relatively long period of time.

Some sites can be restored by simply allowing them to revert naturally. This course of action requires you to discontinue any practice or land use such as mowing, pasturing, or cropping that hinder the development of woody plants. You must be willing to surrender some land and possibly some monetary profit for the cause of conservation. Keep in mind that short-term sacrifice can translate to long-term prosperity.

Habitat improvement techniques

Plantings

To speed the development of riparian habitat, you can plant various bottomland plants. Planting native vegetation is usually the best. Vegetation should have the ability to stabilize the streambank and control flooding during heavy rains. It should buffer the stream from siltation and animal manure. Plants should be selected which will require little care once they are established. Plants selected should not be invasive, that is, spreading to choke the streambed with growth. Plants should also be selected for their ability to provide wildlife habitat. These plants will provide food, cover and habitat for fish and birds and migration corridors for other types of wildlife.

Riparian revegetation plans should aim to achieve high diversity and density of woody vegetation. The types of trees and shrubs to select will depend on soil type and geographic location. It is best to use native woody plants for restoring streamside habitat. These plants are recommended: hardwood trees such as sycamore, sweet gum, green ash, cottonwood, hackberry, box elder, and silver maple, and shrubs such as silky dogwood, common alder, and red-osier dogwood. The tree seedlings should be placed 7-12 feet apart within the row and the rows should be far enough apart to allow maintenance mowing during stand establishment (10 feet apart.) Shrubs can be intermixed with the hardwood seedlings at approximately five-foot spacings. Alternate species as you plant them. Contact your county Extension agent or Service Forester for more detailed information.

Competition from existing vegetation (especially sod forming grasses) can hinder riparian reestablishment. Therefore, it is recommended that you Mow or spray two- to three-foot wide bands approximately 10 feet apart. Apply the herbicide during the fall growing season, preferably in September. (The trees and shrubs will be planted in the center of these strips.) The first band should be at least 10 feet away form the crest of the streambank. Be careful not to allow overspray to drift into the stream channel. Herbicide application is not necessary in bean or corn stubble fields. Simply plant the trees directly into the stubble. Try to minimize soil disturbance so as not to encourage the growth of annual weeds. Establishing a temporary cover such as annual rye will also aid in preventing weed invasion Mowing or spraying directly around each seedling may be required until the plants have cleared the competing weed growth. Contact the county Extension Office for more information on herbicide selection and use. Plant the trees and shrubs in the spring between March 1 and May 1.

Human elements should be incorporated into a vegetation plan also. Some plants should be pleasing to the eye and offer a diversity of color and texture throughout the year. The concept of "edible landscaping" can be integrated in the stream corridor by planting fruit-bearing plans such as pear, huckleberries, and blueberries.

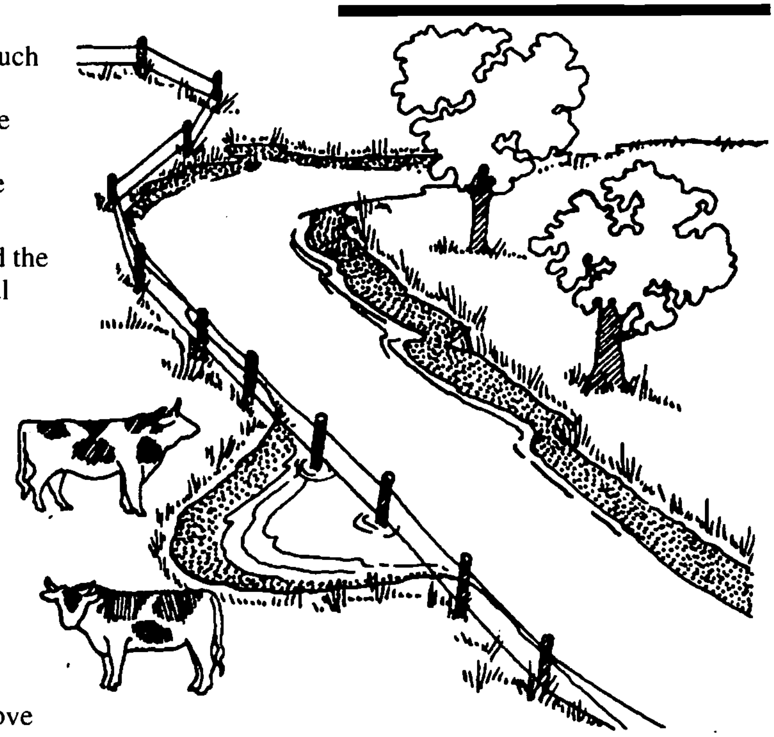
Streambank fencing

Under certain circumstances, fencing or otherwise limiting usage of disturbed streamside areas can be very useful for restoring deteriorated streamside vegetation. The major purpose of fencing is to control livestock grazing in terms of numbers, season and timing of use along edges of streams, Gates and water gaps must be provided in the fencing and wildlife must be considered in the placement of the bottom and top wires.

Streamside fencing should be constructed far enough back from the stream to prevent fence damage from ice, high flows and debris.

Some grazing systems and/or techniques (such as alternative water developments, upland improvements, planting of nutritious, palatable species well away from riparian areas and/or riding and herding practices) can eliminate the need to fence.

If fencing is appropriate, it is recommended the entire riparian area be fenced as an "ecological unit." In this manner, the land manager can control livestock in the entire watershed efficiently (e.g., north slopes, south slopes, riparian areas) without trying to manage subdivisions within an ecological unit.



Bioengineering techniques

Bioengineering is a branch of engineering that utilizes plant material or engineering purposes. Bioengineers use live plants and plant parts as building material for erosion control and landscape restoration. Live material not only helps to stabilize slopes, it helps to improve infiltration, filter runoff, transpire excess moisture, moderate ground temperatures and improve habitat. These practices are an economically effective means of protecting, restoring and improving the environment. A real positive point for bioengineering is that it looks natural and therefore is more environmentally friendly.

There are numerous bioengineering techniques. Generally they all utilize dormant cuttings of native plant species in some form. These species (such as willow and dogwood) root easily from cuttings that can be obtained from local sources. Once these cuttings take root and grow, the new plants will help to slow wave actions and stream currents and reduce siltation of the waterways. The slowing of wave actions and stream currents helps to minimize streambank erosion.

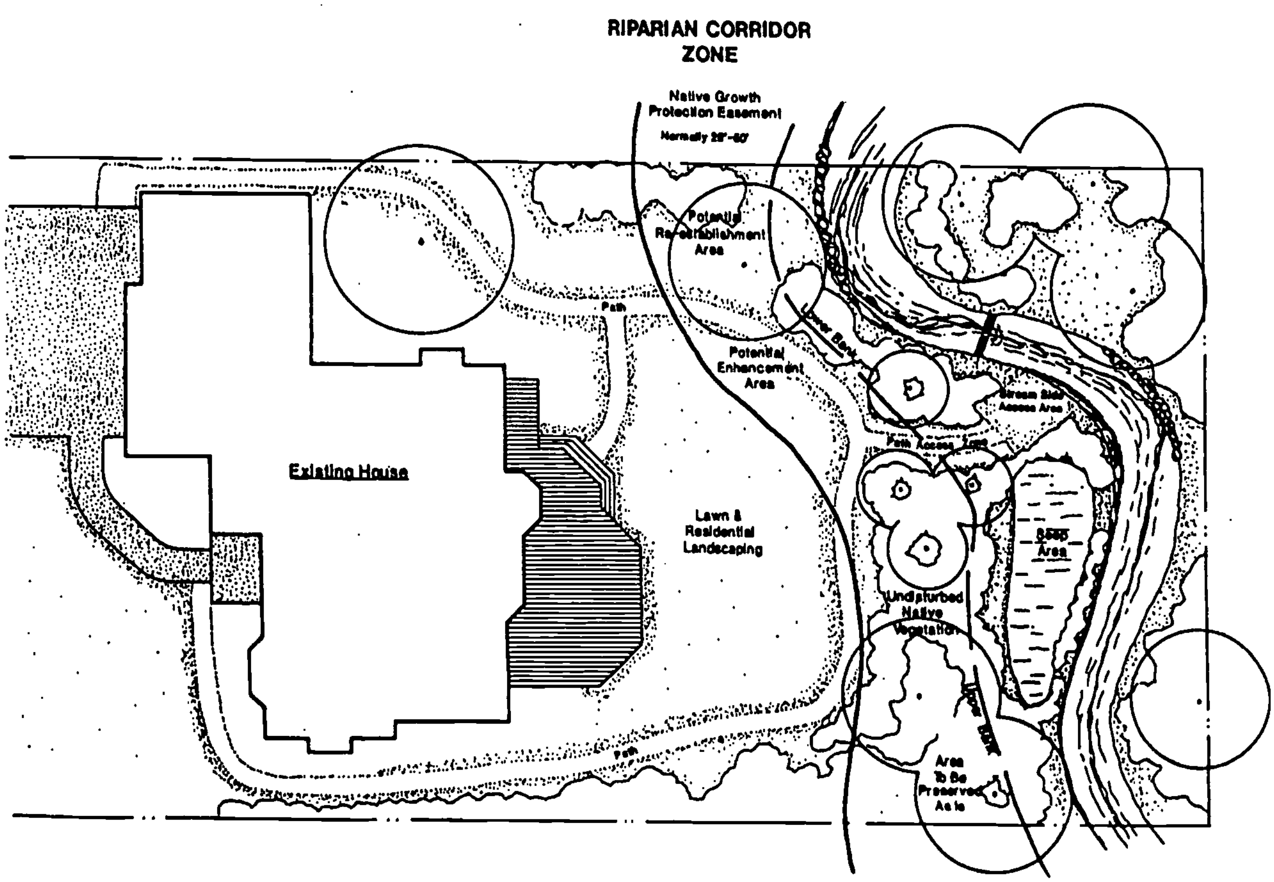
These dormant cuttings are installed after leaf drop and before the species begins to sprout in the spring. Cuttings may vary in size from a stake (1-3 inches in diameter and 18-36 inches in length) to a post (2-4 inches in diameter and 6-12 feet in length). The size used depends on the severity of the erosion problem. These stakes or posts are sharpened on one end and driven into the streambank like a fence post or a hole is created with an auger or ram and the cutting is placed into the hole. There are variations on this procedure that may be used depending on specific site conditions. Any application of live plant material needs to be implemented when plant material is in the dormant state. Some common uses of dormant vegetation include, willow postings; live fascines; brushlayering and brush mattresses.

Because one method is not applicable to all erosion sites, a wildlife biologist, landscape architect, forester or engineer may be consulted for bioengineering projects.

Tips for People Who Live Next to a Stream

A lot depends on you. There are several things you can do to help save and preserve your stream.

- Leave natural streamside vegetation alone and let the stream take its natural course. Leave at least a 10-foot vegetation buffer along the stream banks and a wider strip on sloping land. Channelizing a stream depletes the stream of natural pools, gravel and other features important to fish habitat.
- Keep pets and livestock away from streams. Keep watering and feeding areas for animals away from streams or waterways.
- Keep litter out of streams and remove garbage from the stream area. This includes tree branches, grass clippings, old appliances or trash.
- Avoid using automotive products, household chemicals and lawn and garden chemicals where there is a chance they might enter the water. Follow container disposal instructions carefully. Chemicals that are toxic to humans are usually toxic to fish and may be toxic to aquatic plants and insects.
- Restrict livestock, fowl, and other barnyard animals from streamside areas by constructing fences or using "living fences" (hedges). Trampling by livestock increases the potential for streambank erosion.
- If stock must be watered at the stream, use a ramp-and-fence system to keep them out of the water.
- Avoid excessive runoff from manure storage areas and pastures.
- Avoid excessive runoff when clearing land.



TYPICAL STREAMSIDE ENHANCEMENT PLAN

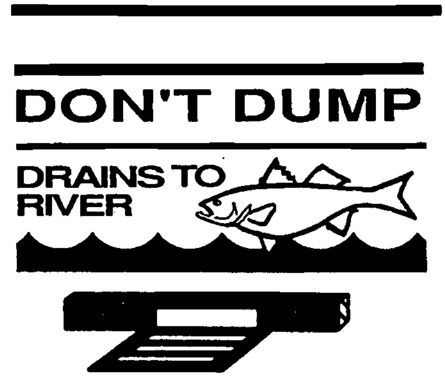
- If streambanks are eroding, consider undertaking a rehabilitation project such as one of the following:
  1. Vegetate streambanks using trees, shrubs, and grasses. Use native species of good-quality planting stock. OSU Extension, the Natural Resource Conservation Service (NRCS), and conservation districts can provide information on streambank revegetation and suitable vegetation types.
  2. Plant grasses and legumes to hold soil in place until trees and shrubs have become established.
  3. Use mulch and/or burlap netting with plants on steep slopes.
  4. In some cases, vegetation alone will not be adequate and structural measures may be required. Contact the NRCS for assistance before attempting any structural work.

Tips for People No Matter Where They Live

Everyone can help save our streams, whether they own a stream or not. Read and follow the tips below and encourage your friends and neighbors to do the same to protect our streams, no matter how small they are.

- Inspect on-site septic systems regularly and keep them in proper working order. Failing septic tanks may pollute a stream with harmful bacteria.
- Avoid driving machinery, cars, motorcycles, and all-terrain vehicles through streams. Driving vehicles of any type through streams ruin potential spawning areas, erode stream banks, and cloud the stream with mud and silt.
- Read and follow directions for fertilizers, pesticides, and herbicides. Applying more chemicals than directed may do more harm than good. Limit spray near ditches, lakes or streams. Spray on windless days when it is not too hot. Avoid spraying during or before rain. Spray only when you actually see the pest or disease and only when the chemical is most effective. Pesticides and herbicides may be toxic to fish and aquatic plants. Fertilizers can cause excess plant and algae growth when they enter water and reduce the available oxygen for other aquatic life.
- Keep all your gasoline and diesel vehicles and equipment in good working order. Recycle your used crankcase oil. Oil leaks from cars can contribute large volumes of pollutants. Antifreeze is also toxic to fish. Lead from car exhausts is washed off the roads into local streams. Careless spills and disposal of fuel and oil containers can pollute streams and lakes.
- Use water conservatively. Keep irrigation to a minimum. Plant drought resistant plants that require less water and keep lawn sizes small. Install shower heads and toilets that use less water or restrict the flow of water. Water diverted to human use reduces the amount of water available in the streams for all aquatic life including fish habitat, migration and spawning.
- Be careful with matches and campfires. Burned areas can lead to silt in streams.
- Don't pour oil or chemicals, or sweep sediment,down storm drains. It will end up in a stream or other waterbody.

- Report any fish kills or polluted waters.
- Join a volunteer organization such as Adopt-A-Stream or Master Watershed Stewards, which sponsors public education projects and stream projects in your community.



Ideas for Projects

- Organize a streamwalk or similar inventory of your community's streams.
- Organize or participate in a stormdrain stenciling project to help keep toxic waste out of streams.
- Get involved in a stream enhancement project. Potential projects include repairing stream beds, clearing unwanted debris and planting streamside vegetation.
- Erect stream road crossing signs to remind travelers that we care about water quality in every community.
- Adopt a neighborhood stream and get your friends, family, scout troop, social club, schools, civic organization, etc. to help.
- Volunteer to help organize stream and water quality awareness educational programs in your local schools.
- Attend public hearings, write letters, and urge your elected officials to strengthen laws. Public awareness and active support can continue to help protect our water resources. Speak up for water quality and other habitat protection.

Volunteer Stream Monitoring

Measuring Stream Health

Measuring Stream Health

A Short History of Water Pollution

Clear, rushing water flowing over rocks through a scene filled with trees and wildlife. This picture looks like a storybook portrait of clean water before civilization. Unfortunately, as industrialism grew and villages became cities, clean waters started to fill with toxins, pollutants and waste.

As the population centers grew, trash, human and animal waste, and eroding soils from agriculture entered waterways. Early cities produced raw sewage, grease, dirt, organic matter from slaughterhouses and other pollutants. The Industrial Revolution brought more severe pollution problems to our nation's waters as factories became concentrated in burgeoning cities. Materials, such as iron, were produced in commercial quantities to build the machines needed for manufacturing and engines for transportation. Discharging pollutants to waterways became an easy way for factories to dispose of industrial waste water and byproducts.

The first water pollution legislation was the Rivers and Harbors Act in 1899, which prohibited dumping refuse or the construction of structures (dams, bridges, piers, etc.) in navigable waters without federal approval. However, the act made no provision for obtaining such approval nor did it designate responsibility for issuing permits to any particular government agency. In addition, there were no inspectors or fines to deal with illegal dumping activities. In short, there were no prescribed penalties for lawbreakers.

In 1927, President Calvin Coolidge asked members of the Izaak Walton League of America to conduct the nation's first water pollution survey. Members of the League also adopted and cared for rivers, since there were no government agencies in place to ensure their protection.

The Water Pollution Control Act was passed in 1948. It was the first attempt by the federal government to exert some control over state and local handling of clean water issues. However, most of the control and management still rested with the states. In 1956, amendments to the Water Pollution Control Act were passed that provided for federal financial support for wastewater treatment plant construction (up to 55 percent of the total construction cost) and direct federal regulation of waste discharges through a process known as the enforcement conference. This only regulated discharges into interstate waters. By 1961, discharges into all navigable waters were covered. In 1965, the Water Quality Act established ambient water quality standards for interstate waterways and required states to file implementation plans.

The most important step in providing real protection for surface waters was the 1972 Clean Water Act, which required a much stronger and more active federal oversight role. The objective of the act is to "restore and maintain the chemical, physical and biological integrity of the nation's waters." The act also required that discharges of pollutants into the nation's waters be eliminated by 1985 and that pollutants discharged up until that point be regulated by the National Pollutant Discharge Elimination System (NPDES), which sets minimum standards for the amount and content of wastewater each type of industry may discharge to surface waters. The act also required that all waters of the United States be "fishable and swimmable." In addition, the act created a permit program to regulate the discharge of dredged or fill material into the

Volunteer Stream Monitoring: Measuring Stream Health

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nation's surface water. This became an important tool for wetlands protection by regulating the destruction and development of wetlands.

The act was amended in 1987 to add programs dealing with nonpoint source pollution (polluted runoff) from the land. The amendments recognized that this runoff makes up as much as 60 percent of the nation's surface water pollution and required states to address the problem through management programs.

Since the Clean Water Act and subsequent amendments were passed, much has been learned about our nation's water quality. For the past few decades, states have instituted programs to monitor the quality of their waterways, lakes and estuaries. Groundwater monitoring also is conducted, although on a much smaller scale than surface water monitoring. Today, the nation monitors about 36 percent of its rivers and streams and 47 percent of its lakes.

Historically, most of this monitoring has taken place around point source dischargers, such as factories and sewage treatment plants. With the focus on runoff pollution in the 1987 Clean Water Act Amendments, states are focusing more monitoring efforts on areas suffering from runoff pollution, such as rural, agricultural and urban areas. Many states have expanded their ability to monitor rivers and streams with volunteer water quality monitoring programs. Many of these monitoring projects are run by secondary schools, colleges, and community groups working with state scientists to ensure methods and procedures are correct and data is consistent.

You will learn how to conduct a volunteer monitoring and use the collected data to determine the water quality of the adopted stream. However, it is important to first understand what constitutes clean water.

What is Clean Water?

There are three primary types of environmental quality to consider - chemical, physical and biological. States determine minimum acceptable standards for what constitutes "clean water". The Clean Water Act calls for all rivers to be fishable and swimmable, but some rivers are not even that clean. States may make exceptions to these standards by granting variances to permitted dischargers, such as industries. A river may be deemed more important commercially as a discharge systems for industry than as a habitat for fish and other wildlife and appropriate permits are issued. Regardless, in Ohio, all streams have water quality standards by which any discharger must follow. Ohio's anti-degradation policy prevents excessive point source pollution from delivery to streams and lakes. However, many studies have shown the benefits of protecting rivers for recreation, such as fishing, often far outweigh financial benefits of using a river as a discharge source.

Chemical Measurements

Water chemistry is a fascinating and complex topic because water has several unusual properties. For example, the density of the solid phase as ice is substantially lower than the density of the liquid phase. Water is formed by the union of two hydrogen atoms and one oxygen atom - H_20. The oxygen atom is bonded to the hydrogen atoms in an asymmetrical pattern. This causes the molecule to be polar and have an electrical charge. This is significant because water is a solvent for many salts and some types of organic matter. Water can also cause materials to leach from the soil especially if the water is somewhat acidic. A weak

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acid called carbonic acid H_2CO_3 can form when carbon dioxide (CO_2) combines with water (H_2O). This acid is found in rainwater and groundwater. As a result, when water flows over the Earth's surface and through geologic materials, soils and rock formations, it picks up and dissolves some materials. Consequently, the chemistry of water can vary depending on the materials suspended and dissolved in it. The water chemistry of a stream is affected by the land use, soils, surrounding geology and precipitation in your watershed.

Chemical water quality often is measured by a few basic parameters. If a river is to be used as a drinking water source, it is subject to stringent standards and more monitoring. In general, drinking water cannot have any volatile organics, radioactive materials, heavy metals or toxic chemicals. Volatile organics are organic chemicals that are unstable or combustible. Toxic substances are poisonous to aquatic and other life forms.

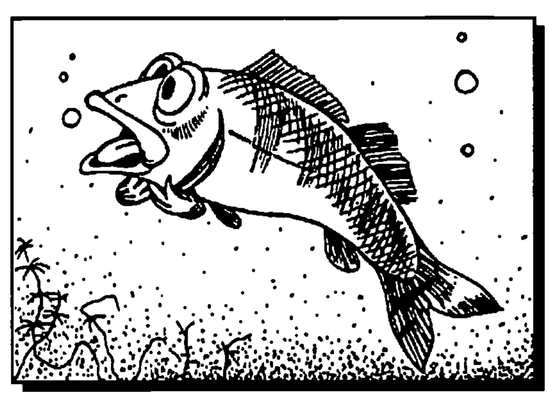
There are two general types of toxicity. Acute toxicity refers to a substance that causes death to a life form during a short exposure. Chronic toxicity causes harm over a prolonged and sustained exposure. Chronic toxicity may occur in small doses but can cause harm by having a cumulative effect on growth, respiration and reproduction of aquatic organisms. Equipment such as a mass spectrometer may be needed to test for toxic substances. Testing should be done in a laboratory using Environmental Protection Agency approved techniques that include stringent testing guidelines to monitor toxic substances, metals or radioactive elements.

The Safe Drinking Water Act of 1974 issued standards for community water systems and set standards for maximum allowable concentration of bacteria, turbidity (clarity) and chemical-radiological contaminants. The 1986 amendments to the act also required standards for specific contaminants to be set by EPA and established civil and criminal penalties for violations.

The amount of a specific contaminant, chemical element or compound is expressed as a concentration which is the specific weight of a contaminant in a specific volume of water. Milligrams per liter (mg/l) are roughly equivalent to parts per million (ppm). Another common reference is micrograms per liter (ug/l), which is roughly equivalent to parts per billion (ppb). A "ppm" means one part contaminant for every million parts of water. This measure serves as a ratio. A milligram is one-thousandth of a gram, and a microgram is one-thousandth of a milligram (one-millionth of a gram). Approximately 28 grams make an ounce, and a liter is equivalent to a quart. One quart is equal to 32 fluid ounces and 1 liter is equal to 33.8 fluid ounces.

Dissolved Oxygen

A basic parameter for determining the health of a stream is dissolved oxygen (DO), a measure of the concentration of oxygen in the water. DO is needed by aquatic organisms for respiration or processes such as decomposition. The DO content of water is influenced by several factors, including water temperature, salinity, atmospheric pressure (or altitude) and the amount of oxygen-demanding waste in the water. Bacteria living in the water use up available oxygen by breaking down organic wastes such as manure, leaf litter, woody debris or organic materials in wastewater. DO usually is expressed as milligrams per liter or mg/l.



Aquatic life have different requirements for oxygen. A tubifex worm that lives on stream bottoms can go for a few days with no oxygen, but some fish, such as trout, need at least 7mg/1 of oxygen at all times to function normally. A healthy, warm-water stream may have oxygen levels of 11 mg/l or higher. Generally, once oxygen levels drop below 3 mg/l, the water is considered oxygen poor. Most fish are stressed at this level, and many species may be absent.

Biochemical Oxygen Demand

Another common measure of water quality is biochemical oxygen demand (BOD). BOD occurs when bacteria in the water uses available oxygen to break down organic matter or nutrients in the stream into simpler elements. This process of organic breakdown which utilizes oxygen, is known as aerobic decomposition. If too much decomposition occurs due to the presence of excessive nutrients, oxygen levels in the stream may drop making the stream oxygen poor. A high degree of decomposition gives a stream a high BOD because it needs a lot of oxygen to break down organic nutrients.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is another measure of water quality. COD refers to the oxygen depleted by oxygen-using chemicals in the water. These chemicals bind with oxygen molecules, making them unavailable for aquatic life. Discharges from industry may have a high COD.

pH

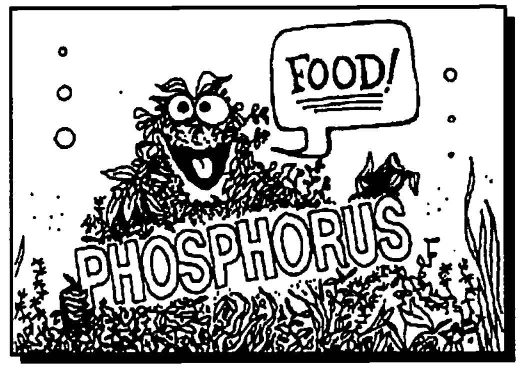
pH is another common indicator of water quality. pH is a measure of the hydrogen or hydroxyl ion concentration of the water, which determines whether the water is acidic or basic (alkaline). The pH scale is logarithmic, with values of 1 to 7 (acidic) and 7 to 14 (basic or alkaline). Because the scale is logarithmic, a pH of 2 is 10 times more acidic than a pH of 3. pH levels less than 1 are equivalent to battery acid, and a pH of 3 is equivalent to vinegar. Ammonia, on the other hand, has a pH value of between 11 and 12 (alkaline).

Rainwater naturally is somewhat acidic with a pH of about 6.5. The pH concentration of water is extremely important to aquatic life. pH affects respiration rates of fish as well as the solubility of many chemicals and metals. Most fish species have pH tolerance ranges from 6 to 8.5. If pH is above or below these levels, fish numbers and reproduction rates are affected. For example, small and largemouth bass cannot survive below pH 5.5. Low pH levels also change the composition of other aquatic life, such as algae, at the bottom of the food chain. Because low pH (acidic) water affects solubility of metal ions, it can liberate harmful metals, such as aluminum, that naturally are present in the soil but do not become mobile until leached by acid water. These metals can reach surface and groundwaters, contaminating fish and poisoning aquatic life.

Hardness

Hardness is another measure of water quality. Hardness measures the concentration of calcium and magnesium ions in the water, usually expressed as mg/l calcium carbonate equivalent. Calcium and magnesium usually enter surface waters through the breaking down of rocks known as weathering. Magnesium levels usually range from 5 to 50 ppm. When total hardness exceeds total alkalinity, chloride and sulfide ions are present. These metals can harm aquatic life.

Phosphates and Nitrates

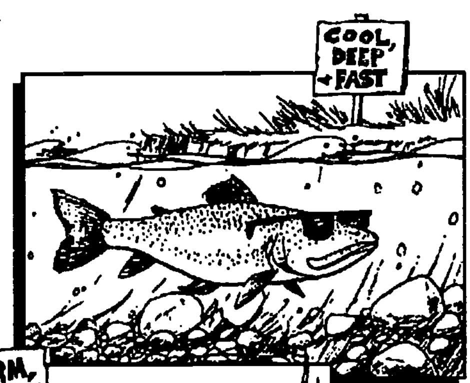


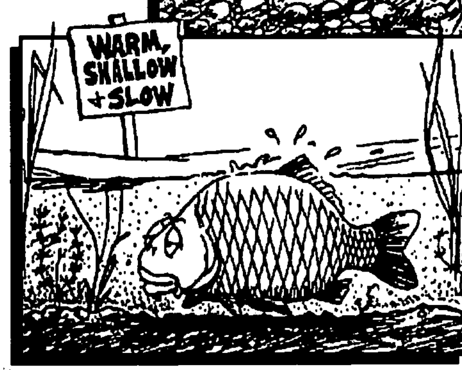
Phosphates (PO_4) and nitrates (NO_3) are plant nutrients that can enter water in excessive amounts due to runoff from fertilizers spread on farm fields or lawns. Some household and industrial detergents also contain phosphates. Excess levels of phosphate can cause too much algae and plant growth in streams. When this excess algae decomposes, the process can rob streams of available oxygen. Excess nitrates and phosphates increase the stream's BOD by causing excessive plant and algae growth.

Simple chemical testing kits can be used to determine phosphate and nitrate concentrations in streams. Nitrate test results usually are expressed as the level of nitrate-nitrogen (NO_3-N), which means nitrogen in the form of nitrate. Unpolluted waters generally have nitrate-nitrogen levels below 1 ppm. The drinking water standard for nitrates is 10 mg/l. This means waters with concentrations 10 mg/l or above are considered unsafe for human consumption.

Total phosphorus levels higher than .03 ppm contribute to increased plant growth; levels above .1 ppm may stimulate plant growth above natural levels and contribute to oxygen-reduced conditions.

Temperature

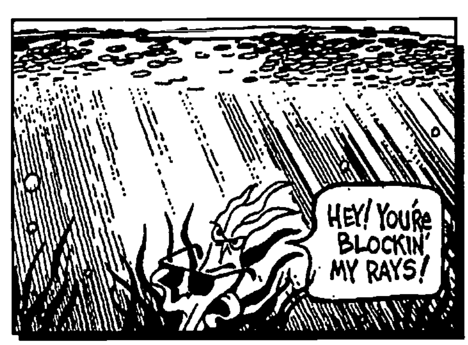




Temperature is another commonly measured water quality indicator. The temperature of water directly affects its chemical concentrations and fish species. Water has a high heat capacity, which makes it resistant to changes in temperature. In the winter, water temperatures are often warmer than air temperatures. Temperature requirements vary among fish species. Trout need cooler water than carp, for example. Rapid changes in temperature (more than 1 to 2 degrees Celsius in 24 hours) can cause thermal stress to fish and other stream inhabitants.

Increased temperatures can decrease water's ability to hold dissolved oxygen impairing feeding, growth and reproduction of fish eventually causing death. Thermal pollution occurs when temperature increases exceed normal levels for the stream. Thermal pollution can be caused by upstream dams, removing streambank shade trees, heated discharges from industries or power plants, and inflow of storm water runoff from urban streets.

Turbidity



Turbidity (cloudiness) is another water quality indicator. Turbidity is caused by the amount of suspended solids in the water. Although all natural streams and lakes have a certain amount of materials suspended in the water from decayed organic matter, sediment carried by the stream, minerals and other particulate matter, the concentration of these solids must not exceed the normal amount for the stream. Too many solids in the water can block light to underwater plants and clog fish gills, suffocating the fish. Fish spawning beds are buried as solids settle to the streambottom. Suspended solids are also a problem because they may contain nutrients, pesticides and toxins.

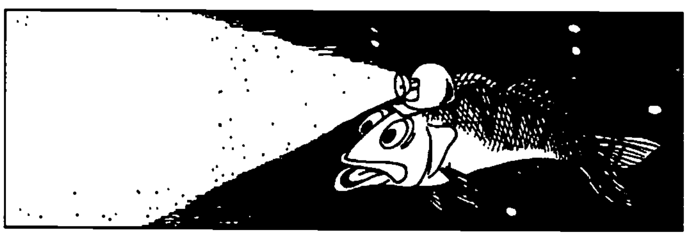
Total suspended solids (TSS) is a measure of the total amount of solids in a liter of water. Simple tests for turbidity in streams can be conducted in the field using portable turbidimeters or other devices (prices can be high). Secchi disks are colored disks used to measure turbidity in lakes or standing water.

Another measure of solids is total dissolved solids (TDS), which are materials left behind after a water sample is filtered and evaporated. Rather than measuring, drying and weighing a water sample in a laboratory, conductivity tests can be done to determine the amount of material dissolved in a sample of water. This is because materials dissolved in water conduct electricity. The amount of electricity conducted is the water's conductivity. Portable conductivity meters can be used to measure the approximate dissolved material in the water. Rainwater has about 10 ppm TDS.

Streams may contain between 100 to 2,000 ppm of dissolved materials. This variability occurs because the amount of material dissolved and carried into a waterway is affected by factors such as local geology, acidity of rainfall, amount of nonpoint source runoff, etc.

Color

Apparent color of water is also important when reviewing water quality. Color is affected by the presence of dissolved substances and suspended matter in the water, or possibly discharges from industry. Although color is not a value regulated by the Environmental Protection Agency, color change caused by industry can be considered a pollutant because water that is colored above normal levels may block sunlight from reaching aquatic plants. When the amount of sunlight reaching aquatic plants is reduced, photosynthesis is curtailed and less oxygen is produced.



Pathogens

Another important indicator of water quality is the presence or absence of pathogens, which are disease-causing organisms. Pathogens can be enteric, which means they are found in the intestine and feces of warm-blooded animals, including people. Fecal coliform bacteria are found in the lower intestine and feces of warmblooded animals including humans. Fecal coliform are not a pollutant, but can indicate the presence of contamination from animal wastes, or by human waste from failing septic systems or wastewater treatment plants and other nonpoint sources such as food lots, storm water etc. Fecal coliform is measured as the number of colony forming units (CFU) per 100 ml of water.

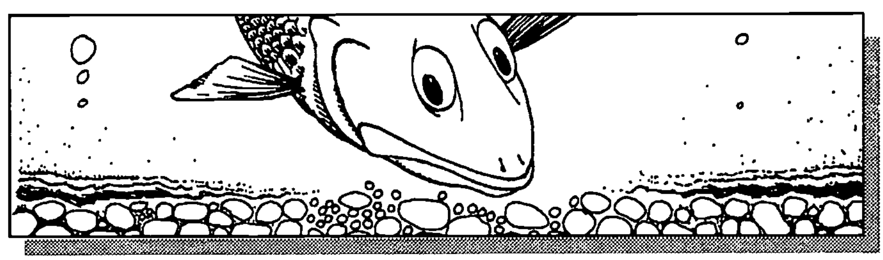
Simple coliform filtration test kits can be ordered from chemical supply companies. No fecal coliform should be found in drinking water. Between 200 and 1,000 CFU per 100 ml of water is considered acceptable for swimming, and 1,000 to 5,000 CFU per 100 ml of water is considered safe for secondary contact, such as boating and fishing. However, it is important to note that people often swallow water when swimming, so allowing fecal coliform levels of 200 CFU per 100 ml of water for swimming is a questionable practice.

Habitat Quality and Physical Characteristics

Stream health also can be assessed by evaluating the waterway's physical characteristics, such as habitat quality. The amount of water flow in a river directly affects the habitat of a river. The volume of water flow of a stream or river is critical to the types of aquatic life that can survive there. Common measures of water flow are cubic feet per second (CFS) for waterways and million gallons per day (MGD) or even billion gallons per day (BGD) for dischargers. The minimum flow a river needs to provide for various uses is the minimum in-stream flow (MIF). For instance, a MIF level for boating uses may be higher than an MIF level for survival of fish.

Many states now are in the process of determining MIF values for their rivers so industrial and agricultural withdrawals of water do not jeopardize the amount of water that must remain in the river to support other uses, such as boating or fish habitat. Flow can be calculated relatively easily on smaller rivers and streams.

Other habitat values that affect water quality are shading from trees and the presence of pools, riffles and meanders in the stream. Pools trap nutrients and provide hiding places for fish. Riffles are areas where stones of varying size provide hiding places for aquatic insect larvae and fish and where the stream can get more oxygen as water bubbles over the rocks and interacts with air. Sediment polluted streams with low gradient can often cause riffle substrate to become "embedded" with silt. Embeddedness is the amount of sediment covering rocks and the degree to which rocks are cemented together in a stream.



The greater the degree of embeddedness, the poorer the habitat for aquatic critters. This is because loose rocks trap food and are easier for aquatic animals to crawl under for shelter. If rocks are cemented together, it is more difficult for aquatic organisms to find places to live.

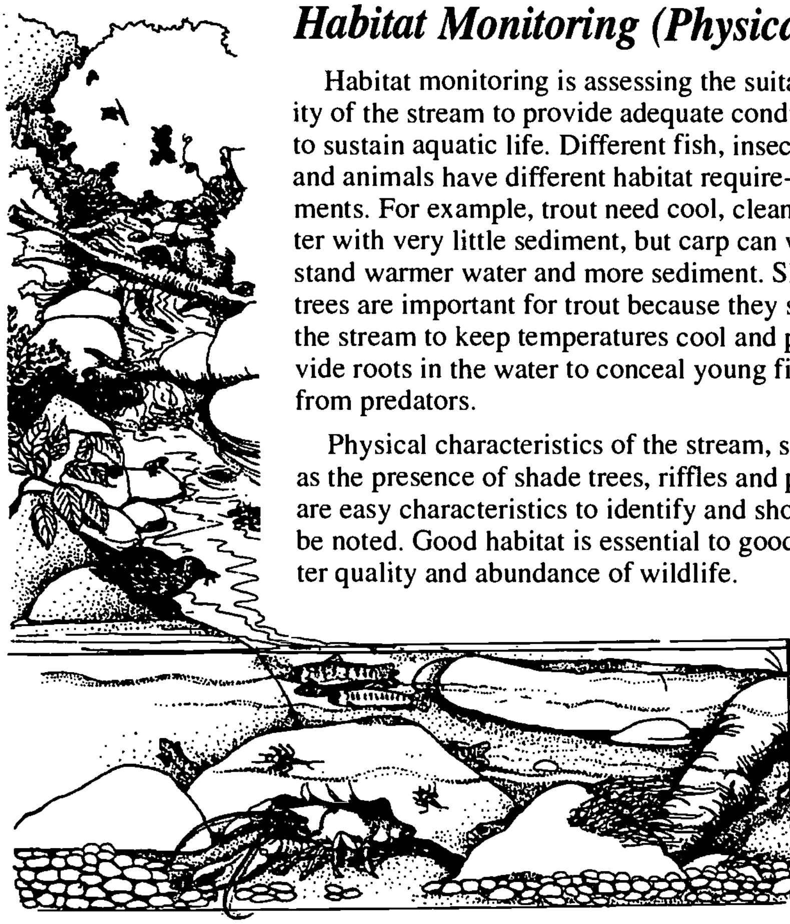
Land uses in the watershed also must be considered when determining chemical and habitat quality. For example, if a farmer removes all trees along a stream to plant corn, there will be less shade for the stream and possibly greater runoff of harmful agricultural chemicals.

Monitoring Water Quality

Monitoring water quality can be simple or complex depending on monitoring methods chosen, the frequency of monitoring and the time involved. For example, an in-depth study can be conducted in which a great deal is learned about a particular stream or stream section, or a more general study can be done to determine a few values of several different streams. The amount of research and monitoring conducted depends on the goals of the project.

Volunteers should decide on a monitoring purpose or objective, mainly the monitoring goal, such as collection of high quality data or for educational purposes only. For example, if the goal is to present the data to a city or county planning board or to make valid conclusions about a stream, it is important to follow the instructions for chemical and biological monitoring exactly. If volunteers have sloppy techniques when using chemistry kits, their data will not be valid. If stream organisms are not properly identified, the results will be incorrect.

Some states have volunteer monitoring programs that accept water data from volunteers. If volunteers want to generate useable data, they should carefully practice their techniques and test their skills periodically. Volunteers can help provide quality assurance for data collection by watching other volunteers' techniques and inspecting final survey results before they are submitting to state agencies.



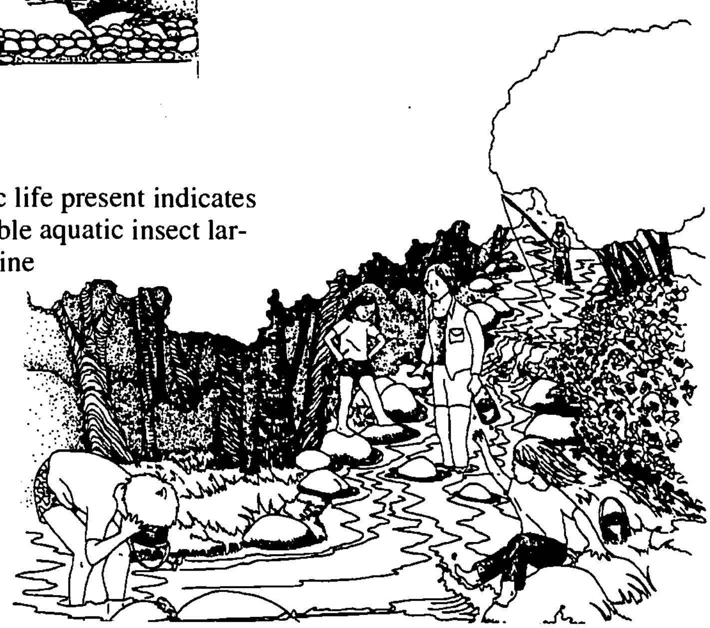
Habitat Monitoring (Physical)

Habitat monitoring is assessing the suitability of the stream to provide adequate conditions to sustain aquatic life. Different fish, insects and animals have different habitat requirements. For example, trout need cool, clean water with very little sediment, but carp can withstand warmer water and more sediment. Shade trees are important for trout because they shade the stream to keep temperatures cool and provide roots in the water to conceal young fish from predators.

Physical characteristics of the stream, such as the presence of shade trees, riffles and pools, are easy characteristics to identify and should be noted. Good habitat is essential to good water quality and abundance of wildlife.

Biological Monitoring

Stream biology is important because the aquatic life present indicates stream health, and by studying populations of visible aquatic insect larvae, known as macroinvertebrates you can determine the health of a stream . The word "macroinvertebrates" refers to large (macro) organisms that can be easily seen without a microscope and have no backbone (invertebrate). Macroinvertebrates have varying sensitivity to pollution. One assesment technique charts the numbers and kinds of organisms found,then streams are classified as excellent, good, fair or poor quality. Biological monitoring indicates stream health by the presence or absence of different kinds of macroinvertebrates.



Recording fish populations is another method of determining water quality, because fish species have different pollution tolerances. For example, trout need oxygen levels of at least 7.0 mg/l and are considered intolerant of pollution. Carp, on the other hand, can withstand lower levels of oxygen and are very pollution tolerant. Fish such as carp can accumulate toxins in their flesh. Thus, even though a fish looks healthy, it may contain toxic chemicals at levels that are hazardous to humans who consume the fish. Half of the states in the United States have published advisories against eating certain fish species caught in certain rivers, lakes, bays and reservoirs. However, because fish are mobile, they are not the only indicators of water quality at a particular location.

Macroinvertebrates, on the other hand, complete the larval stages of their life cycle within a few meters of the streambottom. Although macroinvertebrates may float a few feet downstream at night (a process called drift) they are generally stable in population within several yards and are not as mobile as fish. Because they are so stable, macroinvertebrates can indicate water quality and land use effects on the stream at the specific monitoring location.

Algae are another measure of water quality. Excessive algae covering most rock surfaces in riffle areas indicate nutrient pollution. High nutrient levels in the water from land runoff and sewage can cause excessive growth of algae, depleting the stream's oxygen supply when it breaks down and decomposes. Excessive algae also blocks light to underwater plants and invades the macroinvertebrates' habitat.

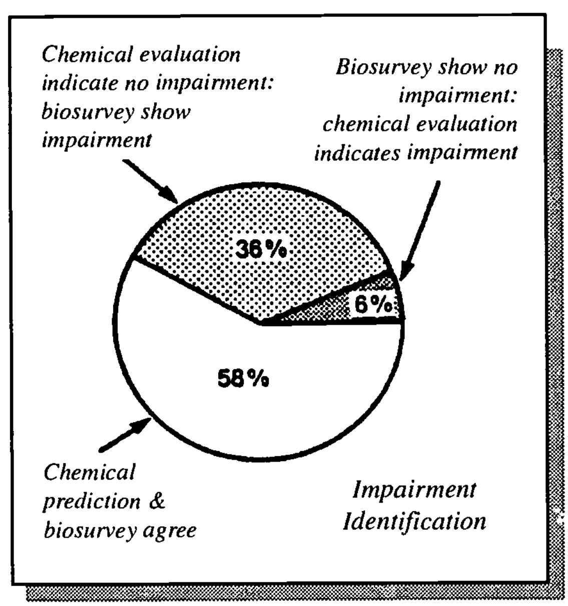
The type of algae present also indicates relative water quality since algae types vary in pollution tolerances and nutrient (ie. nitrates and phosphates) needs for growth. For instance, Cladophora glomerata is a clean water indicator, but Oscillatoria indicate polluted water. Algae identification techniques are useful, but are beyond the scope of this manual.

Aquatic plants, often referred to as submerged aquatic vegetation (SAV), also can be monitored as water quality indicators. Aquatic plants are important to the stream ecosystem by producing oxygen for the stream during photosynthesis and providing habitat and food for fish. For example, duckweed is a free-floating aquatic plant often found in good quality water.

Chemical Water Monitoring

Chemical monitoring also can be conducted by volunteers. Easy-to-use chemical monitoring kits that include parameters, such as dissolved oxygen, pH and hardness, can be obtained through the Hach or LaMotte companies. However, sophisticated monitoring is usually required to determine the presence of toxics and heavy metals. Analytic instrumentation and a controlled laboratory setting usually are required. Thus, the scope of chemical monitoring may be limited by cost or technical requirements.

In addition, measuring water chemistry in a stream will indicate the chemical makeup of the water at the particular moment the water is sampled. Dissolved oxygen rates differ depending on location in the water body, the time of day and temperature of the water. Thus, a range of different values could be obtained depending on the time of testing and sampling location.



Chemical monitoring will not always indicate the presence of water pollution. A 1988 study done by the Ohio Environmental Protection Agency indicated that the presence of a water pollution impairment in a stream was not detected 36 percent of the time using chemical monitoring alone. This means chemical monitoring showed impairment in only 64 percent of the cases in which the stream was polluted. However, using biological surveys indicated the presence of an impairment problem 94 percent of the time. Six percent of the time only chemical monitoring was able to show impairment. According to the 1990 EPA publication, "Biological Criteria: National Program Guidance for Surface Water", biological monitoring can identify impairments from contamination caused by sediments, unknown or unregulated chemicals, nonchemical impacts and altered physical habitat. Biological monitoring also can detect impacts from cumulative pollution or other impacts that periodic chemical sampling is unlikely to detect.

> "... the presence of a water pollution impairment in a stream was not detected 36 percent of the time using chemical monitoring alone."

To conduct chemical monitoring, equipment is needed from either Hach, LaMotte or other suitable companies to conduct the tests. These companies are recommended because they provide simple kits that can be used by nonscientists. Chemical kits may be purchased or borrowed, see your Master Water Steward coordinator for further information. Because the instructions for performing the tests vary depending on the chemistry kit, instructions for conducting chemical monitoring are not included in this manual.

Ideally, volunteers can measure physical, biological and chemical aspects of rivers or streams to gather a complete picture of the water quality. The stream survey form found at the end of this chapter includes spaces to record chemical test results, habitat characteristics and stream biology.

Stream Quality Survey Instructions

Stream health can be assessed by stream macroinvertebrates, organisms such as insects and crayfish large enough to be seen by the unaided eye. Many stream dwelling organisms are sensitive to changes in water quality, and their presence or absence can serve as an indicator of environmental conditions. Macroinvertebrates are easy to find. By following the technique below and filling out the Stream Survey, the stream's water quality can be diagnosed. Before choosing a site to monitor you should follow these rules:

Before monitoring:

1. Check with state and county agencies to make sure the area is not a survey area used by government agencies (over-monitoring may harm the stream).
2. Always contact local landowners and obtain written permission before monitoring to avoid trespassing. Ask for permission to cross private land. Most landowners will give permission for the study and may even want to help you conduct your survey.
3. Make sure that someone knows the date, time, and location of the monitoring so in case of injury, someone will realize you are missing or late in returning. Monitoring with a partner or group is best so someone can go for help in an emergency.
4. Make sure to know the phone number and location of the nearest medical center to the monitoring site and the location of the nearest phone. Know local emergency numbers from memory (i.e. 911, sheriff or fire department).
5. Pack a first aid kit

Rules to monitor by:

1) Never monitor when the stream is at flood stage or is flowing much swifter than normal. It is better to delay monitoring than to risk life or serious injury.
2) While monitoring, keep hands away from eye and mouth areas. Always wash with soap and water after monitoring. Never eat during or after monitoring without washing first.
3) If the water appears to be severely polluted or is posted as unsafe for human contact, (strong smell of sewage or chemicals, unusual colors, lots of dead fish) you may decide not to monitor, or you should at least take the following precautions:
   - Wear boots high enough to avoid water coming in contact with your skin.
   - Wear rubber gloves such as dishwashing gloves or rubber gloves which extend to the shoulders (available at most automotive supply stores). Surgical gloves will not work. They can be easily punctured by snags or sharp objects, and are not long enough to protect your arms.
   - Wear a protective covering for your mouth such as a painter's mask easily purchased at most drugstores or pain stores. Breathing in vapors from sewage-contaminated water can cause illness.
   - Report any problems or suspicious activities to state water regulatory agency.
4) Do not monitor if a large oil or other toxic spill occurs. Report any spills to the local authorities, such as police and fire departments. Spills should also be reported to the EPA , Department of Natural Resources, and the local Soil and Water Conservation District.

Monitoring should be conducted at the same station (location) each time you sample during the year. If monitoring several stations on a stream, make sure the stations are spaced no closer than one quarter mile. If the stations are spaced more closely, the monitoring activity may become the main impact to water quality. For example, to monitor a one mile segment of a stream, there should be a maximum of four monitoring locations. Be sure to revisit the same exact station each time so the results will be comparable over time.

Carefully record the monitoring station location on the Steam Survey form. Include roads, bridges and significant landmarks when noting the monitoring location. Locating and recording the station on a topographic map, with longitute and latitude coordinates, allows the station to be located from anywhere in the world and allowing for easy descriptions to government officials.

If monitoring more than one station, begin monitoring downstream and move upstream. This will prevent macroinvertebrates disturbed by the first test from washing downstream and getting caught in the net a second time. Each station survey should record only the organisms present at that particular location and not those disturbed (and counted!) in previous tests. In addition, three separate samples should be taken. The average score should be recorded. This will ensure that your sample was truly representative of the organisms present in the stream.

Monitoring should be conducted four to six times per year at each station you are monitoring. Monitor once each in the spring, summer, winter, and fall and then at two other times. Good "other times" include after floods, oil spills, or other events that could potentially impact water quality. These extra surveys, when compared to your regular seasonal surveys, will help to determine water quality impacts. Monitoring once each season will accurately record the yearly cycle of life in the stream. Less frequent monitoring, while still useful, will not allow for volunteers, biologists, or other persons interested in water quality to get the complete "full picture" of life in a stream.

When scheduling monitoring events, remember excessive monitoring can become the major threat to stream health. In general, monitoring stations should have four to six weeks to "recover" from a monitoring event. It is crucial to the integrity of the data that to not over monitor stations. There is some flexibility in this rule. For example, if an oil spill occurs, monitoring may be necessary even if the six surveys have been completed for the year. The data collected might be the only data available on the immediate impacts of the spill.

Rocky Bottom Sampling Techniques

Catching the Macroinvertebrates

Required equipment includes a kick seine (a fine mesh net with a supporting pole on each side) or a window screen with no holes, tweezers, a shallow plastic container, several jars or an ice cube tray for collecting, a microscope or magnifying glass and a macroinvertebrate identification sheet and survey forms.

1. Selecting a site: Select a riffle typical of the stream, that is, a shallow fast-moving area with a depth of 3-12 inches and cobble-sized stones (2-10 inches) or larger.
2. Positioning the net: Place the net at the downstream edge of the riffle. Be sure that the bottom of the seine or screen fits tightly against the stream bed so that no insects escape under the net. Rocks can be used to secure the net against the stream bottom. Also, don't allow any water to flow over the top of the net.
3. Collecting the sample: Monitor the stream bed for a distance of three feet upstream of the kick-seine. Firmly and thoroughly rub your hands over all rock surfaces (top, sides, and bottom) to dislodge any attached insects. Carefully place any large rocks outside of the three foot sampling area after rubbing off any macroinvertebrates. Stir up the bed with hands and feet until the entire three foot square area has been worked over. All detached insects will be carried into the net. Then for at least 60 seconds, kick the stream bed with a sideways shuffling motion towards the net. Disturb the first few inches of sediment to dislodge burrowing organisms.

4. Removing the net: When step three is completed, remove the seine with a forward- scooping motion. Hint: Before removing the net, rub any rocks used to anchor the net to the stream bottom and remove the rocks from the bottom. Firmly grab the bottom of the net so that the sample does not fall from the net. The idea is to remove the net without allowing any insects to be washed under, washed from the net surface, or fall off the net.
5. Picking the sample: Place net on a flat, well-lit area. Using tweezers or fingers, pick all the insects from the net and place in a collecting container (half full of water). Any creature that moves, even if it looks like a worm, is part of the sample. Look closely, since most insects are only a fraction of an inch long.

Place a white trash bag under the net before picking the sample to catch any tiny critters that crawl through the net. A watering can be used to periodically water the net. Critters will stop moving as the net dries. Occasionally wetting the net will cause the critters to move, making them easier to spot. Watering the net is especially important on hot, dry days.

Sort insects into look-alike groups, to make your identification quicker when recording results on the survey form.

Muddy Bottom Sampling

The Muddy Bottom Sampling Method was written by the Izaak Walton League for use by volunteers involved in sampling streams that do not have rocky bottoms or "riffles", but are instead composed of muddy, silt or sand substrate, overhanging bank vegetation and submerged woody and organic debris. These instructions are based on methods developed by the Mid-Atlantic Working Group of eastern states. This method was created to enable sampling of streams where kick-seining techniques would not yield the best representative sample or allow easy collection from the most productive aquatic habitats. Field testing of this approach has been carried out by scientists in several east coast and southern states. While the collection techniques are appropriate for muddy-bottom and slow-flowing waters, it should be noted that this approach is relatively new and may be modified over time by MWS staff as further research is conducted.

Catching the Macroinvertebrates

Monitoring is conducted using an aquatic D-Frame net with a four foot handle. The dip net is used to provide ease of sampling when working in streams and rivers with muddy, sandy or soft bottoms in which a wide variety of habitat must be sampled in order to collect many different kinds of organisms.

Equipment:

- One D-Frame aquatic dip net with mesh of 1/32 inch
- White enamel or plastic shallow pan
- Macroinvertebrate identification sheet and survey forms
- Specimen jars for samples needing additional identification
- Fahrenheit thermometer
- Two small magnifier boxes to aid in specimen identification
- Magnifying glass

- One screen bottom bucket with a mesh of 1/32 inch for washing specimens (optional)
- Tweezers (optional)
- Ice cube trays for sorting organisms (optional)
- Clipboard to write on (optional)

Before monitoring, become familiar with the four main habitats of muddy bottom streams: steep banks/vegetated margins, silty bottom with organic matter, woody debris with organic matter, and sand/rock/gravel/substrate. Look for these habitats in the section of stream in an area up to 50 yards upstream from the monitoring station.

To provide for accuracy of collection and comparability of data from one station to another, scoop the stream a total of 20 times. Each scoop involves a forward motion of one foot. The D-frame net is one foot wide. Thus, one scoop equals one square foot. A total area of 20 square feet is sampled at each monitoring station.

Identify the location of the four main habitat types, and collect the recommended number of scoops from each habitat. The following are the best scenario recommendations. Follow them as closely as possible, no one particular monitoring site will always contain all four main habitat types in precise proportions. Each sample should consist of a maximum of 20 scoops (20 square feet). Record the number of scoops by habitat type on the stream survey form.

- 10 scoops from steep banks/vegetated margins
- 3 scoops from silty bottom with organic matter
- 4 scoops from woody debris with organic matter
- 3 scoops from sand/rock/gravel/substrate.

Following are simple descriptions of the habitat types and collection techniques for each habitat:

Steep banks/vegetated margins

This habitat is the area along the bank and the edge of the waterbody consisting of overhanging bank vegetation, plants living along the shoreline, and submerged root mats. Vegetated margins may be home to a diverse assemblage of dragonflies, damselflies, and other organisms. Move the dipnet in a bottom-to-surface motion, jabbing at the bank to loosen organisms. Each scoop of the net should cover one foot of submerged area.

Silty bottom with organic matter

Silty substrates with organic matter can be found where the water is slow-moving and areas with overhanging vegetation or other sources of organic matter. These silty substrates harbor burrowing organisms such as dragonflies or burrowing mayflies. Samples are collected by moving the net forward (upstream) with a jabbing motion to dislodge the first few inches or organic layer.

Woody debris with organic matter

Woody debris consists of dead or living trees, roots, limbs, sticks, cypress knees and other submerged organic matter. Woody debris are very important habitat in slow-moving rivers and streams. The wood helps trap organic particles that serve as a food source for the organisms and provides shelter from predators, such as fish.

To sample woody debris, approach the area from downstream and hold the net under the section of wood , such as a submerged log. Rub the surface of the log for a total surface area of one foot. It is also good to dislodge some of the bark as organisms may be hiding underneath. Also collect sticks, leaf litter, and rub roots attached to submerged logs. Be sure to thoroughly examine any small sticks collected with the net before discarding them. There may be caddisflies, stoneflies, riffle beetles, and midges attached to the bark.

Sand/rock/gravel/substrate

In slow moving streams, bottoms are generally composed of only sand or mud because the velocity of the water is not fast enough to transport large rocks. Large rocks and gravel bars located at a bend in the river provide the most productive habitat. An area of the stream where the water is bubbling over the rocks is called the riffle. The bottom can be sampled by moving the net forward (upstream) with a jabbing motion to dislodge the first few inches of gravel, sand, or rocks. Gently wash the gravel in the screen bottom bucket and then discard gravel in the river.

With large rocks (greater than two inches diameter) kick the bottom upstream of the net to dislodge any borrowing organisms. Remember to disturb only one foot upstream of the net for each collection.

For each sample sweep the mesh bottom of the D-Frame net back and forth through the water (not allowing water to run over the top of the net) to rinse fine silt from the net. This will avoid a large amount of sediment and silt from collecting in the pan and clouding the sample.

Sorting the sample

After collecting samples, dump the net into a shallow white pan filled with a few inches of river water. Dump the debris into the pan of water after every three scoops to avoid clogging the net. Dumping the net periodically will also prevent having to sort a great deal of debris all at once. Collect organisms from the pan and place like organisms in ice cube trays for identification.

Sorting insects into look-alike groups will make identification quicker when recording results on the survey form. Use a plastic ice cube trays to do this. For example, put all organisms with legs in one section and all organisms with no legs in another section, etc.

Identification

Once organisms are collected, they are sorted and identified using the Macroinvertebrate Identification Sheet. Not all organisms found in a stream are listed on the Macroinvertebrate Identification Sheet. For instance, macroinvertebrates such as whirligig beetles, water striders, and predaceous diving beetles are not included on the survey form. They are surface breathers and do not provide any indication of the dissolved oxygen content of the water.

Specimens can be put into magnifier boxes to ease identification. Use characteristics such as body shape, number of legs, tails and antennae, size, color, swimming movement, and gill locations to identify organisms. When using the bug sheet, remember to read the descriptions for each organism. Also remember that the lines on the bug sheet indicate the sizes of the organisms. However, a young macroinvertebrate that has just hatched and has not yet reached full size, it may be smaller than indicated on the bug sheet.

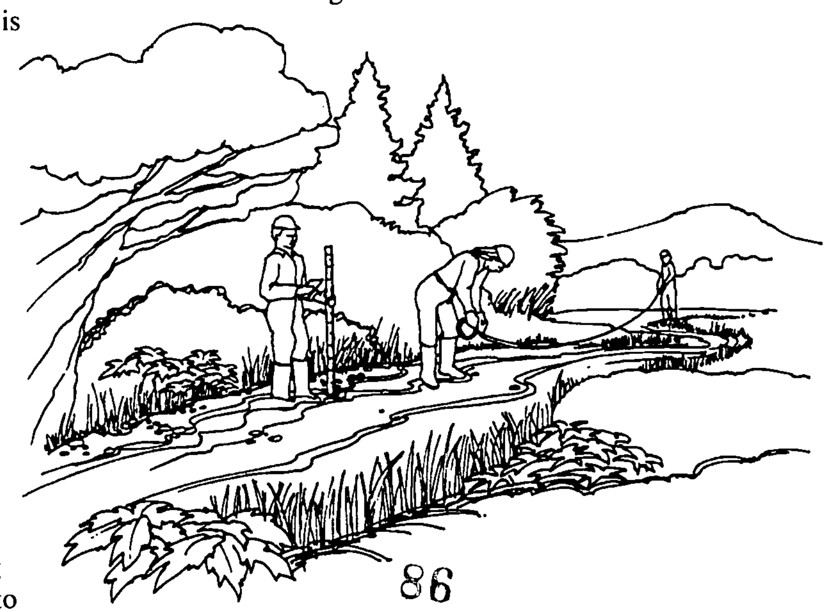
To identify the organisms use body shape, size and other characteristics (number of legs and tails), since the same family can vary in size and color (Refer to the macroinvertebrate identification sheet). Volunteers can also ask experienced volunteers and local professionals for help.

Ask the following questions to identify an organism:

1) How large is the organism?
2) Is the body long and slender, round, or curved?
3) Does the organisms have any tails? How many?
4) Does the organism have any antennae?
5) Does the organism have legs? How many? Where?
6) Is the body smooth and all one section or is it segmented (two or more distinct sections)?
7) Does the organism have any gills (fluffy or plate-like appendages)?
8) Where are the gills located? Sides, back, underside, under its legs?
9) Does it have pinching jaws like a beetle larvae?
10) Are any legs or antennae missing because they were broken off in the net?
11) What color is the organism?
12) Does the organism swim under water or remain on the surface?

After identifying the organisms, record the results on the Stream Quality Survey Form. Specimens are returned to the stream after sampling is completed. The survey also includes information relating to habitat and physical parameters of the stream. Tabulate results to determine the water quality using the instructions on the survey form. Use letters to indicate the number of each type of organisms (A = 1 - 9, B = 10 - 99, C = 100 or more). Add the number of letters in a column and multiply by the index value at the bottom of the column. Add the subtotal for each column to arrive at the final stream rating.

Notice that the letter (A, B or C) does not affect the final rating score of excellent, good, fair or poor. This is because the survey is based primarily on diversity, not the individual organisms found. The letters are valuable, however, because they document changes in populations over time. For instance, the spring survey has only C's in the pollution sensitive column and only A's in the pollution tolerant category. In the next survey, only A's in the sensitive range and C's in the tolerant range are found. The conclusion might be made that the overall water quality was becoming poorer because populations of the tolerant organisms are increasing (A to C) while those in the sensitive category are decreasing (C to A). Monitor for an entire year to



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Explanation of Survey Form Questions

The stream survey form asks a number of questions about the land and vegetation surrounding the stream. These questions will help characterize the quality of stream habitat and its ability to support a healthy population of stream organisms. The land use information will also paint a picture of the stream for other people who might review the survey form. Guidelines for correctly answering these questions are given below. Questions where the answer is obvious are not explained.

Record answers based on the area that is upstream from the monitoring site. Generally, always record the data for the area that can be seen. For land use information, include land uses for one mile upstream from the site or the section of stream being monitored (ie. one-quarter mile).

Surface Water Appearance: You can check more than one of the colors listed, but not all of them. Note if strange colors are present throughout the stream or only in one section, such as immediately below a discharge pipe or highway runoff culvert.

Stream Bed Deposits: Record the general overall appearance of the stream bottom. If the stream bed does not have any apparent coating, note it as other and write in "normal".

Algae: Algae feels slimy and you will notice it while rubbing rocks during monitoring. A great deal of algae may indicate a nutrient enrichment problem. Sometimes there is more algae in the Spring after snowmelt releases extra nutrients to the stream. However, note the amount of algae present in the stream to make sure it is not increasing over time.

Questions about stream banks and vegetation: Remember to look at both sides of the stream's banks. When questions ask for a percentage, use the information for both the left and right bank and combine values. For instance, if one side of the bank is completely bare from erosion while the other side is well-vegetated, record the percent of bank coverage as 50% (one half is covered and the other is not).

When recording total percentages of shrubs, grasses, and trees, look at both sides of the bank. However, if one side has artificial structures such as rock rip rap or concrete you will have to account for such ground cover. For instance, if the left side of the bank is not vegetated you cannot have more than 50% of shrubs, grasses and trees total when you add those values together.

Bottom composition: This question refers to the 3 x 3 foot area of stream sampled for rocky bottom sampling techniques with a kick-seine net and is best answered before disturbing the site. You do not have to fill out this question when using the muddy bottom sampling technique. Simply check off the number of scoops taken from each of the four types of muddy bottom stream habitats found in the next question on the survey form (muddy bottom only).

The organisms collected are most abundant in riffles composed of predominately cobble-sized stones (>70% cobbles is a good riffle habitat). Start with the largest rocks first when recording bed composition. If you don't have any boulders (rocks > 10 inches), write 0%. Record the amount of cobble-sized stones and continue until the percentages equal 100%. A typical riffle in a medium gradient stream might be recorded as 5% boulders, 65% cobbles, 15% gravel, 10% sand and 5% silt. Ranges are given on the survey form for the rock sizes. For the smaller rock sizes, remember that silt feels like talcum powder and sand feels gritty. If riffle had 40% silt, 10% gravel and no cobbles, either find another station to monitor or switch to the muddy bottom sampling technique.

get a clear picture of a stream and consult with a Extension Agent or state biologists from Ohio Department of Natural Resources or Ohio Environmental Protection Agency to discuss the findings.

Studying the Find

Check another spot about a quarter mile upstream. If there is a decrease in water quality, check the stream for new discharge pipes, evidence of erosion, farm runoff, and other possible sources of stream pollution.

Macroinvertebrate Count and Water Quality

If you find:	Look for:
Little variety of insects, with great of each kind	Water overly enriched with organic matter
Only one or two kinds of insects in great abundance	Severe organic pollution
A variety of insects, but only a few of each kind, or no insects, but the stream appears clean	Toxic pollution

Stream Problems and Their Impact on Stream Organisms

1. *Physical Problems* may include excessive sediment from erosion, street runoff, or a discharge pipe. Sediment may create poor riffle characteristics; contribute to excessive flooding, reduce flow, change temperature, and smother aquatic life. The result is usually a reduction in the number of all animals in the study area.
2. *Organic Pollution* is from excessive human or livestock wastes or high nutrient enrichment from farm or yard runoff. The result is usually a reduction in the number of different kinds of insects and an increase of collectors/scrapers (such as the caddisflies).
3. *Toxic Pollution* includes chemical pollutants such as chlorine, acids, metals, pesticides, and oil. The result is usually a reduction in the number of insects.

When considering land use as the controlling factor in stream quality, look not just at the area visible from the stream, but at all the land draining to the stream - the watershed. If the stream drains an intensely developed area, do not be surprised if no organisms are found. Should this be the case, consider visiting a forested or agricultural tributary or ditch for a sampling comparison. It may be surprising the different types of organisms found.

Pollution sources causing poor or fair stream quality include sewage treatment plants, industries, construction sites, sewer overflows, landfills, and mining operations. A pollution source can be identified by sampling the stream at one-quarter mile intervals upstream from the initial sampling point (where a pollution impact is suspected) until quality improves. The pollution sources should be located somewhere between the point where degraded conditions were first found and the point where water quality improves.

Map of sampling area: This box is space provided to draw a basic sketch of the sampling area. Include pool - riffle areas, hydraulic structures (i.e. bridges, dams), areas of physical impact point sources, graveling bars, islands etc. Describe banks, width of riparian zone and adjacent land uses. Show dwellings, businesses, roadways and inputs such as tributaries and culverts. Also show direction stream flow and a north arrow. This information will allow others to return to exact locations for future monitoring or direct water quality professionals to suspected problems.

Now, with this brief introduction to monitoring, you are ready to begin!

Master Watershed Stewards

Stream Quality Survey

Name:____________________

Date:____________________

Stream:____________________

Station #____________________

# of participants: _______________

Location ____________________ County _______________ Township/city ____________________

Weather conditions (last 72 hours): ____

Weather (current) ❑ Clear ❑ Overcast ❑ Rain Other ________________________ Air Temp ________ °F

Average stream width ft _______ at site Average stream depth ft _______ at site Water Temp ________ °F

Surface Water Appearance:

- ❑ clear
- ❑ clear, but tea-colored
- ❑ colored sheen (oily)
- ❑ foamy
- ❑ milky
- ❑ muddy
- ❑ black
- ❑ grey
- ❑ other ____________

Stream Bed Deposit (bottom):

- ❑ grey
- ❑ orange/red
- ❑ yellow
- ❑ black
- ❑ brown
- ❑ silt
- ❑ sand
- ❑ other ______

Odor:

- ❑ rotten eggs
- ❑ musky
- ❑ oil
- ❑ chlorine
- ❑ sewage
- ❑ other _____
- ❑ none

Stability of stream bed:

bed sinks beneath your feet in:

- ❑ no spots
- ❑ a few spots
- ❑ many spots

Stream Flow rate:

- ❑ High
- ❑ Low
- ❑ Normal
- ❑ Negligible

Algae color:

- ❑ light green
- ❑ dark green
- ❑ brown coated
- ❑ matted on stream bed
- ❑ hairy

Algae located:

- ❑ everywhere
- ❑ in spots
- ❑ attached
- ❑ floating
- ❑ other _________

Chemical Water Quality Test Results

Dissolved Oxygen	_________	Phosphates	_________
pH	_________	Nitrates	_________
Other	_________	Other	_________

Stream channel shade

- ❑ >80% excellent
- ❑ 50%-80% high
- ❑ 20%-49% moderate
- ❑ <20% almost none

Stream bank composition (= 100%):

- ______ % trees
- ______ % shrubs
- ______ % grass
- ______ % bare soil
- ______ % rocks
- ______ % other __________

Stream bank erosion:

- ❑ >80% severe
- ❑ 50%-80% high
- ❑ 20%-49% moderate
- ❑ <20% slight

Bottom composition (=100%):

- ____ % silt (mud)
- ____ % sand (1/16"-1/4" grains)
- ____ % gravel (1/4"-2" stones)
- ____ % cobbles (2"-10" stones)
- ____ % boulders (>10" stones)

MUDDY BOTTOM ONLY: Record the number of scoops taken from each habitat type.

- ❑ Steep bank/vegetated margin _______________
- ❑ Rock/gravel/sand substrates ____________________
- ❑ Woody Debris with organic matter ____________
- ❑ Silty bottom with organic matter _______________

Land Uses ❑ Crops ❑ Pasture/Grazing ❑ Urban ❑ wooded ❑ Other____________

Are there any discharge pipes? ❑ no ❑ yes how many? _______

What Type of pipes are they? ❑ runoff (field or storm water) ❑ sewage treatment ❑ industrial: type of industry? ____________________

Map of Sampling Area . . .

List pool - Riffle Areas, Hydraulic structures (i.e. bridges dams), areas of physical impact, point sources, gravel bars, islands, etc. Describe banks, width of riparian zone and adjacent land uses. Show dwellings, businesses, roadways and tributaries, direction of stream flow and a north arrow (N).

MACROINVERTEBRATE COUNT

Use the stream monitoring instructions to conduct a macroinvertebrate count. Use letter codes (A = 1-9, B = 10-99, C = 100 or more) to record the numbers of organisms found. Add up the number of letters in each column and multiply by the indicated index value. The following columns are divided based on the organism's sensitivity to pollution.

SENSITIVE	SOMEWHAT SENSITIVE	TOLERANT
_____ caddisfly larvae	_____ beetle larvae	_____ aquatic worms
_____ gilled snails	_____ clams	_____ blackfly larvae
_____ hellgrammite	_____ crane fly larvae	_____ leeches
_____ mayfly nymphs	_____ crayfish	_____ midge larvae
_____ riffle beetle adult	_____ damselfly larvae	_____ pouch snails
_____ stonefly nymphs	_____ dragonfly nymphs	
_____ water penny larvae	_____ scuds	
	_____ sowbugs	
_____ # letters times 3 = _____ index value	_____ # letters times 2 = _____ index value	_____ # letters times 1 = _____ index value

Now add together the three index values from each column for your total index value. Total index value = ________

Compare this total index value to the following ranges of numbers to determine the water quality of your stream. Good water quality is indicated by a variety of different kinds of organisms, with no one kind making up the majority of the sample. Although the A, B, and C ratings do not contribute to the water quality rating, keep track of them to see how your macroinvertebrate populations change over time.

WATER QUALITY RATING

_____ Excellent (>22) _____ Good (17-22) _____ Fair (11-16) _____ Poor (<11)

Wetlands

The Importance of Being Wet

Wetlands: The Importance of Being Wet

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Introduction

A Heritage of Ignorance

A century ago, the president of the American Health Association expressed the prevailing view about wetlands: "Although individuals may neglect swamp lands, or find their reclamation and drainage too expensive, the state cannot afford to be indifferent to their continuance, because they check production, limit populations, and reduce the standard of vigor and health."

People filled, drained and plowed wetlands, destroying insects and animals that used wetlands for habitat. Wildlife either died out or moved away as wet habitats were destroyed. As over 90% of Ohio's wetlands have been destroyed the ecology and landscape of the state has been changed forever.

Better sanitation, and an understanding of diseases, have brought malaria and yellow fever under control in most developed countries. But centuries of fears, phobias, and misunderstandings have adversely colored the public's perception of wetlands. Only during the last few decades has the science of ecology given us a greater awareness of the true value of natural ecosystems and their many functions.

Wetlands, as the name implies, lie between what is clearly wet and dry land. Where to draw the line between waterways and uplands has caused considerable controversy as the public seeks to protect its right to clean water and landowners fight to preserve their private property rights. Public perceptions about the meaning of the term "wetland," and a multitude of governmental programs that deal with floodplain management, water quality, and allocation of water resources add to the confusion.

Because of the unique location in the landscape, marshes, swamps, and other wetlands play a vital role in water quality management. The ability of many types of wetlands to trap pollutants in runoff and flood waters may provide an essential link to keeping our water clean. Wetlands are also appreciated for their aesthetic, recreational, habitat, and educational values.

Whether through indifference, exploitation, or misguided views, we have damaged or destroyed most of Ohio's wetlands. Even now, in spite

of our new understanding of the ecological importance of wetlands, the degradation continues. We are still losing hundreds of acres of wetlands a year.

Ohio's Wetlands Loss

Ohio has suffered more destruction than most states. Since European settlement of the state, Ohio has lost over 90% of the wetlands. This statistic distinguishes Ohio as second worst in the nation for wetlands loss, next only to California. It is estimated that in the 1780s Ohio had roughly 9,773,000 acres of wetland which translates to 37% of the state. Recent estimates puts the acreage of wetlands in Ohio at a mere 482,800 acres, only 1.8% of Ohio.

Ohio has lost more than 90 percent of wetland acreage.

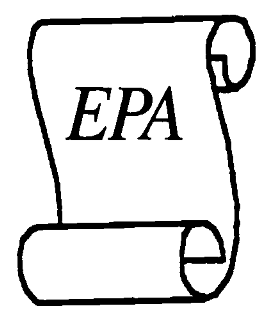
Fresh marshes and wet prairies, such as the Scioto and Hog Creek marshes of Hardin County, once covered 25,000 acres or 39 square miles. Bottomland hardwood swamps, which are nearly gone from the current Ohio landscape, are estimated to have occupied 2 million acres. The Great Black Swamp of Northwestern Ohio, since drained for agricultural, was 120 miles in length and averaged 40 miles in width, which is about the size of Connecticut.

What Is a Wetland?

The term wetland encompasses virtually all areas of land that are flooded or wet during at least part of the year. This includes river bottoms, beaches, rocky shores and a host of other environments. Wetlands are places where land and water meet to create special environments.

In Ohio, the definition from the federal Clean Water Act was officially adopted in the state code:

Wetlands are those areas that are inundated or saturated by surface or groundwater 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, but are not limited to swamps, marshes, bogs and similar areas.



Wetlands vary considerably in their location, size, characteristics, both presently and over time. They can be found from mountains to the sea in depressions, flat areas, on slopes, by surface waters, and in isolated spots. They may be large or small. They take many shapes: complex, regularly shaped or convoluted. Wetlands can be permanently flooded, flooded daily, or only occasionally.

Over time, wetlands can vary with the season, with the water cycle, in water depth and amount and type of vegetation. Soils can alternate between dry and saturated. Natural and human processes can alter wetlands. In recent years, however, human activity has dramatically affected the number and quality of our wetland resources.

Field Definition of Wetlands

Wetland scientists can visually confirm the presence of a wetland by going through a checklist. The U.S. Fish and Wildlife Service publishes the official federal handbook used to delineate wetlands, federal Manual for Identifying and Delineating Jurisdictional Wetlands. In lay language, the following describes characteristics of a wetland.

Topography

The shape of the land is largely responsible for the formation of wetlands. Vegetated wetlands occur:

- In the shallow waters of lakes and rivers (e.g., water lily patches in a sheltered lake bay).
- Along low shores and banks of rivers, streams, lakes and estuaries (e.g., forested wetlands in a floodplain, a saltwater wetland flooded at high tide).
- In depressions in the landscape where surface water tends to collect (e.g., a wet meadow in the middle of agricultural land).
- Where groundwater meets an impervious layer that intersects the surface (e.g., where water seeps out of the side of a bluff).

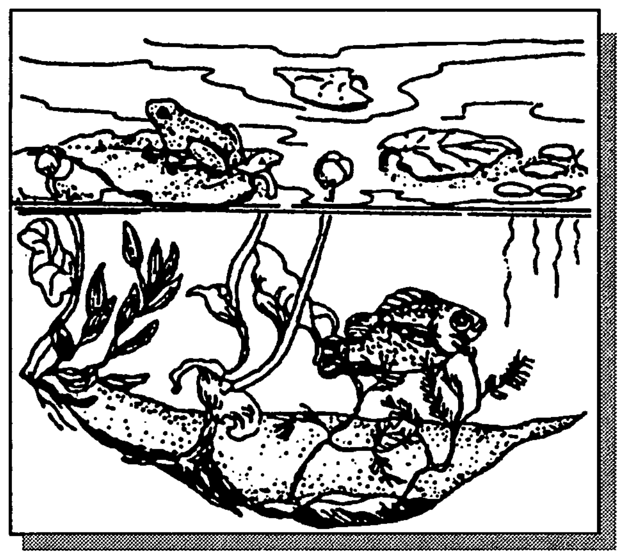
Water

While the shape of the land is conducive to the formation of wetland, there must also be a source of water. Water irrigates wetlands in various ways:

- Continual irrigation by a stream, river or lake.
- Periodic flooding by a stream, river or lake or by high tides.
- Ground water seepage or spring.
- Irrigation of agricultural lands.
- Flowing water widens, becomes shallow, or is restricted and spread out.
- Water moves from a waterbody through the spaces between soil particles.

Water leaves wetlands through:

- Evaporation from surface of the water, soil and plants.
- Flow into streams and other surface waters.
- Percolation into ground water.
- Withdrawal.



Aquatic bed

Plants

Water favors the establishment of certain kinds of plants and therefore wetland areas tend to support vegetation that differs from the vegetation of upland areas. This difference can be extreme or almost negligible.

Nearly 5,000 plant types in the United States may occur in wetlands. These plants are known as *hydrophytic vegetation.* You can usually determine if wetland vegetation is present by knowing a relatively few plant types that commonly occur in your area. In west central Ohio you will likely find wetland plants such as:

sedge, sneezeweed, rose mallow, softstem bulrush, Ohio buckeye, green ash, and eastern cottonwood.

Soil

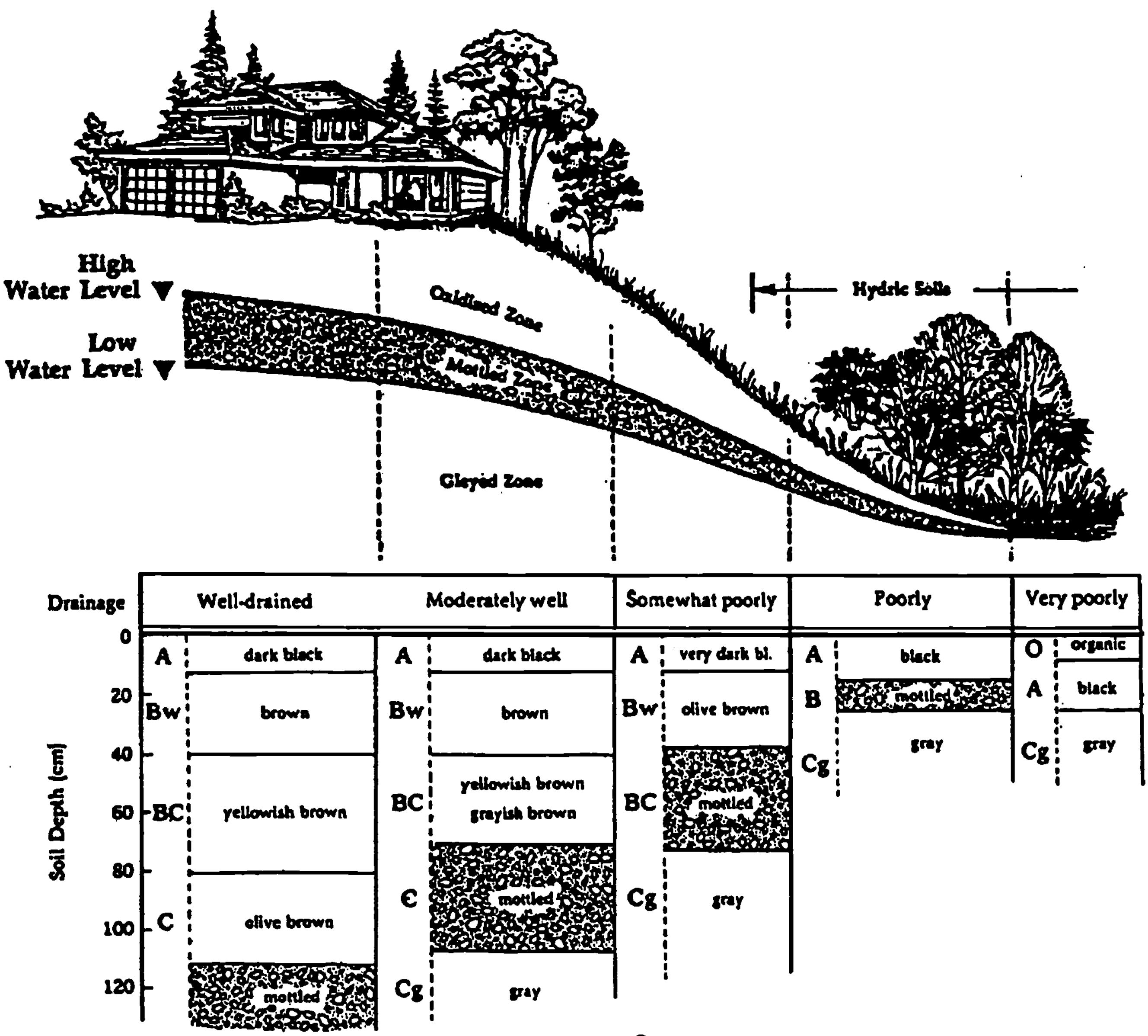
The presence of hydric soils (soils formed by wetland conditions) is a good indicator of wetland conditions. Water makes the soils different.

The water replaces oxygen and the lack of oxygen limits biologic activity. Interpreting soil requires expertise, but the following are general indicators of wetland characteristics:

- There are at least 12 inches of organic soil (peat or muck). If touched, the soil leaves dark stains on fingers. It may also have a slight rotten egg smell.
- The soil at the surface or beneath the organic layer may be sand, silt and/or clay with the following characteristics:

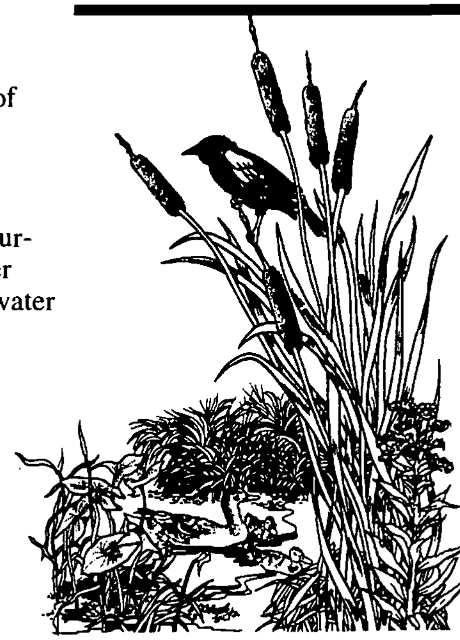
Mottling: spots or blotches of a different color or shade than the background color or shade.

Gleying: the soil appears greasy and is gray (sometimes slightly greenish or blueish) or it may be almost black.



Plants Define Wetland Types

The dominant manner in which plants grow determines the type of vegetated wetland.



Floating Plants

These may be rooted on the bottom but have their leaves on the surface, such as water lilies. They may trail their leaves below the water and be loosely rooted, such as the invasive noxious weed Eurasian water milfoil. They may also be free floating, such as the tiny duckweed.

Emergent plants

These are grasslike plants and other plants with their stems and leaves growing out of the waters, such as cattails. Other emergent plants are bulrushes, sedges, rushes, and certain grasses, such as the noxious reed canary grass and barnyard grass. Emergent plants are those most commonly associated with wetlands. Some live in more than two feet of water while others can easily live in areas that are wet only part of the year.

Shrubs

These wetland plants include shrubs such as silky, gray, and red-osier dogwood, buttonbush, common alder, willow, and elderberry. Hardwood trees less than 15 feet tall are also considered shrubs.

Palustrine forested wetland

Trees

Forested wetlands are dominated by deciduous trees taller than 15 feet. Tree species such as green ash, swamp white oak, pin oak, hackberry, red maple, and silver maple are prevalent. Two frequent characteristics of wetland trees are a swollen base and shallow root system.

Wetland Plant Associations

Plant associations in a wetland are more important than individual species. Some species may dominate in one area and gradually give way to other species, depending on such factors as shade or water level. Many species have overlapping ranges but prefer growing in mutually exclusive conditions. The preferred water regime of plants is especially important in understanding the springtime hydrology of a wetland that is dry during the summer. Percentages of wetland plants present help define wetland boundaries.

Wetland Classifications

Wetlands go by many names: marshes, swamps, bogs, fens, flats and others. While these names have specific scientific meaning, in common usage marsh, swamp and bog are often used interchangeably. Scientists have made several attempts at developing a flexible and comprehensive way to classify wetlands. The most accepted categorizing scheme was developed by Lewis Cowardin for the U.S. Fish and Wildlife Service. It is widely used by wetland scientists and planners for the purpose of identifying and characterizing wetlands.

Cowardin divides wetlands into five major categories based on the type of aquatic environment to which they are connected. Cowardin further divides wetlands by soil type, vegetation, persistence of wet conditions, and other characteristics. By combining all the different categories and wetland characteristics, scientists can identify hundreds of specific wetland types.

You might be able to impress your friends by telling them that a given wetland is a "littoral nonpersistent emergent wetland in the lacustrine system," but most people don't need to know all that to be good wetland stewards. You will be more familiar with the common terms "swamp," "bog," and "marsh," which refer to specific kinds of wetlands, each distinguished by its plants, soils, and water chemistry.

Swamps

This wet area is dominated by woody species. The canopy includes maple, elm, and ash. The periodically wet floor boasts skunk cabbage, march marigold and cardinal flower. Openings in the forest are filled with shrubs such as willows and buttonbush.

Bog and fen

Bog

One of the most interesting of wetland sites, the bog is a relic of the glacial history of the state. The waters are either decidedly acidic or alkaline, creating a unique environment for specific plant species.

In the acid bog, sphagnum moss, sun dew and pitcher plant represent herbaceous species while surrounding shrubs include leatherleaf and highbush-blueberry.

Alkaline bogs or fens also originated during the glacial period and typically occur at the base of glacially deposited mounds of gravel such as kames, eskers, moraines or outwash plains were cold alkaline springs emerge. The difference in peat deposition and corresponding alkalinity dictates different plant communities. Rather than sphagnum peat, fens are based on marl mineral soils. Sedges, rushes and grasses from the bulk of the peat and herbaceous mass of the fen. Shrubby cinquefoil and a variety of colorful wetland wildflowers dominate the slightly drier zones. Surprisingly, some species such as tamarack, poison sumac and sundews may inhabit both the acidic and alkaline bog.

Marshes

Herbaceous plants form the dominant vegetative feature in the marsh. Cattails, water lilies, bladderworts and pickerweed all thrive, the species assemblage determined by the depth of the water.

Wet Meadows

Perhaps the most difficult wetland type to identify, wet meadows are found where water saturates the soil for most of the year, but seldom stands on the soil surface. Also called "sedge meadows" because of the predominance of tussok sedge and other grassy species, these plant communities may grade into wet prairie on slightly drier sites, and marsh on wetter ground.

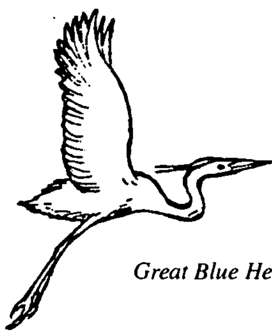
Wet meadow

Major Functions and Values of Wetlands

Wetlands have many important ecological functions and values that have only in recent years begun to be understood and appreciated by the public. Because wetlands were traditionally regarded as places to be drained and filled when necessary to accommodate growth, almost half the nation's wetlands were eliminated for agriculture and other, often beneficial, purposes. The use of wetlands has become a major public policy issue in recent years due to open conflicts between those who want to preserve them and those who wish to convert them to other uses. Only recently has public policy been changed to reflect an appreciation of wetlands as resources having important ecological functions and values. The following discusses some of the most important functions and values attributed to wetlands.

Wildlife

The importance of wetlands to many species of mammals, reptiles, and amphibians is well documented. Some species, including furbearers such as beaver, mink, and muskrat, spend their entire lives within a particular wetland while others, including deer and fish, depend on wetlands during part of the year or part of their life cycle. During times of drought, wetlands play an especially critical role in providing food and water for wildlife. Many species of wildlife that are dependent on wetlands (muskrats for example) are an important part of the aquatic ecosystem and are of considerable economic, social, and aesthetic value. An estimated 50 million people spend nearly $10 billion annually to observe and photograph wetland dependent birds alone.

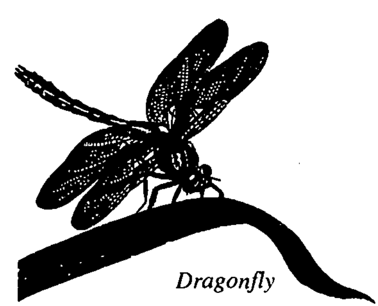


Great Blue Heron

Raccoon

Endangered Species

Because wetlands are often the last place in the landscape that retain natural habitat, they can provide refuge for endangered or threatened plants and animals. Also, the special conditions that are found in bogs, fens, and other rare habitat types support unusual species that cannot survive elsewhere. For these reasons, there is a large percentage of locally or regionally endangered and threatened species found in wetlands.



Dragonfly

There are 114 wildlife species on Ohio's endangered list, sixty percent are wetlands dependent. Wetlands loss is the second leading cause of wildlife endangerment in Ohio. Some of the wetland dependent species found on Ohio's threatened and endangered lists include the woodland jumping mouse, river otter, bald eagle, sandhill crane, northern copperbelly watersnake, fox snake, and spotted turtle, to name a few.

Bald Eagles

Ohio has 19 nesting pairs of bald eagles, which in 1992 produced a record 31 eaglets. Eagles prey largely on fish and other aquatic life. Continued growth of Ohio' bald eagle population is dependent on wetlands restoration and protection.

Other Raptors

Birds of prey, such as the red-tailed hawk, northern harrier, rough-legged hawk, peregrine falcon, and screech owl, are vitally dependent on healthy wildlife populations. Wetlands provide an abundance of many types of water-loving plants and grasses which allow small rodents to thrive in large numbers. Without these areas, numbers of small rodents and other wildlife would be insufficient to meet the food needs of Ohio's raptors.

Muskrat

Aquatic Wildlife

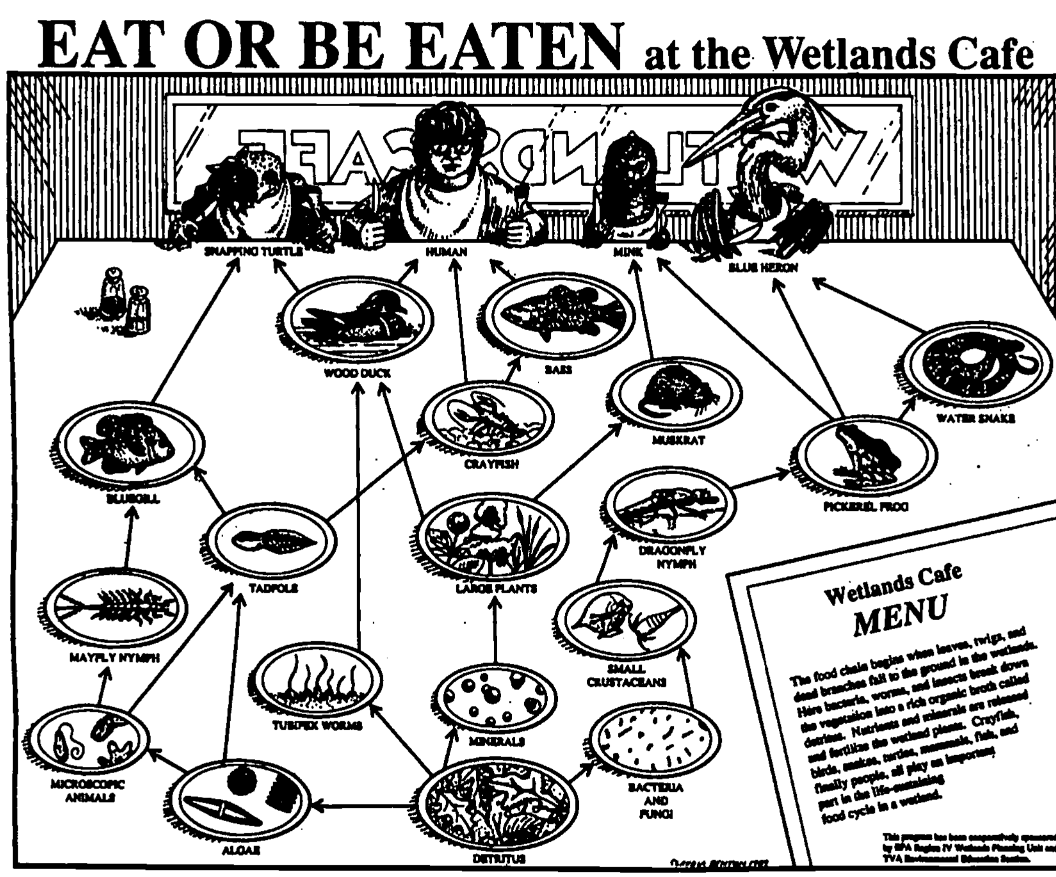
As the name implies, aquatic wildlife are exclusively dependent on wetlands for their survival. Reptiles, amphibians, fish, and mullusks would not thrive without wetlands. Various insects, birds, and mamals are dependent on wetlands and the various aquatic vegetation associated with wetlands.

Ducks

The North American Waterfowl Management Plan has identified five key areas, or focus areas of Ohio that are important to waterfowl and other wetlands wildlife. The Lake Erie Marshes have been a historical migration stop for hundreds of thousands of ducks each spring and fall. This region is the most important migration rest area for black ducks in North America. Wood ducks have made a strong comeback thanks to wetlands management in Ohio.

Food Chain

Habitat is not complete without a food chain. Wetlands are often more efficient than upland or aquatic ecosystems in production and dispersal of nutrients that form the base of the aquatic food chain. Cattails, algae, and other wetland plants convert solar energy into organic carbon, gaseous nitrogen into nitrate, and inorganic minerals into useful organic matter. The conversion of inorganic phosphorus and nitrates from



runoff and flood waters into organic compounds is essential for support of the aquatic food chain. Most fish and invertebrates can use these nutrients only as organic byproducts.

Wetland plants, as well as the less obvious algae, contribute to the primary productivity of the area. Submerged aquatic plants that are readily decomposed can rapidly recycle and disperse potential food sources. Emergent plants play an important role by slowing currents and providing sites in the wetlands for algae growth. Algae are an important and stable source of food for aquatic animals and micro-organisms.

Import and export of dissolved or particulate food sources from a specific wetland typically follow seasonal and annual patterns. Because wetlands physically and chemically regulate the rate of nutrient exchange, "boom and bust" cycles of nutrients are less likely to exist where wetlands are present in the watershed.

Flood Control

Wetlands play an important role in slowing and storing flood waters. Riverine wetlands and floodplains provide flat expanses where flood waters are able to spread out and slow down, thereby reducing the height and velocity of floods. Once the velocity of floodwaters is stemmed, the water may then drain slowly out of these wetland areas, reducing streambank erosion and flood peaks downstream. If the soil in a wetland area is not fully saturated, the soil itself will provide some storage capacity during periods of flooding. Shallow depressions where these wetlands usually form will also hold standing water for weeks or months, thereby slowly recharging groundwater.

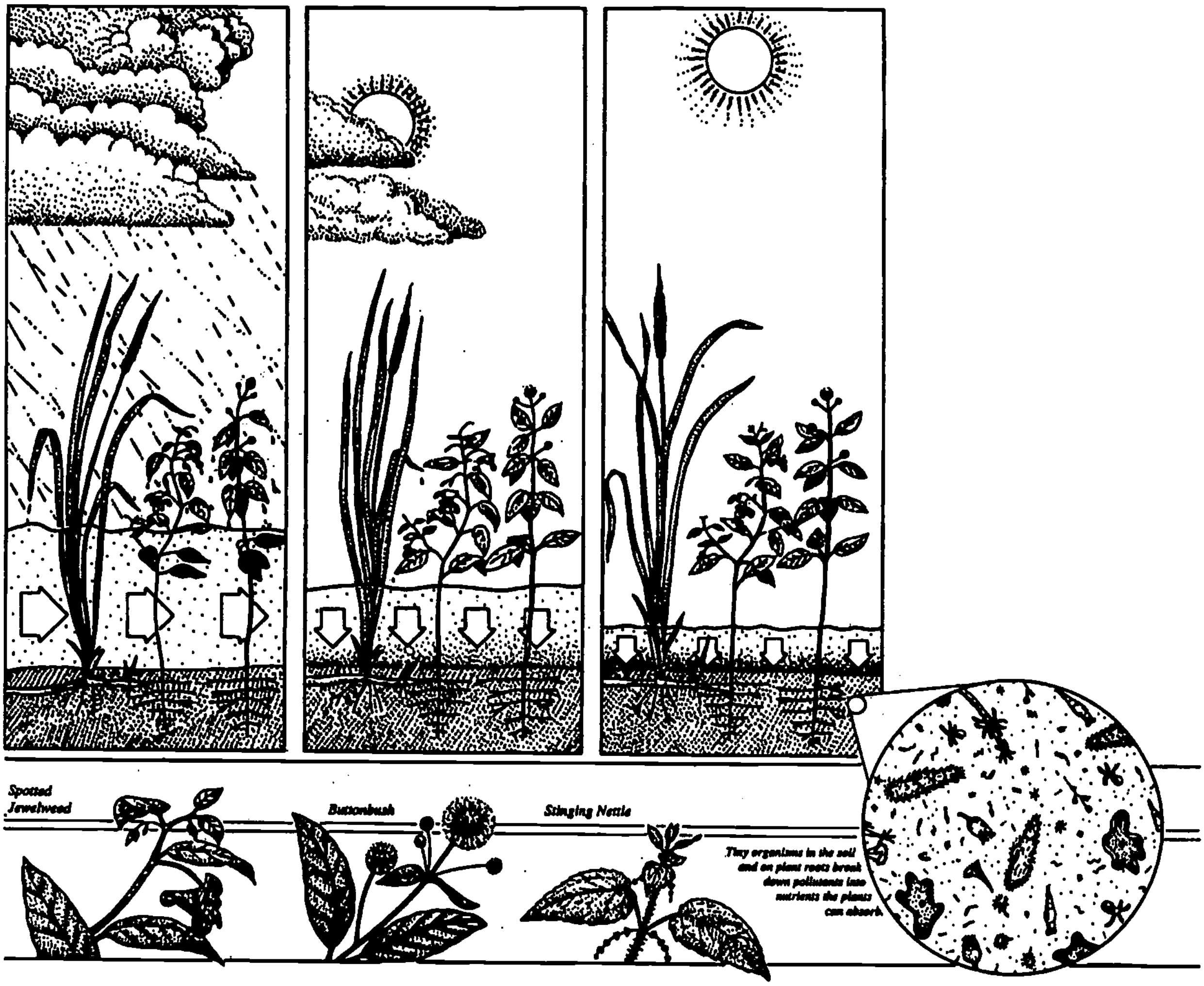
Building structures or filling within floodway areas confines flood flows to narrower channels and causes increased flood heights and rates. Studies have shown that flood peaks may be as much as 80 percent higher in watersheds without wetlands than in similar basins with large wetland areas. For example, a U.S. Army Corps of Engineers study on the Charles River in Massachusetts predicted that a 40 percent reduction in wetland areas along the river would increase flood damages by at least $3 billion annually.

A study in DuPage County, Ill., found that 80 percent of all flood damage reports came from homeowners whose houses were built on converted wetlands. The county is currently spending from $0.5 to $1 million annually to correct the problem. The Illinois State Water Survey found that for every one percent increase in the area of watershed's wetlands, a flood peak flow in the streams that drain the watershed is reduced by an average of 3.7 percent.

Erosion Control

Wetlands effectively reduce erosion of shorelines from tides, waves, wind, and river currents by slowing down and dissipating much of the water's energy and by stabilizing shorelines with their vegetative root systems. Replacing wetlands with bulkheads, riprap, and other shore-hardening structures often cause the erosive forces to be transferred to other areas and other properties downstream or downcurrent.

In the Indian Lake Watershed, streambank erosion is a major problem which adds tons of sediment to the lake every year. The restoration of wetlands along streams can help slow down the flow of water and prevent streambank erosion.



Sedimentation and Pollution Control

Wetlands improve water quality by filtering out sediments, nutrients, and toxic chemicals. Moving water carries sediments and other materials in suspension and, as this water enters a wetland, its flow decreases so that soil and other suspended material settles out. The sediment is then trapped by the wetland vegetation and held in place by the root system. This trapping and storing of sediment contributes greatly to the reduction of siltation in lakes and reservoirs.

Many pollutants, including excess nutrients, disease organisms, and toxic chemicals, have a tendency to adhere to suspended matter. The ability of wetlands to trap and temporarily retain this matter can reduce the level of both organic and inorganic pollution in water supplies. Some dissolved nutrients such as nitrogen and phosphorus may be taken up directly by plants during the growing season and by chemical absorption and precipitation at the wetland soil surface. As organic and inorganic suspended material settles out in a wetland, some pollutants associated with this trapped material may be converted by biochemical processes to less harmful forms, some may be taken up by the wetland plants and either recycled or transported away, and some may simply remain buried in the bottom sediments. While the trapping and storing of pollutants can certainly result in improved water quality, the bioaccumulation of some pollutants may also be toxic to some species of fish and wildlife.

Agriculture

While many wetlands have been converted to crop production areas, others left in their natural state provide benefits to the agricultural economy. Wetlands serve as catch basins to hold surface water and they recharge ground water for agricultural uses. They also trap sediment and runoff from cultivated land, thereby reducing soil loss and the pollution of water supplies. Many wetland plants have high nutritional value and are used for livestock and hay production. Production of hay in wetlands is especially common in areas where periodic drought conditions cause failure of upland crops. Some berry crops such as cranberries and blueberries are also produced in farmed wetlands.

Education and Research

Because wetlands contain a variety of flora and fauna not found in other environments, they provide unique educational and scientific research opportunities. The diversity of wetland plant life (over 5,000 species nationwide) creates habitat for every form of animal life including insects, amphibians, reptiles, mammals, and birds.

Ecological relationships are easily observed in wetlands, making excellent locations for teaching the environmental sciences at every level from elementary school through graduate education. The tremendous diversity of plant and animal life and the unique interactions where land and water meet also present biological research opportunities not found in other ecosystems.

Open Space and Recreation

The scenic and recreational qualities of wetlands are highly valued. Ohio has a number of noteworthy wetland areas to be appreciated for their scenic beauty including Kent Bog, Cedar Bog, and Magee Marsh. More than half of all U.S. adults (98 million Americans) hunt, fish, birdwatch or photograph wildlife. These activities, which rely on wetlands, added an estimated $59.5 billion to the Nation's economy in 1991.

Other Functions and Values

In addition to the functions and values previously discussed, there may be other less obvious but significant intrinsic reasons for preserving wetlands and other natural areas. Natural systems can provide baseline conditions that help determine the extent to which the environment has been affected by human activity and pollution. They also provide models for restoring or replacing significantly altered habitats, and are valuable as part of the natural order of things, regardless of any tangible benefits or ecological services society may receive from them.

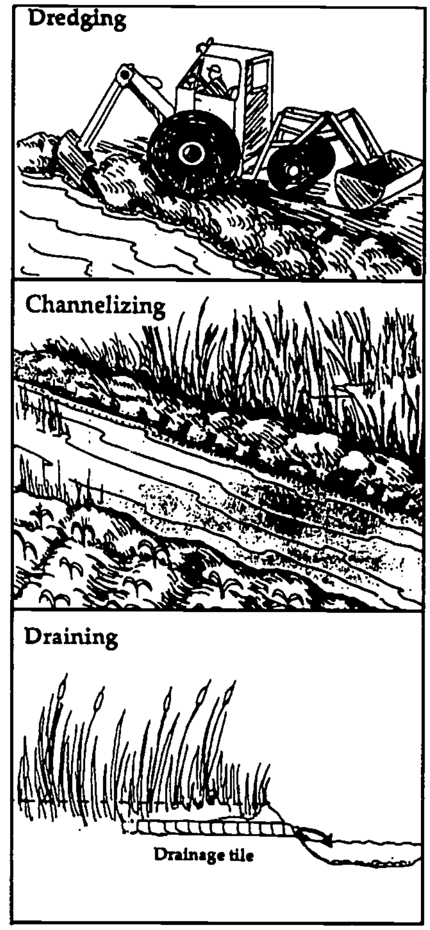
Wetland Regulation

Federal

The Clean Water Act

The most far-reaching law protecting wetlands is Section 404 of the Clean Water Act. When Congress passed the Clean Water Act in 1972 the primary goal was to "restore and maintain the chemical, physical and biological integrity of the nation's waters." Unlike most other provisions of the Clean Water Act, which are aimed at controlling polluted wastewater discharges; Section 404 regulates the dumping of solid materials into waterbodies.

The 404 program is intended to minimize adverse impacts by preventing the unnecessary loss of wetlands and other sensitive aquatic areas. The U.S. Army Corps of Engineers and the EPA jointly administer the Section 404 permit program. Dumping fill materials or dredge spoils into a waterway requires a permit from the Corps. The Corps reviews permit applications, issues the permits and has authority to bring enforcement actions against people who violate the permits.



The EPA is responsible for setting the guidelines which are used to assess the environmental impacts of proposed disposal permits. It also has veto power over any disposal permit that would have an unacceptable impact on water supply, fish, shellfish, wildlife, and recreational uses.

The Clean Water Act prohibits the discharge of dredged or fill material into specific sites if they do not meet environmental criteria established by the EPA and Corps.

The U.S. Fish and Wildlife Service is charged with reviewing permit applications to assure that the impacts on wildlife and endangered species are minimal.

Natural resource agencies in each state also play an important role in reviewing and approving Section 404 permits. Section 401 of the Clean Water Act provides that every state has the right to veto a Section 404 permit if it can show that the project will impair water quality.

Wetlands are an integral part of waterways and play an important role in restoring the chemical, physical and biological integrity of our nation's waters. Section 404 provides an important tool, in combination with other laws and regulations, to prevent the unnecessary loss of the water quality function of wetlands.

Scope of Section 404

The law provides a means to review and comment on projects that alter or destroy wetlands and waterways by filling or disposal of dredge spoil. Unnecessary loss of wetlands is often prevented through the permit review process by modifying project plans or through environmental mitigation measures. Permits for projects that do not comply with the EPA and Corps regulations can be denied.

Section 404 authorizes the Corps to regulate the disposal of dredges or fill material into the "waters of the United States." These waters are defined as waters that are, or could be, important to interstate commerce; waterways used for navigation or lead to navigable waters; headwaters of interstate waters and bordering wetlands; and isolated lakes and wetland that contribute to interstate commerce (i.e., commercial fisheries, fur trade or recreation).

Most wetlands that are directly connected to a river or lake, or a stream that flows into a river or lake, are considered to be part of the waters of the United States. Regulation of isolated lakes and wetlands under Section 404 varies from state to state.

Other laws support the Clean Water Act. The Fish & Wildlife Coordination Act requires that fish and wildlife resources be given equal consideration when reviewing 404 permits. The National Environmental Policy Act requires federal agencies to consider the impacts of 404 actions on the human and natural environment. The Endangered Species Act, the Wild & Scenic Rivers Act, and the Coastal Zone Management Act also must be considered by the Corps of Engineers when reviewing applications for 404 permits.

State Regulations

Ohio has no comprehensive wetlands legislation or state permit program, but relies primarily on use of the Federal Water Pollution Control Act §401 water quality certifications to protect wetlands. In addition, the Ohio Environmental Protection Agency can protect wetlands as "state resource waters" under the Anti-Degradation Policy (chapter 3745-1-05 of the Ohio Administrative Codes).

The Ohio Department of Natural Resources (ODNR) has issued a policy statement "to affirm departmental policy to protect, restore and create wetland ecosystems to ensure that wetlands are considered in the environmental review of state and federally assisted projects under state jurisdiction.

Ohio has used funds from the Federal Land and Water Conservation Fund to acquire wetlands across the state for preservation and education. The state has developed at least 10 wetlands preservation and public-access projects featuring boardwalks and trails.

In 1989, Ohio enacted a coastal management program that grants ODNR the authority to issue permits on submerged lands. While rules for the program have not yet been promulgated, ODNR will consider wetlands protection when determining whether to issue permits for activities on submerged lands.

Local Jurisdictions

Many local governments have wetlands ordinances or other forms of regulation including floodplain management regulations, clearing and grading ordinances, comprehensive plans and zoning ordinances. However, the requirements of the local laws will vary, depending on the willingness of the people to adopt zoning codes and ordinances which protect wetlands stringently. Most codes and ordinances will include provisions for variances, so need to watch over wetlands will continue in lieu of comprehensive wetlands policy and regulations.

Wetlands Protection Techniques

Buffers

Buffers, regulated land areas, help stabilize soil and prevent erosion from entering wetlands. They filter sediments and harmful substances from water before it enters the wetland. They moderate stormwater impacts and microclimates. Wetland buffers support species in themselves and protect wetland habitat. Many buffers discourage human intrusion.

Wetland buffer zone

Mitigation

Mitigation is an important tool in finding a compromise between governmental agencies and developers. If the developer cannot build without disturbing a wetland, mitigation and mitigation banking may be considered as a viable solution to the problems facing the developer and government agencies.

The term "mitigation" is broadly defined to include avoiding, minimizing, rectifying, reducing, eliminating, or compensating for the adverse environmental effects. In wetlands protection, mitigation can include changing project plans or selecting alternative sites to avoid or reduce adverse impacts, using preferred construction or management practices to reduce on-site and off-site effects, and compensating for unavoidable wetlands losses by creating or restoring other on-site or off-site wetlands areas. The theory behind mitigation is to allow certain types of development in certain types of wetlands while ensuring that wetlands will eventually be "made whole again".

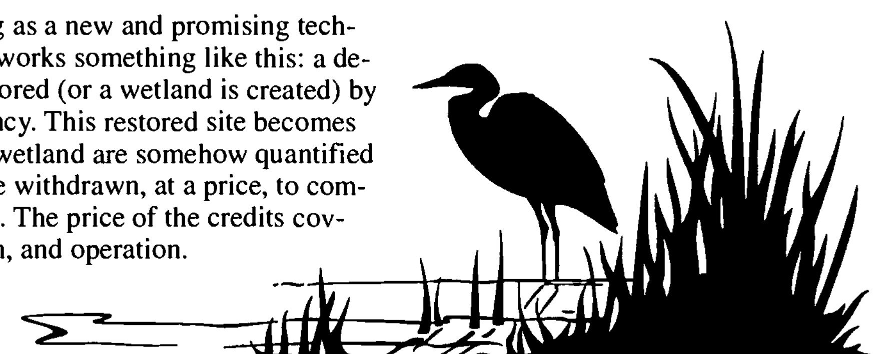
Several federal, state and local agencies have developed mitigation policies related to their wetlands protection responsibilities, but many significant issues remain unresolved. In practice there is still much controversy about mitigation because a consensus has not been reached on exactly what constitutes mitigation and whether it is always effective. Many mitigation strategies are still considered experimental, often involving tradeoffs of certain losses for uncertain gains.

The costs of mitigation are considerable, with restoration of wetlands over $10,000 per acre on the average and creation of wetlands averaging between $25,000 and $50,000 per acre (1990 estimates).

Mitigation Banking

Developers see mitigation banking as a new and promising technique. Mitigation banking generally works something like this: a degraded wetland is purchased and restored (or a wetland is created) by one party, such as a government agency. This restored site becomes the bank. The values of the restored wetland are somehow quantified and used as "credits" that can later be withdrawn, at a price, to compensate for unavoidable wetland fills. The price of the credits covers the cost of acquisition, restoration, and operation.

The attraction of a mitigation bank is that rather than

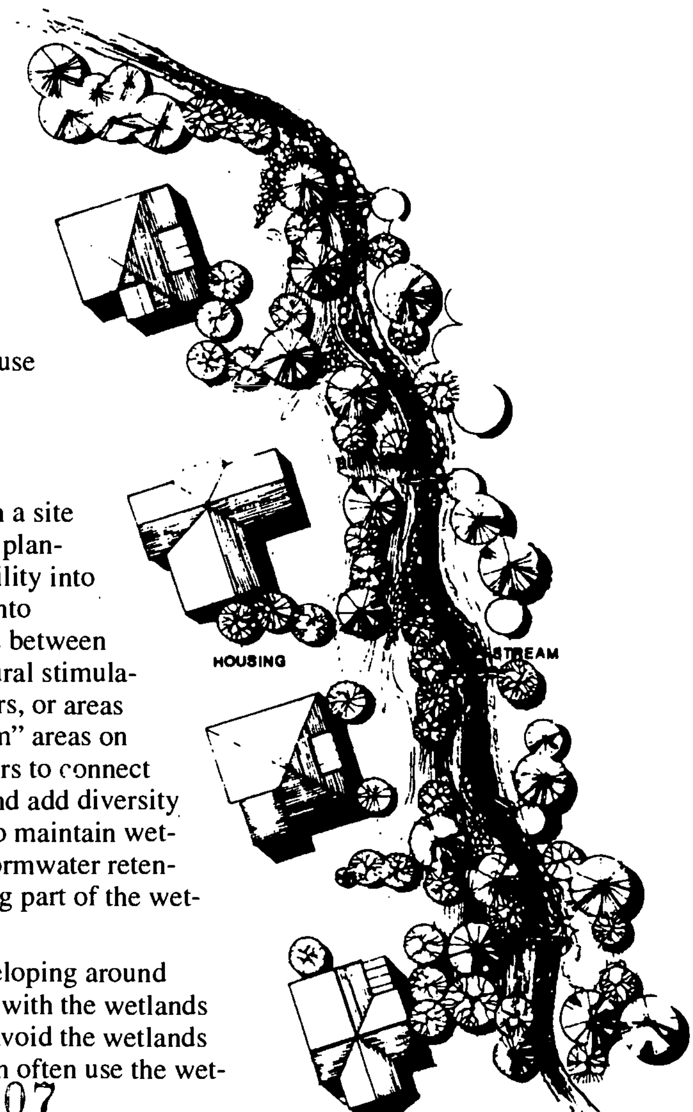


creating small, isolated wetlands to compensate for each wetland alteration, one large, contiguous wetland can be created to mitigate many individual alterations. A single, 10-acre wetland is more valuable and easier to create than 20 unconnected, half-acre wetlands. Also, many developers have neither the experience nor the inclination to restore or create a wetland. It may be more efficient, therefore, to let a resource agency select a site, design and implement a mitigation plan, and be responsible for monitoring and maintaining the wetland.

Development impact reduction

Many local jurisdictions believe that development of many marginal areas is inevitable and that wetlands may need to co-exist with construction. They are attempting to work with developers to reduce the impact of construction on wetlands. Some of the options include the following:

- Credits for the zoning density in wetlands or buffer areas. This concept gives a builder credit for avoiding wetlands and leaving buffers. The builder receives increased density in an upland area of the project site. Some jurisdictions permit transfer of these density credits to other sites.
- Allowances for buffer averaging or reduction of buffers where no adverse impact to the wetlands can be demonstrated.
- Flexibility to allow for certain limited uses of buffers such as wells, previous trails, placement of underground utility lines and on-site septic drainfields, grass-lined swales and detention/retention facilities and access roads.
- Grandfathering existing uses or legal lots of records as exempt from new, more stringent regulations. Also grandfather requirements related to remodelling or expanding an existing use already located in a wetland or buffer area.



Wetlands as Development Assets

Although developers tend to think of wetlands on a site to be strictly an impediment to development, sound planning and design can transform wetlands from a liability into a development asset. Wetlands can also be turned into project amenities, such as: providing natural buffers between different product types or land uses; acting as a natural stimulator, whether natural open space, golf course corridors, or areas for water retention. Wetlands can provide "premium" areas on the project. Wetlands can create long visual corridors to connect amenities, as well as break-up large tracts of land and add diversity to the project's visual character. Careful planning to maintain wetlands functions and values may allow for on-site stormwater retention to be incorporated into wetland areas, thus using part of the wetland and often enhancing it.

Good land planning and design is the key to developing around wetlands. Because of the time and costs associated with the wetlands permitting process, the first objective should be to avoid the wetlands if at all possible. Moreover, a good land planner can often use the wetlands as a design feature.

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For example, linear wetlands (such as those associated with drainage swales, ditches and streams) offer several design opportunities:

- Separate different product types.
- Serve as "natural" property lines between parcels or lots.
- Provide natural habitat areas.

Broad, flat wetlands often contain open water or treeless core areas that can be the focus of views from surrounding uplands. Selective thinning of vegetation, with proper approvals, can sometimes create open water that may enhance wildlife habitat and offer spectacular views. These broad wetlands areas also frequently accommodate large volumes of stormwater in their natural condition, and this capacity can be integrated into stormwater master planning of a project for absorption of treated stormwater. The result can be an aesthetic system with significantly lower initial construction and less long term maintenance costs than conventional systems. When site planning adjacent to wetlands, location of building envelopes should take precedence over lot size and configuration. Building envelopes should be sited to minimize grading and removal of existing vegetation, with an emphasis on views to the wetlands.

Citizen Roles

Each person has a role to play in taking care of wetlands, no matter where we live. There are many ways to tackle the issue:

Preservation

1. If you have wetlands on your land, protect them. Find out how to best manage wetlands to retain their existing functions and value. Consider applying a permanent approach to maintaining them in perpetuity such as a conservation easement.
2. Work with your local community land trust, or work toward setting up a land trust if your community doesn't have one.
3. Make sure your local government is addressing wetland preservation and support their activities and those at the state or national level.
4. Voice your opinion on the issue of preserving wetlands and support funding for preservation program efforts.
5. Talk with your neighbors and friends about preservation.
6. Join preservation organizations.
7. Take whatever action you can to save wetlands.

Stewardship

1. Teach your children about wetland stewardship.
2. Learn if your county has conducted a wetlands inventory. If not, support financing and resource allocation for this task.
3. Monitor major construction projects proposed for your community. If they appear to impact an area you consider to be a wetland, investigate to ensure that wetlands protection has been included in permits and that an environment impact assessment has been conducted.

4. If you own a wetland, consider wetlands enhancement and restoration projects.

Projects

1. Build and place wood duck nesting boxes, duck and geese nesting "islands" or other habitat improvement structures.
2. Adopt a wetland for long-term care and monitoring.
3. Sponsor an essay or art contest for schoolchildren to generate creative thinking on the significance of wetlands, wildlife habitats, clean water, stewardship ethic, etc.
4. Monitor and document wildlife uses and species diversity within the wetland and over time.
5. Organize a field trip to a wetland.

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Ground Water

Our Hidden Water Resources

Ground Water: Our Hidden Water Resources

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A Growing Dependence on Ground Water

Ground water is a critical resource for modern society. Ground water is used for about 50 percent of the nation's agricultural irrigation, nearly 33 percent of the industrial water needs, and 75 percent of our cities depend on it for all or part of their water supplies. For more than 50 percent of Americans—and 95 percent of our rural population—ground water is the primary source of drinking water.

Our dependence on this vital resource is growing. Between 1950 and 1985, consumption of ground water nearly tripled. Protection of this resource may be one of the most important environmental issues of the next decade.

Over the last 10 years, public attention has been drawn to incidents of ground water contamination. This has led to the development of ground water protection programs at federal, state, and local levels. Because ground water supplies and conditions vary from one area to another, the responsibility for protecting a community's ground water supplies rests substantially with the local community.

How Is Ground Water Used?

According to the U.S. Geological Survey, ground water use increased from about 35 billion gallons a day in 1950 to about 87 billion gallons a day in 1980. Approximately 25 percent of all fresh water used in the nation comes from ground water. Whether it arrives via a public water supply system or directly from a private well, ground water ultimately provides approximately 35 percent of the drinking water supply for urban areas and 95 percent of the supply for rural areas, quenching the thirst and meeting other household needs of more than 117 million people in this nation.

Overall, more than 33 percent of the water used for agricultural purposes is drawn from ground water. Arkansas, Nebraska, Colorado, and Kansas use more than 90 percent of their ground water withdrawals for agricultural activities. In addition, approximately 30 percent of all ground water is used for industrial purposes.

Ground water use varies among the states with some states, such as Hawaii, Mississippi, Florida, Idaho, and New Mexico, relying on ground water to supply considerably more than 75 percent of their household water needs. Other states, such as Colorado and Rhode Island, supply less than 25 percent of their water needs with ground water.

What is Ground Water?

Definition of Ground Water

Many people think of ground water as streams, rivers or lakes that occur under the ground. Such bodies of water can be found in exceptional cases (some limestone formations) and they are called Karst formations or aquifers.

However, for the most part, ground water does not exist as underground pools, but rather as subsurface water filling the spaces between the particles of sand, soil or rock. Thus, ground water may be defined as subsurface water that occurs in fully saturated soils and geologic units called aquifers.

Vast Resource

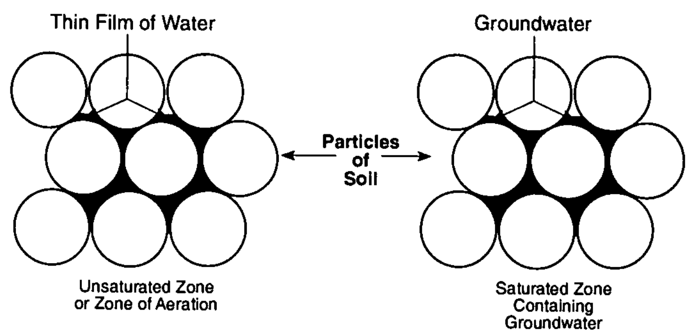
Groundwaters and surface waters are the two major sources of water available for human consumption or other uses. Since surface waters (streams, rivers, lakes, reservoirs, dams and irrigation canals) are readily visible, it is easy to think of them as the only major source of water for human needs. Yet, less than 3 percent of the earth's fresh surface water is available for use at any given time. The remaining 97 percent (an estimated 8 trillion acre-feet) is subsurface, or ground water—truly a vast and most important water resource.

The Geology of Ground Water

Definition of an aquifer

Near the surface of the earth, the soil pore spaces are partially filled with air and partially filled with water, forming the unsaturated, or vadose zone. This area is also called the zone of aeration.

Lower down, beneath the vadose zone, water completely fills the pore spaces, forming the saturated zone, or ground water. Ground water that is capable of yielding water to springs or wells at a rate sufficient to serve as a practical source of water is called an aquifer.



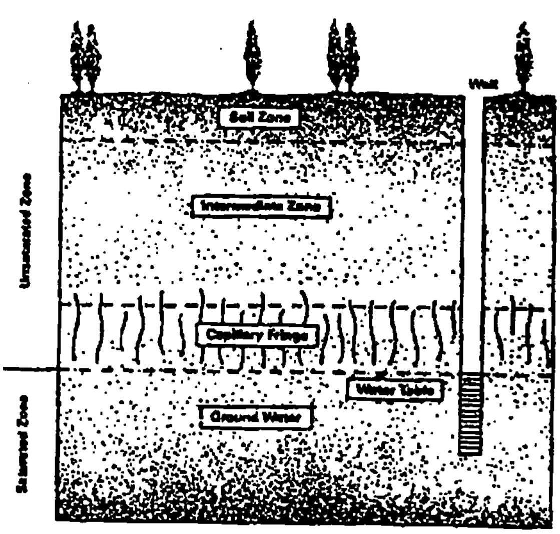
Water in Unsaturated and Saturated Zones

Aquifers can vary in vertical thickness from several feet to hundreds of feet. They may range in area from a few acres to hundreds or thousands of square miles. Aquifers may be shallow formations, or they may be hundreds or even thousands of feet deep. In general, most U.S. aquifers occur within 2500 feet of the earth's surface. Estimates of the volume of water stored within this 2500-foot depth range from 35 to 100 quadrillion gallons.

Unconfined and confined aquifers

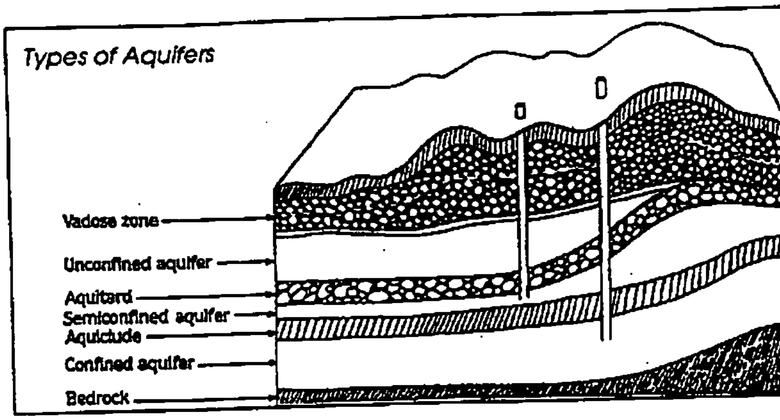
There are two kinds of aquifers: unconfined and confined. An unconfined aquifer usually occurs near the land's surface and may be called a water table aquifer because the upper surface of its water is the water table. The lower boundary is an impermeable layer of clay or rock. Unconfined aquifers are replenished (recharged) primarily by rain that falls on the ground directly above the aquifer and percolates down to the water table. The water in such aquifers is at atmospheric pressure and flows in the direction of the water table's slope.

In some cases, a localized zone of saturation may exist above the water table. For example, an impervious layer (such as clay) may occur within the vadose zone to interrupt some seepage of water. Ground water may accumulate in a limited area above this layer to form what is called a perched aquifer.



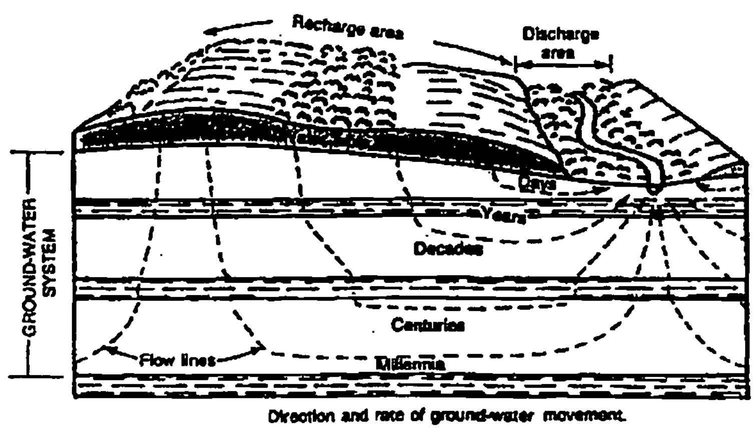
Groundwater zones

A confined, or artesian aquifer, is bounded on the top and bottom by confining layers. It is saturated with water that is subject to higher-than-atmospheric pressure. The artesian aquifer is primarily replenished by rain and surface water from a recharge zone that may be many miles from the point where the aquifer is tapped for use. If water cannot pass through the confining layer (impermeable) of an artesian aquifer, the layer is called an aquiclude. If water can pass in and out of the confining layer (permeable), the layer is called an aquitard.



Storage and Transmission of Ground Water (Porosity and Permeability)

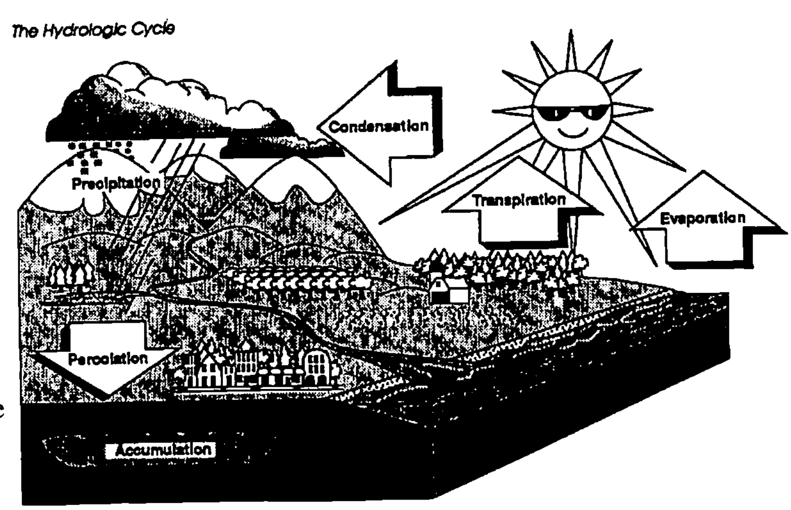
The ability of an aquifer to store and transmit ground water is a function of its porosity and permeability. Porosity describes the void volume of the aquifer—that part of the aquifer made up of openings, or pores. Porosity is an index of how much ground water the aquifer can hold (storage capacity). It is usually stated as a percentage figure; i.e., if one cubic foot of sand has 0.4 cubic feet of pore space, the porosity is stated to be 40 percent.



Groundwater time

Permeability is defined as the capacity of the aquifer to transmit ground water. A permeable aquifer is one that has many interconnecting pore spaces or cracks and crevices to allow relatively free movement of ground water. Sand aquifers are an example of both highly porous and permeable formations that tend to allow large volumes of ground water to move fairly rapidly. Granite or rock formations may be very low in porosity, but may contain large cracks that allow fairly rapid ground water movement. Clay aquifers tend to have high porosity, but the pore space between particles is very small. As a result, water transmission in such aquifers is very slow.

The Hydrologic Cycle



The circulation of water between the oceans and surface waters, the atmosphere and the land is called the hydrologic cycle, or earth's water cycle.

In this continuous cycle, water vapor enters the atmosphere by evapotranspiration, a combination of evaporation from the oceans and surface waters and transpiration from the soil by plants. Water returns to the earth as rainfall, hail, sleet or melting snow, where it replenishes surface water sources or seeps into the ground.

A major part of the precipitation soaking into the ground is held up in the plant root zone. The remainder continues to seep down through the vadose zone to enter the aquifer (saturated zone) and recharge the ground water. To complete the cycle, ground water naturally discharges to the surface as springs or is brought to the surface by man-drilled wells.

Through the hydrologic cycle, ground water and surface water interact. Oceans, lakes, rivers and streams are recharged partly by ground water. In fact, ground water discharge to surface water accounts for about 30 percent of surface stream flow in the U.S. In arid parts of the country, ground water supplies streams that otherwise would not flow during dry seasons.

Natural forces and processes such as solar radiation, evaporation, transpiration, capillarity and gravity interact to bring about and complete the hydrologic cycle.

What Are the Limits on Ground Water Usage?

A Renewable Resource

Ground water is a renewable resource. The replenishment of ground water is termed recharge. The source of all recharge is precipitation from the Earth's atmosphere.

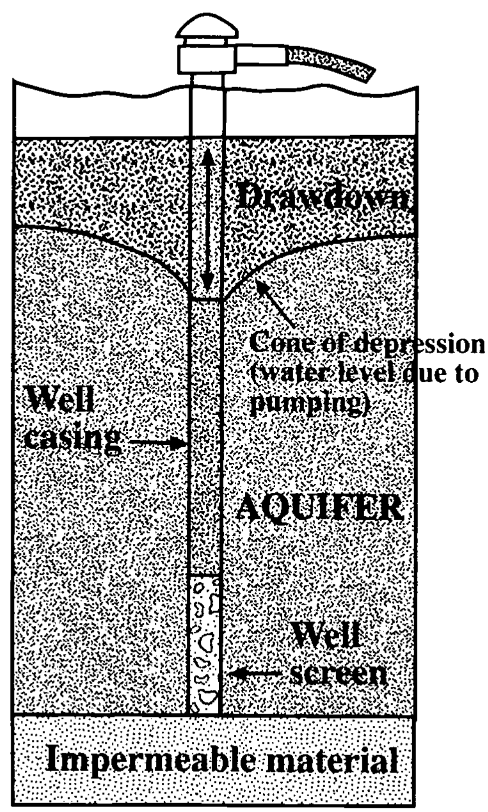
Recharge may occur as the result of rainfall or snowmelt infiltrating the Earth's surface. Infiltration is greatest in areas where the soil is sandy and where slopes are gentle so that the water does not tend to run off. However, all infiltrated water does not necessarily contribute to ground water recharge. Other moisture needs such as soil and plant requirements must first be met. Only the water in excess of these requirements contribute to recharge.

Recharge also may occur as seepage from surface water sources such as rivers, lakes, and wetlands. This happens when the surface water is at higher altitudes than the ground water, thus providing a downward driving force (Hydraulic head). The reverse is true also, of course; when ground water is at the higher altitude it will move to the surface water bodies. This is termed ground water discharge. Recharge and discharge also may take place in the subsurface as leakage from one aquifer to another.

Prior to man's developmental activities, aquifers are in a state of equilibrium, and recharge is balanced by discharge. However, when a well is completed in an aquifer and water pumped from it, the balance, at least temporarily, no longer exists.

When water is withdrawn through a well, the water level in and around the well is lowered, and a cone of depression is formed, with the well at the center. The water level must decline in order that water may flow from the aquifer to the well. The rate and depth of decline depend upon the hydraulic characteristics of the aquifer, construction of the well, and the rate and duration of pumping.

Withdrawal of water from an aquifer will immediately result in a decrease in the volume of water stored within the aquifer. Prolonged withdrawal may result in either a decrease in the natural discharge from the



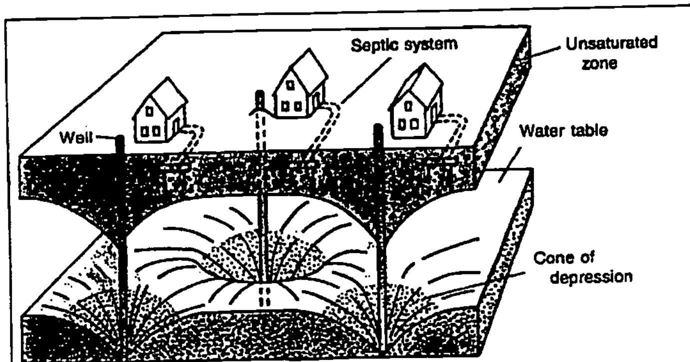
Cone of depression

aquifer or an increase in recharge, or both. However, water use may be adversely impacted long before effects on natural recharge or discharge are noted.

The "Safe Yield" Concept

One often hears the term "safe yield" used as an expression of balance between ground water usage and recharge. In theory, the volume of water that can be safely withdrawn from an aquifer is dependent on the volume of water the aquifer receives as recharge. In other words, discharge must equal recharge. Most hydrologists and water managers would consider such a rigid definition of safe yield impractical, if not unworkable.

Over the years, numerous attempts have been made to provide a practical definition of safe yield, but without much success. Some definitions were concerned only with the quantity of water that could be withdrawn from an aquifer without producing severe water-level declines. Other definitions included economic aspects such as energy costs. The cost of pumping water from great depths can become prohibitively expensive, as has already occurred in some parts of the United States. Still others included references to water quality. As the hydraulic head within an aquifer is decreased by withdrawals, water of a different quality may move into the aquifer from another source. This is not to say that the change in quality is always for the worse, but it commonly is.

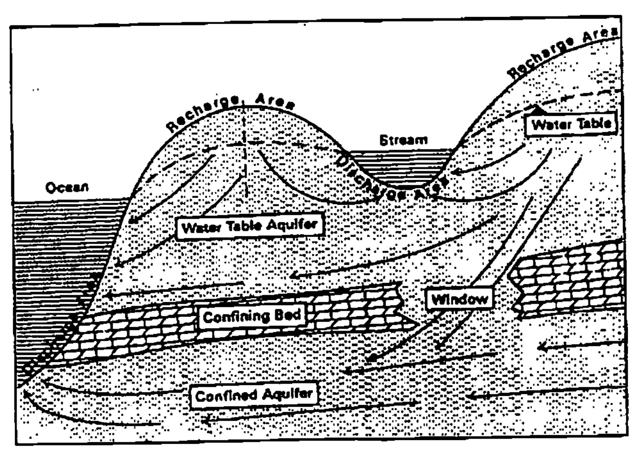


Effect of concentrated housing on ground-water level.

Ground Water "Mining"

Another term commonly associated with ground water use is ground water "mining." Ground water mining occurs when water is withdrawn at rates faster than it is replenished. The usual result is declining water levels. It is unfortunate that this term ever came into use because, to many, it has an undesirable connotation and is associated with exploitation or irresponsible use of ground water.

Obviously such concepts as safe yield and ground water mining are difficult to define and quantify. The more we learn about ground water occurrence the more we realize that the problems of ground water use must be dealt with on an aquifer-by-aquifer basis. Instead of thinking in terms of safe yield and ground water mining, we should be thinking in terms of best management practices or optimum development.



Groundwater charge-recharge cycle

Ground Water Interaction with Streams, Lakes, and Wetlands

In the hydrologic cycle, ground water may at times and in places be discharging from aquifers to surface water bodies, or vice versa, depending on hydraulic head relationships and hydraulic connection. As would be expected, the importance of this interaction to the water user varies greatly from place to place.

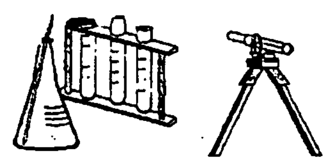
Questions often arise concerning the effects of lakes and wetlands on ground water levels. For example, would a significant rise in a lake level or the creation of a new lake by impoundment cause significant and possibly detrimental rises in nearby ground water levels? Conversely, would the lowering of a lake level or the complete drainage of a lake or wetland significantly affect nearby ground water levels? Unfortunately, the answers to questions such as these usually are not readily apparent and require rather intensive hydrologic studies. One needs to know the altitude of the lake or wetland in relation to the ground water levels, but also other factors such as the rate and direction of ground water movement and the rate of evapotranspiration in the area. Where there is good hydraulic connection between ground water and surface water systems, significantly altering one obviously will affect the other.

The questions relating to the effects of wetland drainage on ground water levels and ground water recharge are very difficult to answer quantitatively. In an 1980 study of a wetland complex in North Dakota, some wetlands appear to recharge ground water, some wetlands are flow-through types where ground water enters one side and surface water seeps into the ground on the other side, and some wetlands are discharge points for ground water.

Ground Water Quality

Measuring the Purity of Ground Water

Until the 1970s, ground water was believed to be naturally protected from contamination. The layers of soil and particles of sand, gravel, crushed rocks, and larger rocks were thought to act as natural filters, trapping contaminants before they could reach the ground water. Since then, every state in the nation has reported cases of contaminated ground water, with some instances receiving widespread publicity. We now know that some contaminants can pass through all of these filtering layers into the saturated zone to contaminate ground water.



Our knowledge of the purity of ground water depends on how well we can detect and identify kinds and amounts of substances in the water.

Over the past quarter of a century, advances in analytical techniques have enable us to detect chemical substances in smaller and smaller quantities. In 1950, state-of-the-art techniques could detect some substances by the part per million (ppm) level. By 1965, detection levels for some substances dropped to about one part per billion (ppb), on the way to one part per trillion (ppt) by 1975.

More recently, analytical chemists have pushed the limits of technology to find certain substances at one part per quadrillion (ppq). Finding one part per quadrillion can be compared to finding a postage stamp in an areas as big as the state of Alaska.

Although the ability to detect and identify these small constituents represents fantastic progress, it adds confusion to issues of ground water purity. We can now discover chemicals and other substances not previously thought present in our ground water; yet, in many cases, we still lack scientific data to tell us how they affect human health and the environment.

Nature's Contaminants

Precipitation can dissolve, or leach, a variety of materials from subsurface layers or zones it contacts. In fact, water is frequently referred to as "the universal solvent." In general, the concentration of dissolved substances increases as water seeps through the soil. As a result, all ground water contains some dissolved salts or other soluble substances.

Chlorides are one of the most common contaminants leached into ground water. Fluorides, sulfates, nitrates and iron are other mineral salts that may leach into ground water from localized natural deposits.

As a result, the natural quality of ground water varies greatly. It is influenced by geographic location, geologic characteristics and chemical composition and frequency and amount of rainfall in a given area. For example, in arid areas of the United States, such as the Southwest, or along coastal areas, high levels of dissolved salts (salinity) or calcium or magnesium (hardness) may make ground water unsuitable for drinking or other domestic purposes and limit its use for livestock watering, farming, or industry. In humid areas with more frequent rainfall, the natural quality of ground water can range from good to excellent. In most parts of the United States, ground water salinity or mineralization tends to increase as the depth of the aquifer increases.

Other factors that may influence the natural quality of ground water include naturally occurring radioactive materials, other naturally occurring toxic substances and pH changes, which can be either natural or induced by microbial action, or by contamination from surface activities.

Man's Contaminants

Major sources of contaminants

A wide variety of activities, some once thought harmless, have been identified as potential sources of ground water contamination. In fact, possible sources of man-induced ground water contamination span every facet of social, agricultural and industrial activities.

Septic tank systems and ground water pollution

Septic tank systems have become the most widely used method for on-site treatment and disposal of sewage. Approximately 25 percent of all homes in the United States rely on septic systems to dispose of their human wastes. Estimates of the number of units in use range from 18 to 22 million. The annual volume of wastewater effluent discharged from these units is approximately 800 billion gallons—frequently discharged directly to the soil above groundwaters.

If these systems are improperly sited, designed, constructed, or maintained, they can allow contamination of the ground water by bacteria, nitrates, viruses, synthetic detergents, household chemicals, and chlorides. Although each system can make an insignificant contribution to ground water contamination, the sheer number of such systems and their widespread use in every area that does not have a public sewage treatment system makes them serious contamination sources.

Gastrointestinal illnesses are the major type of disease associated with drinking water contaminated with untreated or inadequately treated septic tank effluent. Ground water contaminants other than microorganisms include household products (cleaning solutions, paints, thinners),

Major sources of contaminants include:

- Municipal, domestic and industrial waste disposal practices
- Septic tanks and septic systems
- Municipal landfills
- Hazardous waste landfills
- Municipal wastewater systems
- Industrial wastewater impoundments
- Land spreading of sludge
- Mining wastes
- Waste disposal wells

Underground storage tanks

- Leaks from gasoline storage tanks
- Leaks from other petroleum product storage tanks
- Leaks from chemical product or waste storage tanks

Well-drilling operations

- Brine disposal associated with oil and gas operations
- Improper drill casing and management of oil, gas and water wells
- Abandoned wells

Agricultural practices

- Irrigation return flows
- Improper fertilizer and pesticide applications
- Animal feedlots
- Holding ponds and lagoons

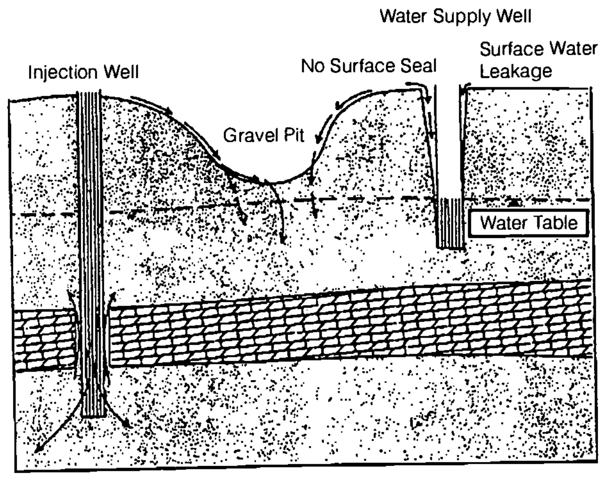
Miscellaneous

- Snow control (salting) operations
- Surface water pollution
- Airborne source particulates
- Graveyards
- Leaks in underground pipelines

Everyone Contributes to Groundwater Contamination

Activity	Estimated Sites*	Contaminants Frequently Cited As Result of Activity
Waste disposal:		
Septic systems	22 million	Bacteria, viruses, nitrate, phosphate, chloride, and organiz compounds such as trichloroethylene
Landfills (active)	16,400	Dissolved solids, iron, manganese, trace metals, acids, organic compounds, and pesticides
Surface impoundments	191,800	Brines, acidic mine wastes, feedlot wastes, trace metals, and organic compounds
Injection wells	280,800	Dissolved solids, bacteria, sodium, chloride, nitrate, phosphate, organic compounds, pesticides, and acids
Land applications of wastes	19,000 land application units	Bacteria, nitrate, phosphate, trace metals, and organic compounds
Storage and handling of materials:		
Underground storage tanks	2.4-4.8 million	Benzene, toluene, xylene, and petroleum products
Above-ground storage tanks	Unknown	Organic compounds, acids, metals, and other petroleum products
Material handling and transfers	10,000-16,000 spills per year	Petroleum products, aluminum, iron, sulfate, and trace metals
Mining activities		
Mining and spoil disposal — coal mines	15,000 active; 67,000 inactive	Acids, iron, manganese, sulfate, uranium, thorium, radium, molybdenum, selenium, and trace metals
Oil and gas activities		
Wells	550,000 production: 1.2 million abandoned	Brines
Agricultural activities:		
Fertilizer and pesticide applications	363 million acres**	Nitrate, phosphate, and pesticides
Irrigation practices	376,000 wells, 49 million acres irrigates**	Dissolved solids, nitrate, phosphare, and pesticides
Animal feedlots	1,900	Nitrate, phosphate, and bacteria
Urban activities		
Run-off	47.3 million acres urban land**	Bacertia, hydrocarbons, dissolved solids, lead, cadmium, and trace metals
Deicing chemical storage and use	Not reported	Sodium chloride, ferric ferrocyanide, sodium ferrocyanide, phosphate, and chromate
Other:		
Saltwater intrustion or upconing	Not reported	Dissolved solids and brine

*Estimates by the U.S. Environmental Protection Agency unless otherwise noted; **Statistics from the U.S. Bureau of the Census, 1984 septic tank cleanser, solvents and a variety of other substances when disposed of through a septic system, poured directly onto the ground, or placed in a landfill.



Sources of groundwater pollution

Surface impoundments

Surface impoundments (e.g., ponds and lagoons) used by municipalities, industries, and businesses to store, treat and dispose of a variety of liquid wastes and wastewater are another potentially significant source of ground water contamination. Although these impoundments are supposed to be sealed with compacted soils or plastic liners, leaks can and do develop.

Agricultural activities

Agricultural activities also can make significant contributions to ground water contamination with the millions of tons of fertilizers and pesticides spread on the ground and from the storage and disposal of livestock wastes. Homeowners, too, can contribute to this type of ground water pollution with the chemicals they apply to their lawns, rosebushes, tomato plants, and other garden plants.

Landfills

There are approximately 24 hazardous waste landfills in the U.S. and 1 in operation in Ohio. There are 12 commercial treatment, storage, or disposal facilities for hazardous waste in Ohio (unpublished data Ohio EPA 1995). By the end of 1994 there were 69 operating or legally capable of operating public and captive industrial land fills in Ohio (OEPA division of Solid and Infectious Waste Management, 1995 Ohio Solid Waste Facility Data Report). The National Solid Wastes Management Association reports that the number of municpal solid waste landfills in the U.S. in 1995 was 2,893.

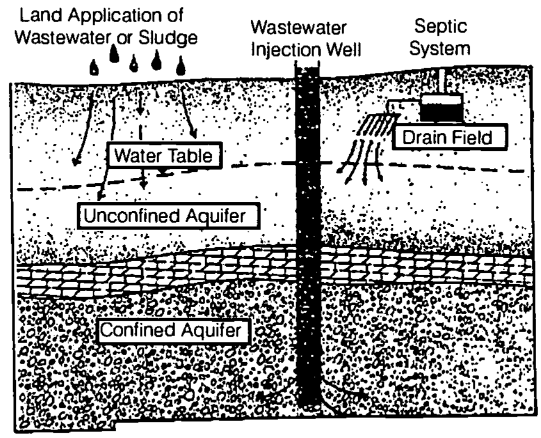
To protect ground water, these facilities are now required to be constructed with clay or synthetic liners and leachate collection systems. Unfortunately, these requirements are comparatively recent, and thousands of landfills were built, operated, and abandoned in the past without such safeguards. A number of these sites have caused serious ground water contamination problems and are now being cleaned up by their owners, operators, or users; state governments; or the federal government under the Superfund program. In addition, a lack of information about the location of many of these sites makes it difficult, if not impossible, to determine how many others may now be contaminating ground water.

Underground storage tanks

Between five and six million underground storage tanks are used to store a variety of materials, including gasoline, fuel oil, and numerous chemicals. The average life span of these tanks is 18 years, and over time, exposure to the elements causes them to corrode. Now, hundreds of thousands of these tanks are estimated to be leaking, and many are contaminating ground water. Replacement costs for these tanks are estimated at $1 per gallon of storage capacity; a cleanup operation can cost considerably more.

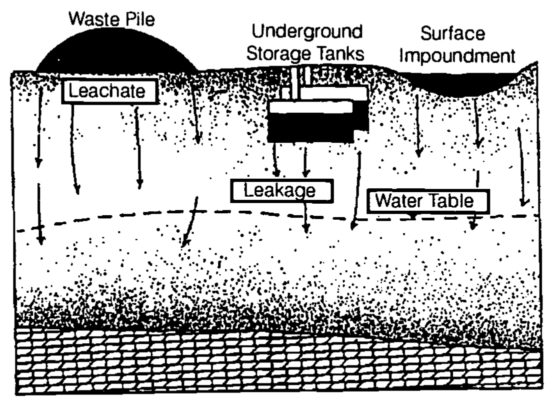
Abandoned wells

Wells can be another source of ground water contamination. In the years before there were community water supply systems, most people relied on wells to provide their drinking water. In rural areas this can still be the case. If a well is abandoned without being properly sealed, however, it can act as a direct channel for contaminants to reach ground water.



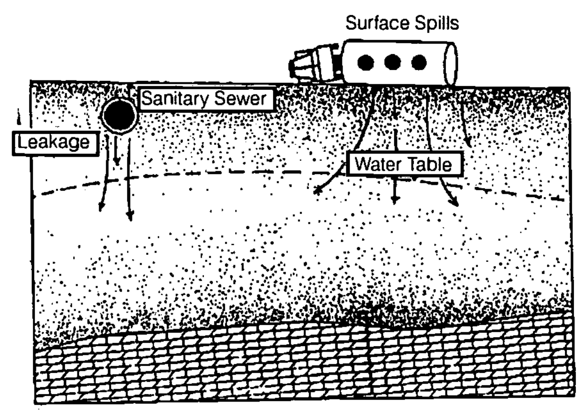
Accidents and illegal dumping

Accidents can also result in ground water contamination. A large volume of toxic materials are transported throughout the country by truck, train, and airplane. Every day accidental chemical or petroleum product spills occur that, if not handled properly, can result in ground water contamination. Frequently, the automatic reaction of the first people at the scene of an accident involving a spill will be to flush the area with water to dilute the chemical. This just washes the chemical into the soil around the accident site, allowing it to work its way down to the ground water. In addition, there are numerous instances of ground water contamination caused by the illegal dumping of hazardous or other potentially harmful wastes.



Highway de-icing

A similar flushing mechanism also applies to the salt that is used to de-ice roads and highways throughout the country every winter. More than 11 million tons of salt are applied to roads in the United States annually. As ice and snow melt or rain subsequently falls, the salt is washed into the surrounding soil where it can work its way down to the ground water. Salt also can find its way into ground water from improperly protected storage stockpiles.



How Contaminants Move in Ground Water

Ground water contamination can originate on the surface of the ground, in the ground above the water table, or in the ground below the water table. Where a contaminate originates is a factor that can affect its actual impact on ground water quality. For example, if a contaminant is spilled on the surface of the ground or injected into the ground above the water table, it may have to move through numerous layers of soil and other underlaying materials before it reaches the ground water.

As the contaminant moves through these layers, a number of processes are in operation (e.g., filtration, dilution, oxidation, biologically decay) that can lessen the eventual impact of the substance once it finally reaches the ground water. The effectiveness of these processes is also affected by both the distance between the ground water and where the contaminant is introduced and the amount of time it takes the substance to reach ground water. If the contaminant is introduced directly into the area below the water table, the primary process that can affect the impact of the contaminant is dilution by the surrounding ground water. Because ground water is hidden from view, contamination can go undetected for years until the supply is tapped for use.

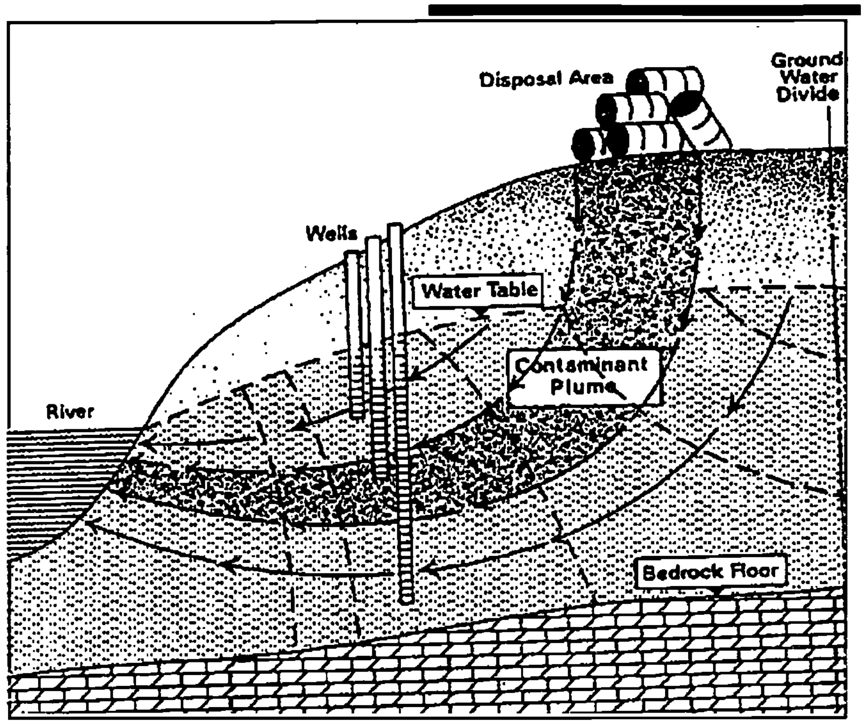
Once a contaminant reaches ground water, its movement in the aquifer is influenced by several factors:

- Solubility
- Density
- Ground water movement

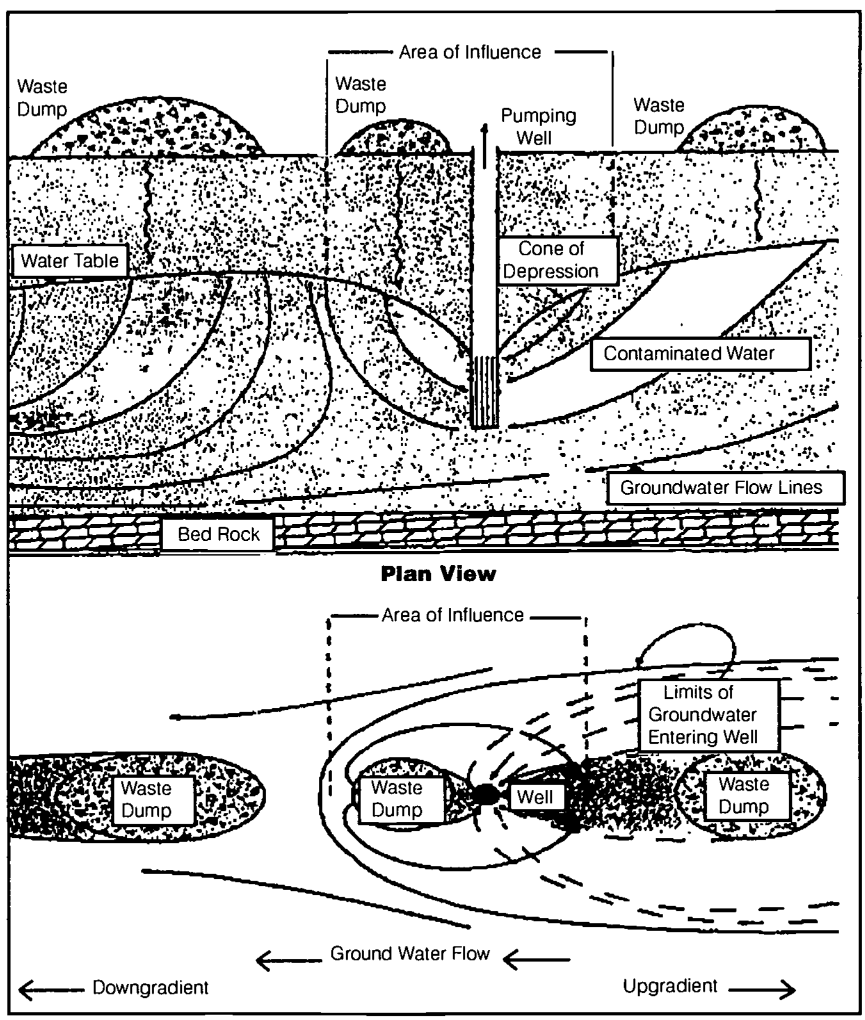
If a given contaminant is not very water soluble, it would not be expected to be very mobile in ground water. Similarly, the density of a contaminant will also affect its mobility; heavy substances will tend to sink to the bottom of the aquifer while lighter ones will float to the top.

Flowing ground water in most aquifers moves very slowly (10 to 1000 feet per year), and most contaminants will generally move with the ground water flow and rate of speed. Very little mixing occurs in the flowing ground water because movement is usually well below turbulent flow conditions. Dispersion may provide some dilution of the contaminant, however in most cases contaminants tend to remain localized and move as a plume through the aquifer.

Under ideal conditions, contaminant movement would take the form of an elliptical plume with well defined boundaries. While ideal conditions are not present in an actual aquifer, contaminants do travel within the ground water, dispersing into three-dimensional "plumes" of contamination. As a result, ground water can be heavily contaminated in one location and free of contamination only a short distance away from the plume.



Containment plume



Groundwater area of influence

Quantity and Quality of Ground Water in Ohio

This section is based on information on file at the Ohio Department of Natural Resources, Division of Water and the publications *Ohio Ground-Water Quality*, U.S. Geological Survey Water-Supply Paper 2325; and *Ohio Ground-Water Resources*, U.S. Geological Survey Water- Supply Paper 2275. The following summary groups the water quantity and quality concerns by aquifer type in Ohio.

Sand and Gravel Aquifers

Sand and gravel aquifers are located along the watercourses of many major streams in Ohio. Waters from these aquifers generally have moderate levels of hardness and relatively low values for total dissolved solids. Sulfate is present in low levels, but iron concentrations are generally high.

Most of the major ground water withdrawals in Ohio are from sand and gravel aquifers. Well yields can exceed 2000 gallons per minute to properly constructed large diameter wells. Many of Ohio's larger urban areas are located near major streams, which in turn have large sand and gravel aquifers. The sand and gravel aquifers of the Great Miami River Valley are the most extensively use aquifers in the state. Sand and gravel aquifers are also used extensively in Stark County, and along the watercourse of the Scioto River.

Shaly Sandstone and Shale Aquifers

The shaly sandstone and shale aquifers are located in south-eastern Ohio. Median dissolved solid concentrations from the shaly sandstone and shale aquifers are 435 mg/L, with a median hardness of 263 mg/L. Most of the water hardness is a calcium-magnesium-bicarbonate type, but some sodium-bicarbonate water is present. Sodium concentrations can be very high in these aquifers.

Shaly sandstone and shale aquifers are among the lowest yielding aquifers in the state. Yields of less than 3 gallons per minute (G.P.M.) are common. Wells are commonly drilled deeper than normal to provide additional casing storage for the water supplies. Cisterns and storage tanks are other common ways to augment the low water yields.

Sandstone Aquifers

Sandstone aquifers are located in the eastern and north-eastern portion of the state. Major dissolved constituents from the sandstone aquifers are lower than the other productive aquifers. Median nitrate levels are below the detection limit.

Several moderately high yielding sandstone aquifers are found in north-east Ohio. The Berea, Massillion, and Sharon Sandstones are capable of sustained yields of 25 G.P.M. with some wells exceeding 100 G.P.M.. In these formations, wells exceeding 300 feet in depth may encounter brine waters.

Carbonate Aquifers

Limestone and dolomite comprise the carbonate aquifers in Ohio. Found in west-central and north-west Ohio, the carbonates are the highest yielding bedrock aquifers in Ohio. The median value for total dissolved solids is 617 mg/L. Some localized waters can exceed 2000 mg/L for dissolved solids with sulfate contributing better than 1000 mg/L to that total. The median levels for these constituents is much greater that of the other aquifer types in Ohio. Natural water quality in the carbonates varies more that the other aquifer types. Calcium-bicarbonate water type is found in regional recharge areas and calcium-sulfate water type is found in discharge areas. In carbonate aquifers, dissolved constituents are lower in recharge area and higher in discharge areas.

The carbonate aquifers provide the only water source for most of west-central and north-western Ohio. Agricultural, industrial and residential users depend on this high yielding bedrock aquifer for their water supplies.

Effect of Land Use on Water Quality

The most widespread groundwater quality problems are:

Bacterial contamination is the largest water quality problem in state. Most contamination of ground water is from on-site sewage systems. Nearly 30 percent of private wells from a 1984 study were found to contain coliform bacteria by the Ohio Department of Health. Studies have found up to 43% of the samples from public water supplies have returned from the laboratory as unsafe. Many times the geology of a site exacerbates the bacterial problems. Areas of carbonate bedrock with very little overburden seem to be particularly susceptible to both bacterial and nitrate contamination.

Nitrates contamination continues to be a serious ground water concern. Major nitrate sources are faulty on-site septic systems, and the over application of fertilizer.

Coal mining in the south-eastern portion of the state has contributed to ground water quality problems. Acid mine drainage, containing a high concentration of heavy metals, has contaminated both surface and ground waters in the region. No extensive study to date has detailed the complete impact of coal mining activities in Ohio.

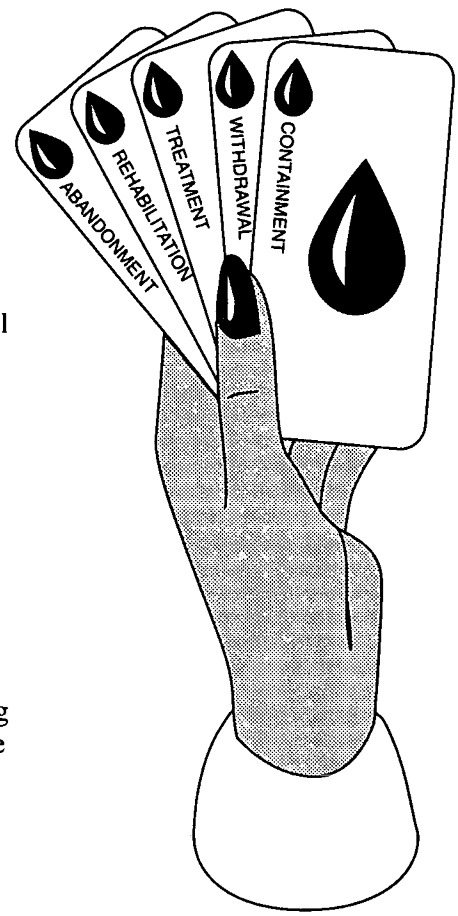
Oil and Gas production provides the risk of brine contamination to the ground water system. Several areas in north-eastern Ohio have brine contamination in shallow aquifer systems.

The effects of heavy urbanization of rural environments puts many high-yielding aquifers at risk. Sand and gravel aquifers are especially sensitive to surface spills or mismanagement of solid waste. Better land use planning is important to preserving water quality in these sensitive areas.

Cleaning Contaminated Ground Water

What Can Be Done After Contamination Has Occurred?

Unlike rivers, lakes, and streams that are readily visible and whose contamination frequently can be seen with the naked eye, ground water itself is hidden from view. Its contamination occurs gradually and generally is not detected until the problem has already become extensive. This makes cleaning up contamination a complicated, costly, and sometimes impossible process.



Attenuating Health or Environmental Hazards

Processes that attenuate (dilute or weaken in severity) the contaminants in ground water may reduce or eliminate the toxicity or environmental hazards associated with the contaminants. Aquifer geology can play a role in this process because different soils have different capacities to bring about the attenuation of organic and inorganic substances. Plant activity in the root zone may transform or degrade chemical substances and may take up mineral salts and remove some heavy-metal ions. Other individual processes that act to attenuate contaminants include adsorption, hydrolysis, volatilization (from soil), mechanical filtration (during seepage through the soil), neutralization, ion exchange and microbial (aerobic and anaerobic) transformation and degradation.

Unfortunately, very little dilution of contaminants occurs in ground water. Over a given transport distance, concentrations would not decrease as much in ground water compared to what would occur in surface waters.

Aquifer Restoration

The difficulty, time requirements, and expense involved in containing or cleaning contaminated ground water clearly point to protection as the best option for ground water management. However, once a contaminated aquifer has been detected, it is necessary to decide what remedial action, if any, should be taken. Some considerations are:

- The importance of the aquifer
- The nature and type of contaminant
- Geohydrology of the aquifer
- Availability and applicability of treatment methods
- Resources available
- Alternative water supplies

Options for action include:

- Containment of the plume
- Monitoring the plume without cleanup
- Removal of the contamination

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Considering the present state of treatment technologies, remediation may not be possible in some cases. Furthermore, because restoring an aquifer is difficult and time consuming, the costs associated with an aquifer restoration program must be determined on a case-by-case basis. They may range from several thousand to several billions of dollars.

Understanding the Problem

In deciding remedial action for a contaminated aquifer, a logical first step is a preliminary assessment of the nature and extent of the problem to determine the threat to human health and the environment. A number of site-specific factors must be investigated before control measures or cleanup activities are started. Some of the major factors to consider include:

- The source and extent of the contamination
- The toxicity and concentration of the contaminant or contaminants
- Local geology and soil types
- Depth and volume of the aquifer
- Intended use of the aquifer

Next a course of action is developed and implemented, followed by monitoring to determine the effectiveness of the control or restoration program.

Ground Water Treatment Technologies

Technology	Contaminants Treated	Status	Relative Energy Requirements	Relative Cost	Comments
Air stripping	VOC	Developed	Low	Low	Secondary air emissions
Steam Stripping	VOC, DO	Developed	Moderate	Moderate	"Reg phase" upsets
Granular activated carbon (GAC)	DO	Developed	High	High	Regeneration of spent carbon
Clarification/ precipitation	SS, DS, DM	Developed	Moderate	Low to moderate	Sludges or mud containing heavy metals, disposal concerns
Wet Air oxidation	DS	Developed	Moderate to high	Moderate to very high	Effluent may require further treatment prior to discharge
Ion exchange	DS, DM	Developed	Low	Moderate	Disposal of regeneration solution; disposal of resin bed
Biological (aerobic and anaerobic)	DO, SS, DS, VOC, DM	Developed	Moderate	Moderate to high	Large space requirements; bacterial solids disposal; subject to upsets
Reverse osmosis	DO, DS, DM	Pilot	Low to moderate	Moderate to high	Pre-treatment needed to prevent plugging; some chemicals may attack RO membrane
Ozone/UV radiation	DO, DS, VOC	Pilot	Moderate	Variable	Experimental to pilot-scale tests
Insitu (biological)	DO, DS	Pilot	Low	Variable	Experimental stage; no extensive field demonstration

Key: VOC=volatile organic chemical; DO=dissolved organic chemical; DS=dissolved solids; SS=suspended solids; DM=dissolved metals

Treatment Techniques

Table 1 contains some of the treatment technologies for ground water remediation. The type of contaminant removed, relative energy requirements, relative treatment costs and general comments, where applicable, are reviewed for each treatment method.

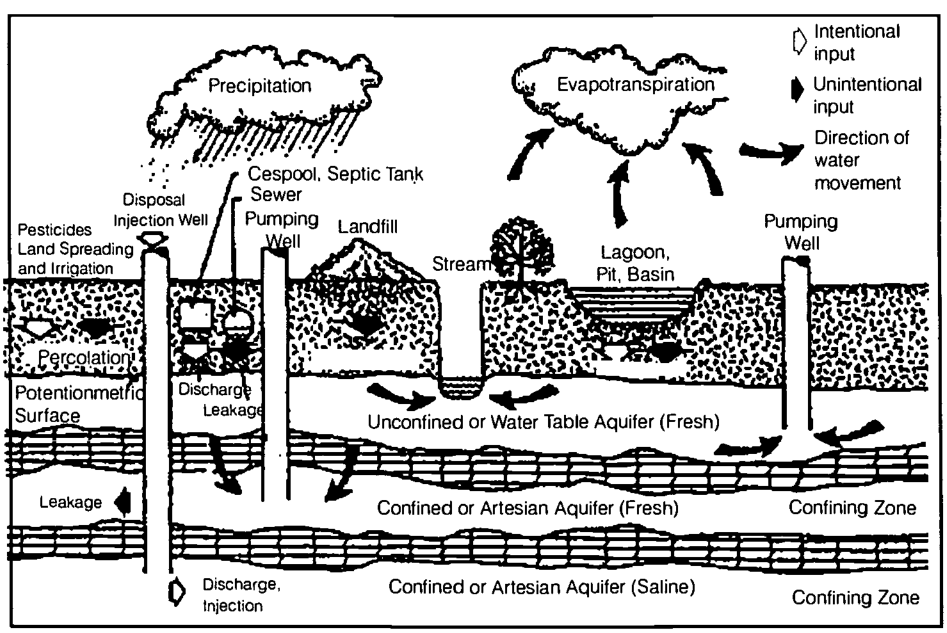
Community Options

In general, a community whose ground water supply has been contaminated has five options:

- Contain the contaminants to prevent their migration from their source.
- Withdraw the pollutants from the aquifer.
- Treat the ground water where it is withdrawn or at its point of use.
- Rehabilitate the aquifer by either immobilizing or detoxifying the contaminants while they are still in the aquifer.
- Abandon the use of the aquifer and find alternative sources of water.

All of the options are costly. For example, a community in Massachusetts chose a treatment option when the wells supplying its public water system were contaminated by more than 2,000 gallons of gasoline that had leaked into the ground from an underground storage tank less than 600 feet from one of the wells. The town temporarily provided alternative water supplies for its residents and then began a cleanup process that included pumping out and treating the contaminated water and then recharging the aquifer with the treated water. The cleanup effort alone cost more than $3 million.

Because of the high costs and technical difficulties involved in the various containment and treatment methods, many communities will choose to abandon the use of the aquifer when facing contamination of their ground water supplies. This requires the community to either find other water supplies, drill new wells farther away from the contaminated area of the aquifer, deepen existing wells, or drill new wells in another aquifer if one is located nearby. As Atlantic City, New Jersey, found, these options also can be very costly for a community. The wells supplying that city's public water system were contaminated by leachate from a landfill. The city estimated that development of a new wellfield would cost approximately $2 million.



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Government Ground Water Protection Activities

Given the importance of ground water as a source of drinking water for so many communities and individuals and the cost and difficulty of cleaning it up, common sense tells us that the best way to guarantee continued supplies of clean ground water is to prevent contamination.

Federal Laws and Programs to Protect Ground Water

The U.S. Environmental Protection Agency (EPA) is responsible for federal activities relating to the quality of ground water. EPA's ground water protection activities are authorized by a number of laws, including:

- The Safe Drinking Water Act, which authorizes EPA to set standards for maximum levels of contaminants in drinking water, regulate the underground disposal of wastes in deep wells, designate areas that rely on a single aquifer for their water supply, and establish a nationwide program to encourage the states to develop programs to protect public water supply wells (i.e., wellhead protection programs).
- The Resource Conservation and Recovery Act, which regulates the storage, transportation, treatment, and disposal of solid and hazardous wastes to prevent contaminants from leaching into ground water from municipal landfills, underground storage tanks, surface impoundments, and hazardous waste disposal facilities.
- The Comprehensive Environmental Response, Compensation, and Liability Act (Superfund), which authorizes the government to clean up contamination caused by chemical spills or hazardous waste sites that could (or already do) pose threats to the environment, and whose 1986 amendments include provisions authorizing citizens to sue violators of the law and establishing "community right-to-know" programs (Title III).
- The Federal Insecticide, Fungicide, and Rodenticide Act, which authorizes EPA to control the availability of pesticides that have the ability to leach into ground water.
- The Toxic Substances Control Act, which authorizes EPA to control the manufacture, use, storage, distribution, or disposal of toxic chemicals that have the potential to leach into ground water.
- The Clean Water Act, which authorizes EPA to make grants to the states for the development of ground water protection strategies and authorizes a number of programs to prevent water pollution from a variety of potential sources.

The federal laws tend to focus on controlling potential sources of ground water contamination on a national basis. Where federal laws have provided for general ground water protection activities such as wellhead protection programs or development of state ground water protection strategies, the actual implementation of these programs must be by the states in cooperation with local governments.

A major reason for this emphasis on local action is that protection of ground water generally involves making very specific decisions about how land is used. Local governments frequently exercise a variety of land-use controls under state laws.

State Laws and Programs to Protect Ground Water

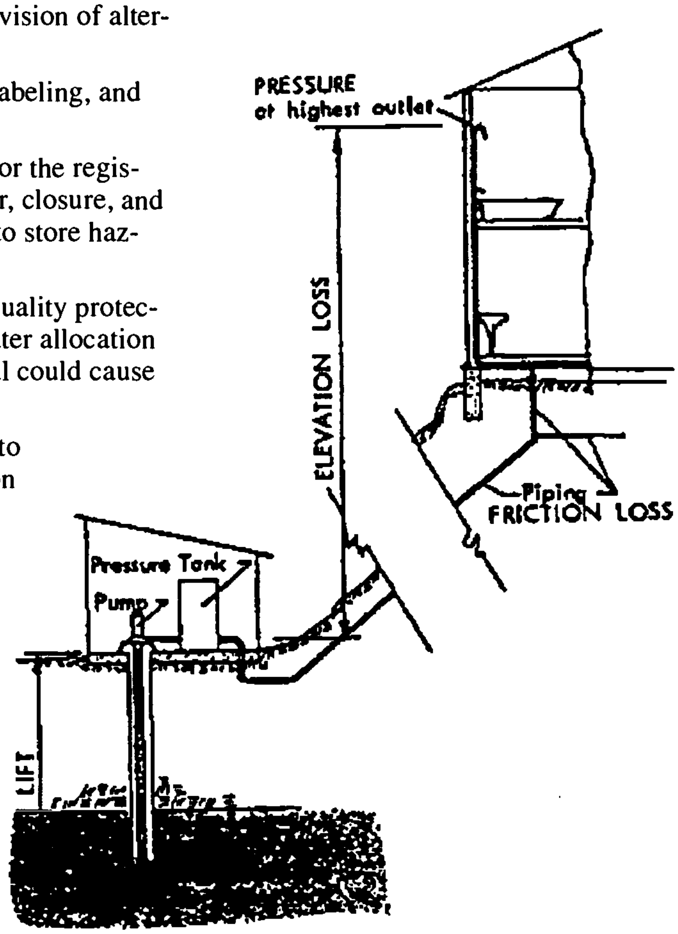
According to a study conducted for EPA in 1988, most of the states have passed some legislation and developed some kind of ground water policies. State ground water legislation can be divided into the following subject categories:

- Statewide strategies—Requiring the development of a comprehensive plan to protect the state's ground water resources from contamination.
- Ground water classification—Identifying and categorizing ground water sources by how they are used to determine how much protection is needed to continue that type of use.
- Standard setting—Identifying levels at which an aquifer is considered to be contaminated.
- Land-use management—Developing planning and regulatory mechanisms to control activities on the land that could contaminate an aquifer.
- Ground water funds—Establish specific financial accounts for use in the protection of ground water quality and the provision of compensation for damages to underground drinking water supplies (e.g., reimbursement for ground water cleanup, provision of alternative drinking water supplies).
- Agricultural chemicals—Regulating the use, sale, labeling, and disposal of pesticides, herbicides, and fertilizers.
- Underground storage tanks—Establishing criteria for the registration, construction, installation, monitoring, repair, closure, and financial responsibility associated with tanks used to store hazardous wastes or materials.
- Water-use management—Including ground water quality protection in the criteria used to justify more stringent water allocation measures where excessive ground water withdrawal could cause ground water contamination.

Although the Clean Water Act does not require states to develop ground water protection strategies, the legislation authorizes states to take this action. As of 1989, all 50 states have at least begun to develop ground water protection strategies, and some of these are in advanced stages. Proceeding at various paces, the states are tailoring their efforts to fit their own perceived needs and budgets.

Wellhead Protection

In addition to ground water protection programs states may have developed under their own laws, one state ground water protection program is required by federal law. The 1986 amendments to the Safe Drinking Water Act established the wellhead protection program and require each state to develop compre-



Wellhead

hensive programs to protect public water supply wells from contaminants that could be harmful to human health. Wellhead protection is simply protection of all or part of the area surrounding a well from which the well's ground water is drawn. This is called a wellhead protection area (WHPA). The size of the WHPA will vary from site to site depending on a number of factors, including the goals of the state's program and the geologic features of the area.

The law specifies certain minimum components for the wellhead protection programs:

- Roles and duties of state and local government and public water suppliers in the management of wellhead protection programs are established.
- The protection area for each wellhead is defined.
- Contamination sources within the protection area are identified.
- Strategies for protecting the water supply within the protection area from contamination sources must are developed.
- Provisions are established for siting new wells to produce maximum water yield and reduce the potential for contamination as much as possible.
- Provisions for public participation in the process are included.

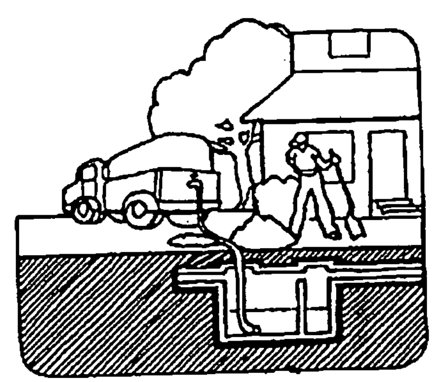
Local Strategies in Your Community

Because no two communities are exactly alike in terms of hydrogeologic conditions, resources, or problems, ground water protection efforts need to be tailored specifically to meet the needs of each community.

In addition to having an incentive to protect ground water, communities have a number of powers that can be used for that purpose. These include implementing zoning decisions, developing land-use plans; overseeing building and fire codes; implementing health requirements; supplying water, sewer, and waste disposal services; and using their police powers to enforce regulations and ordinances.

A few communities have begun developing their own ground water protection programs using a variety of management tools based on these powers. These management tools include:

- Zoning ordinances—To divide a municipality into land-use districts and separate incompatible land uses such as residential, commercial, and industrial. Zoning also defines the type of activity that can occur within a district and specifies appropriate regulations that can be used to prevent activities that could be harmful to the community's ground water.
- Subdivision ordinances—Applied when a piece of land is actually being divided into lots for sale or development to ensure that growth does not out pace available local facilities such as roads, schools, and fire protection. Subdivision ordinances also can be used to set density standards, require open space set asides, and regulate the timing of development, all of which can have significant impacts on ground water quality.
- Site plan review—To determine if a proposed development is compatible with existing land uses in the surrounding area and if



existing community facilities will be able to support the planned development. This review also can be used to determine compatibility of the proposed project with any ground water protection goals.

- Design standards—To regulate the design, construction, and ongoing operation of various land-use activities by imposing specific physical requirements such as the use of double-walled tanks to store chemicals underground.
- Operating standards—To ensure the safety of workers, other parties, and the environment by specifying how an activity is to be conducted. These can take the form of best management practices (BMPs) that define a set of standard operating procedures for use in a particular activity to limit the threat to the environment (e.g., limits on pesticide applications or animal feedlot operations).
- Source prohibitions—To prohibit the storage or use of dangerous materials in a defined area. These can take the form of prohibitions of certain activities or of restrictions on the use of certain materials.
- Purchase of property or development rights—To guarantee community control over the activities on lands that feed water into an aquifer. This may involve outright purchase of the land or of a more limited interest such as surface-use rights.
- Public education—To build community support for regulatory programs, such as controls on pollution sources in special zoning districts, and to motivate voluntary ground water protection efforts, such as water conservation or household hazardous waste management.
- Ground water monitoring—To assess the quality of local aquifers by sampling public and private wells for selected contaminants.
- Household hazardous waste collection—To alleviate the threat to ground water from the disposal in regular trash collection, sewers, or septic systems of household products that contain hazardous substances or other materials that can be harmful to ground water, such as paints, solvents, or pesticides.
- Water conservation—To reduce the total quantity of water withdrawn from ground water aquifers and to protect against contamination by reducing the rate at which contaminants can spread in the aquifer (e.g., excessive withdrawals from an aquifer located near the ocean can draw salt water into the aquifer and contaminate wells.

Citizen Roles

Understand State and Local Ground Water Protection Programs

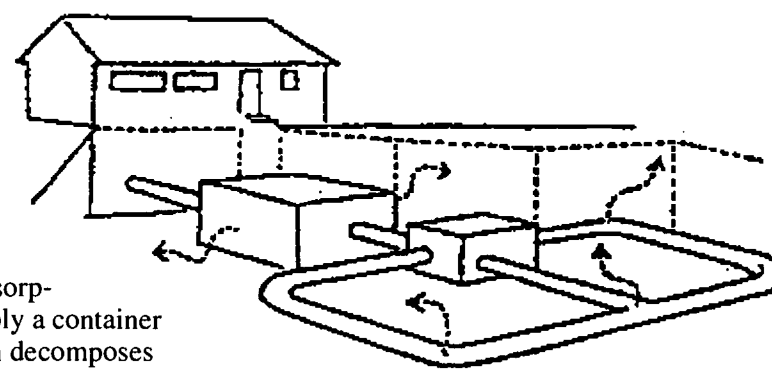
Citizens interested in working to help protect ground water need to know what is being done at the state and community level to protect ground water. Usually the best way to get this information is to begin asking questions. The EPA publication, "Citizen's Guide to Ground water Protection" (EPA 440/6-90-004), describes some of the questions that might be asked and to whom the questions should be directed.

Dispose of Polluting Materials Used in Your Home Responsibly

The way you dispose of products you use at home can contribute to the contamination of your community's ground water. Although this topic will be covered in more depth in later chapters, you should know that products like motor oil, pesticides, left-over paints or paint cans, mothballs, flea collars, weedkillers, household cleaners, and even a number of medicines contain materials that can be harmful to ground water and the environment in general. The average American disposes of approximately one pound of this type of waste each year. So, although the amount of any of these substances that you pour down your drain, put in your trash, or dump on the ground may seem insignificant to you, try multiplying it by the number of people in your community. That amount may not seem so insignificant.

Take Care of Your Septic System

For years man has disposed of his bodily wastes in a variety of ways that reflect convenience, economy, or ignorance. About 25 percent of all homes in the United States have septic systems. Estimates of the number of units in use range from 18 to 22 million. The annual volume of wastewater effluent discharged from these units is approximately 800 billion gallons. It is also estimated that 80 percent of home septic sewer systems are more than 20 years old and are a significant cause of pollution to groundwater and nearby lakes and streams due to raw sewage from inadequate and failing septic systems.



A septic system is comprised of three portions: septic tank, distribution system, and treatment/absorption trenches (leach or tile field). The tank is simply a container into which wastes are discharged. Bacterial action decomposes some of the solids and organic materials. The distribution system conveys the septic tank effluent to the leach field. The successful operation of the septic system depends on proper construction of the distribution system. The leach field must be properly constructed to allow effluent into the soil for further digestion by bacteria and absorption of nutrients by the soil particles.

Septic systems fail for a variety of reasons. The two most common problems are lack of regular maintenance and improperly functioning leach fields. Maintain the septic system by cleaning out the tank every three years. Removal of built of solids will increase the systems effectiveness. Remember a septic system is designed to have its effluent discharge into a drainage field where it undergoes some decomposition by micro-organisms in the soil as it works it way down to ground water. The important thing to remember is that anything in the effluent discharge may end up in your ground water ... what do you want to drink? For more information on home septic systems contact the your local County Extension office.

Use Lawn and Garden Chemicals Appropriately

While this topic will be discussed in another chapter, it is important to know that your gardening and landscaping practices can have an adverse impact on ground water. Eliminating the use of pesticides or using them with care is vitally important.

Get Involved

Around the country, citizens are getting involved in their communities, volunteering their time and energy, and making a difference.

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Agriculture and Water Quality

Food and Water for the Future

Agriculture and Water Quality: Food and Water for the Future

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Ohio—An Agricultural State

Agriculture is the number one industry in the state of Ohio. Data compiled for 1994 shows Ohio's rank as 14th for Net Farm Income. This is very impressive for a State ranking 35th in the nation for total acreage and seventh in population. Ohio's leading industry is food and agriculture with an economic output in commodity sales alone reaching $8 billion. Agriculture contributes $56.2 billion to Ohio's economy and employs one-in-six Ohioans. Major crops are listed in the sidebar, "Ohio's Top Crops."

According to 1995 statistics, Ohio has 74,000 farms with an average size of 205 acres. Nationwide farms number 2,073,320 with average size being 469 acres. Approximately 15.2 million acres of land are farms. A farm is defined as a place with an annual sales of agricultural commodities of $1000 or more.

Today's farmers are well-educated; many use computer technology and high-tech equipment. They belong to farm associations, read trade publications, and treat their farm as a serious business. Many of today's farmers worry about the viability of the industry, the future of the profession for their children, and if they are a vanishing breed.

OHIO'S TOP CROPS

Crop	OHIO Value of Production/Dollars 1995	U.S Value of Production/Dollars 1995
Corn for Grain	1,200,320,000	23,145,365,000
Corn for Silage	—	—
Winter Wheat	291,550,000	6,689,092,000
All Wheat	291,550,000	9.744,472,000
Soybeans	1,041,352,000	14,564,196,000
Oat	11,730,000	265,773,000
Rye	720,000	27,778,000
Potatoes	9,407,000	2,799,067,000
Mushrooms (agaricus)	15,409,000	730,710,000
Sugar Beets	5/	5/
Tobacco-Burley	32,213,000	2,444,319,000
All Hay	309,525,000	10,977,122,000
Alfalfa Hay	239,400,000	6,779,524,000
All Other Hay	70,125,000	4,197,598,000
Strawberries	4,200,000	753,434,000
Apples	20,310,000	1,808,788,000
Peaches	2,442,000	412,607,000
Grapes	2,029,000	1,822,339,000

Crop	OHIO Value of Production/Dollars 1995	U.S. Value of Production/Dollars 1995
Fresh Market		
Sweet Corn	21,923,000	392,491,000
Celery	399,000	269,163,000
Snap Beans	3,219,000	160,113,000
Cabbage	4,694,000	277,030,000
Cantaloups	1,263,000	383,198,000
Escarole/Endive	2,610,000	14,102,000
Leaf Lettuce	1,984,000	300,523,000
Romaine	2,045,000	223,860,000
Onions (Storage)	1,373,000	634,344,000
Tomatoes	15,792,000	852,508,000
Bell Peppers	4,437,000	409,869,000
Fresh Market Total	**60,684,000**	**7,425,060,000**
Processing		
Tomatoes	20,738,000	650,310,000
Cucumbers	9,505,000	133,866,000
Processing Total	**32,589,000**	**1,401,236,000**

Water Quality Concerns about Agricultural Runoff

The main water quality issues for agriculture relate to what is carried into surface water or ground water. Water runoff from cropland may contain soil, crop nutrients, pesticides, animal wastes, and other organic matter. The loss of nutrients and pesticides from cropland can lower crop productivity, reduce pest control, and increase production costs. In addition, soil losses may eventually lower the productive capacity of farmland.

Each of the compounds which can reach water supplies has different effects on water resources. The movement of these various elements and compounds into water resources also affects water quality and may alter the habitat for fish and other wildlife. Spawning grounds for the fish are often damaged or destroyed as soil settles to the bottom of streams, rivers, and lakes. In addition, the water-holding capacity of reservoirs is reduced, increasing the risk of flooding and reducing recreational opportunities.

The flow of nutrients (usually in the form of nitrates and phosphates) into water can alter delicate water balances. Excessive growth of algae and water plants may be stimulated by the flow of commercial fertilizers and animal wastes delivered to water bodies. Short term, these provide additional food and cover for fish that inhabit streams and ponds. But eventually, algal blooms will reduce dissolved oxygen levels through nighttime respiration and upon death and decomposition of algae. An oxygen sag can then occur, stressing fish and other aquatic life. Nitrates, which are acidic, may further aggravate water acidity problems; evidence indicated that excess acidity can slow fish growth and cause improper reproduction in some species. Excessive nitrates in drinking waters pose a health hazard to pregnant women and young children.

Pesticides have been detected in both surface and ground water sources used for drinking water. At certain levels these compounds can pose a health risk for humans. A variety of chemical compounds, including certain pesticides, may cause fish kills if introduced into water at excessive levels. Some pesticides can accumulate in the flesh of fish, where they may present health risks to other wildlife and humans who consume them.

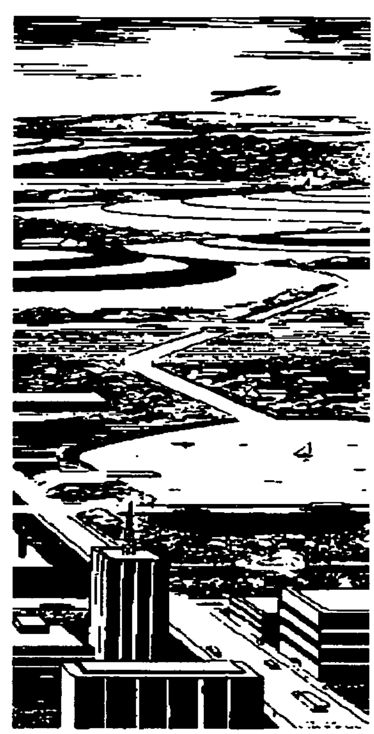
Animal waste poses several concerns when it enters water bodies. Ammonia can be one of the most damaging pollutants found in manure. Even small concentrations of ammonia can be toxic to fish. The toxicity depends on the pH, temperature, and dissolved oxygen content of the stream. Fish are more susceptible to ammonia in high pH, low oxygen streams in the summer. Animal wastes can also contaminate water with disease causing microorganisms known as pathogens. Animal waste contamination may be an additional source of stream nutrients that could eventually lead to increased eutrophication of the stream or lake. When determining water quality, what you see is not always what you get. A fishing area or beach that looks inviting may be marked with a "No Fishing" or "Beach Closed" sign because of contamination.

This chapter will discuss the concerns of agricultural runoff: what it is, why the worry, and what some alternatives are. Then it will describe some of the promising strategies to keep contaminants out of the water. Another section will look at some practices that landowners can employ—whether they are commercial or noncommercial farmers, large or small landholders, or even suburban homeowners—to manage their property to keep animal wastes, fertilizers, pesticides, and sediment out of the water. By changing some of our habits we can maintain the quality of life in rural areas and lessen impacts downstream.

Agriculture Runoff in Ohio

The Ohio EPA and other state and federal agencies have developed the water quality standards for Ohio's water resources. Designated uses or goals have been determined for surface water based on scientific information about its present and potential uses. If a water body can't meet certain numeric or narrative criteria, it is considered impaired. In Ohio, agricultural practices are one of several sources of stream pollutants that lead to stream impairment. According to Ohio EPA's *1994 Ohio Water Resource Inventory* the major sources of impairment are: point sources (2058 miles), habitat modification (817 miles), agriculture (712 miles), mining (595 miles), urban runoff (184 miles), miscellaneous sources (464 miles), on-site septic systems, landfills, and hazardous waste sites (139 miles).

According to the Ohio Department of Natural Resources, agriculture is Ohio's largest source of nonpoint source pollution. Nonpoint source pollution refers to pollution that cannot be traced to a single point of origin or source. It states that agriculture adversely affects 78% of Ohio's perennial stream miles, and over 60% of the public lakes and reservoirs. The major agricultural related pollutants are sediment, organic wastes, nutrients, and pesticides. Livestock facilities have in some cases contributed to beach closings due to high bacteria levels at beaches in several state and regional parks. Nitrogen losses from cropped fields have caused drinking water violations. Phosphorus runoff has created serious oxygen depletion and aquatic weed problems in the state's surface water bodies. In Ohio, pesticides are not as great of a problem as sediment, nutrients, and animal waste but are a concern in shallow or poorly constructed rural wells and some public drinking water supplies. In addition to agriculture, suburban development has been sited by the Ohio EPA as rapidly becoming a significant source of nonpoint source pollution.



Data for Ohio pesticide contamination is limited so definitive statements about the extent of contamination can't be made. Although the data is limited, one interpretation is that pesticide contamination in ground water although present in Ohio is not widespread. The highest documented cases of pesticide contamination in Ohio ground water are associated with spills and mishandling of pesticide at mixing and loading sites. The current evaluation of available data suggests that pesticide contamination of surface water is of greater concern than pesticide contamination of ground water. Ohio's glacial geology, tiled crop lands, and soil types seem to provide a natural barrier to ground water contamination by pesticides. Extensively tiled areas tend to limit the transport of soluble pesticides to ground water (Ohio Department of Agriculture, 1996).

Ohio surface water appears to be more vulnerable to pesticide contamination than ground water. Short term elevated levels of atrazine and alachlor (exceeding four times the maximum contaminant level) have been found when storms produce surface runoff following application of pesticides. Short term elevated levels are limited to May, June, and July because of pesticide application timing. Herbicides can be carried dissolved in runoff or on the surface of eroded soil particles. Runoff risk is greatest when rains follow closely an herbicide application to crops located on steep slopes (Ohio Department of Agriculture, 1996).

It is important to note that since the Nonpoint Source Management Program was first implemented in 1989, Ohio's progress on controlling agricultural nonpoint pollution control has been substantial. Achievements include: establishment of 13 local manure and nutrient management programs, dramatic increase in conservation tillage, and the development of phosphorus reduction steering committees for all Lake Erie Basin counties. The future of agricultural pollution control is bright. Greater public attention is resulting in more state and federal resources being applied, and there is a growing acceptance on the part of agricultural producers to accept more responsibility for environmental concerns linked to agriculture.

Agricultural Chemicals

Pesticide Hazards: An Overview

Pesticide is an all inclusive word which means "killer of pests." Insecticides, herbicides, and fungicides are all classes of pesticides. A pesticide is rarely used in its concentrated form. Pesticides are processed with other ingredients and sold as formulations. The formulation process improves storage, handling, application effectiveness, or safety. Pesticides are sold in 20,000 formulations in the U.S. Pesticides vary considerably in their toxic effects upon humans and vertebrate animals. Some are toxic only at large doses, others can be transmitted through skin contact, still others are quite selective—affecting some animals but not others. Knowing something about the toxic properties of pesticides can help growers gain confidence in control efforts, and assure that the proper amount of care is being given to selection, handling, application, and disposal.

Many steps have been made over the past 20 years to reduce pesticide pollution potential from agricultural lands. Highly atoxic, persistent chemicals like DDT, endrin, and heltachlor have been replaced by "softer," less persistent chemicals. Most newer pesticides break down into less toxic organic compounds 9 to 20 weeks after application, and are aimed at specific pest targets. Another on-going adjustment is the shift toward postemergent chemicals. This application strategy matches pesticides directly to pest control needs rather than simply assuming a pest is present. Other steps being taken by both industry and government include increasing grower awareness on correct spraying, scouting promotion, broadening product testing, and expanding product safety programs.

If pesticides are safer today, why be concerned? What happens to pesticides once they leave fields and enter water systems is not well understood. Of particular concern is the present lack of knowledge about the environmental and human health effects of long-term, low-level exposure. What happens when several compounds come into contact with each other may be more important than the effects of a single compound alone. Finally, when it comes to pesticide pollution, prevention must be given the highest priority. Efforts to remove or neutralize pollutants in water systems are extremely costly—or perhaps impossible as in the case of most ground water aquifers. Natural flushing to reduce pollutant levels may take years.

The knowledge, attitudes, and skills of growers will play an increasing important role in reducing pollution potential. Now that pesticides are being made safer and less persistent, responsibility for properly selecting, applying, and disposing will be shifting toward agri-chemical users. Each grower and pesticide applicator must be willing to do all that is reasonably possible to prevent polluting water supplies.

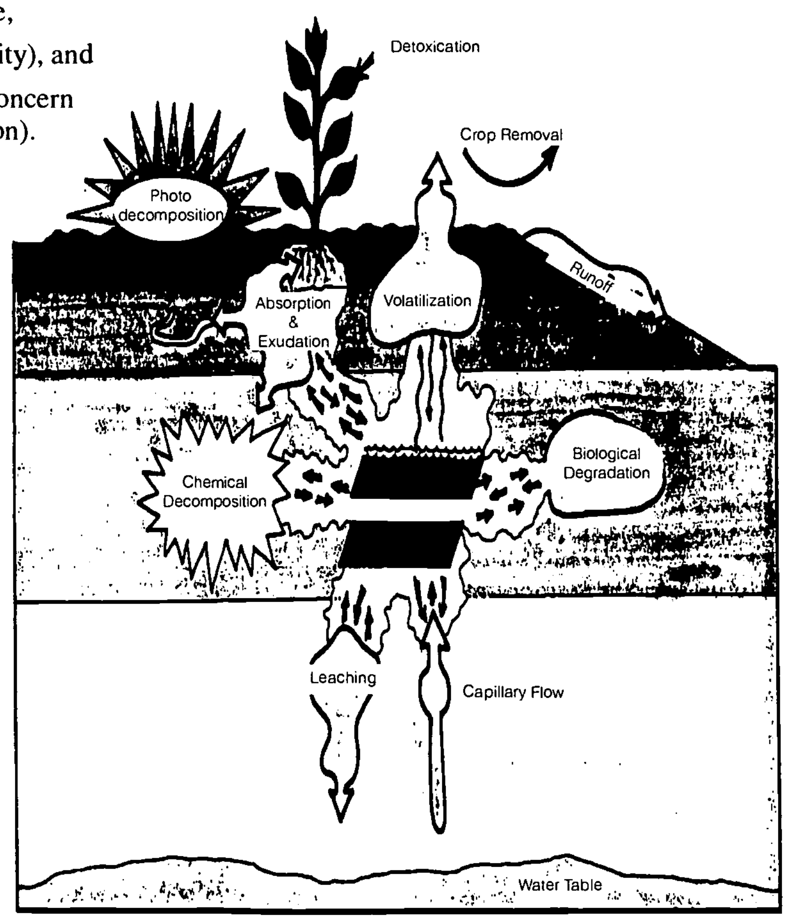
Understanding Pesticide Pollution

Pesticide pollution results from a complex set of interactions between agriculture chemicals, agricultural practices, soil conditions, and climatic events. A pesticide becomes a pollutant when it leaves a field prior to degradation (breaking down into non-toxic, organic compounds). Pesticides may then be carried into surface waters, dissolved in runoff, or adsorbed to organic matter and soil particles. Pesticides may enter into ground water by leaching. All soils and landscapes are not equally prone to pesticide pollution. Areas with coarse-textured soils; shallow, low organic matter content soils; near-surface, fractured bedrock; or steep slopes have greater susceptibilities to pesticide pollution. Excessive rainfall, erosion, misapplication of pesticides, improper tillage practices, and excessive irrigation are events—or activities—which can cause pesticide loss.

Soil scientists and environmental researchers have found that several factors play key roles in determining the concentration of pesticides in water and sediment. The factors are:

- amount of pesticide present,
- pesticide persistence,
- location of pesticides in the soil profile,
- pesticide soil attraction (soil adsorptivity), and
- pesticide water solubility (important concern in areas prone to ground water pollution).

The amount present establishes initial concentration levels. Amount present includes that which was applied plus any carryover from the previous year. Pesticides degrade or breakdown at different rates. A pesticide's persistence is important because the longer it remains in the soil profile as an active compound, the greater the chance that it will be moved into surface or ground water systems. Location affects concentrations of pesticides in runoff. Application methods that leave pesticides on the soil surface will increase concentrations in runoff over techniques that soil-incorporate pesticides. Soil adsorption measures a pesticide's attraction for soil over water. Pesticides with a high soil attraction tend to move with sediment (erosion), whereas pesticides with a low soil attraction are more likely to move with water in solution. Clay particles and organic matter provide excellent adsorption sites for pesticides.



Water solubility provides an indicator of how readily pesticides may go into solution and move downward with leaching processes. Scientists have found that pesticides with water solubilities above 30 ppm tend to pose greater ground water pollution risks.

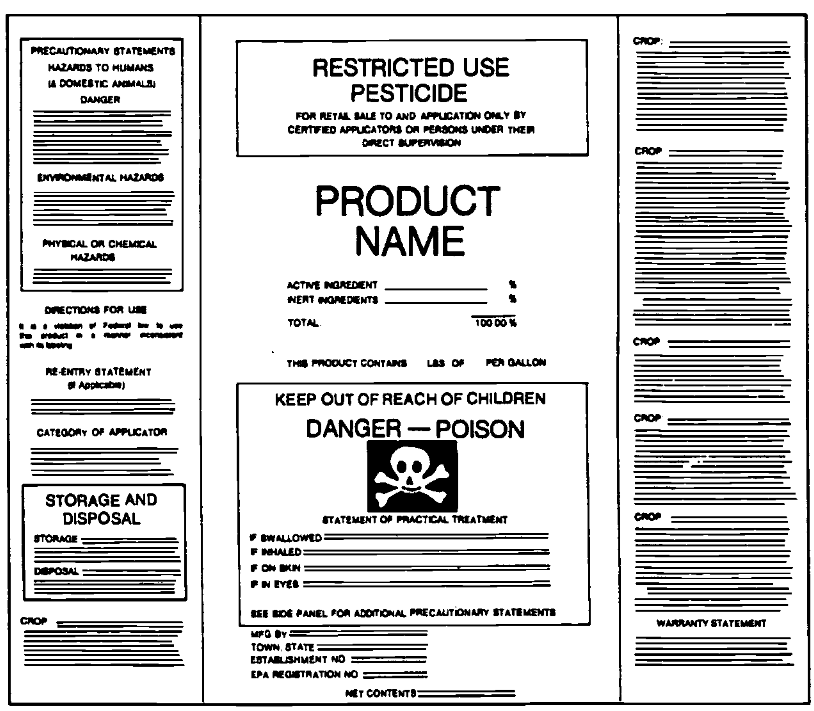
Pesticide pollution begins when water moves compounds beyond the intended zone of pest control. Research continues to show that most serious losses (more than two percent of the amount applied) occur during a two-week period after application. Exceptions to this finding would include when pesticides are soil incorporated or when pesticides have a long persistence. During this critical period, storms that produce significant runoff and/or erosion can move pesticides well beyond the intended zone of pest control. Soil infiltration capacities at the time of precipitation greatly influence the amount and type of pesticide movement.

Agricultural practices and soil conditions that favor runoff over infiltration have the potential to increase pesticide losses (e.g., compact soils, excessive tillage, steep slopes). The reasons for this fact are two-fold:

1. Many agricultural pesticides move readily with surface water because they are not strongly attracted to soil.
2. On a weight or volume basis, runoff greatly exceeds sediment during storm events.

Wisconsin findings show that runoff losses can exceed sediment losses by a 100:1 to 200:1 ratio. While soil concentrations of pesticides can be high if erosion occurs right after application, in looking at the entire growing season, runoff remains the major loss mechanism. Conservation practices that focus primarily on sediment control may have limited effects on total pesticide loss.

Practices that increase pesticide movement into the soil generally do not significantly increase the threat of ground water pollution. Clay and organic matter can adsorb large amount of pesticides. In addition, because degradation begins as soon as compounds enter the soil environment, both concentrations and amounts decrease with time. Agricultural practices that encourage infiltration should have small to negligible effects on ground water where soils have sufficient depth (4 feet or over), good clay and organic matter content, and slow to moderate permeability. Extra precautions will continue to be needed on coarse-textured soil with low organic matter content and light soils under irrigation. Pesticides with a longer persistence, high water solubility, and/or low soil attraction will require extra attention in all higher risk areas.



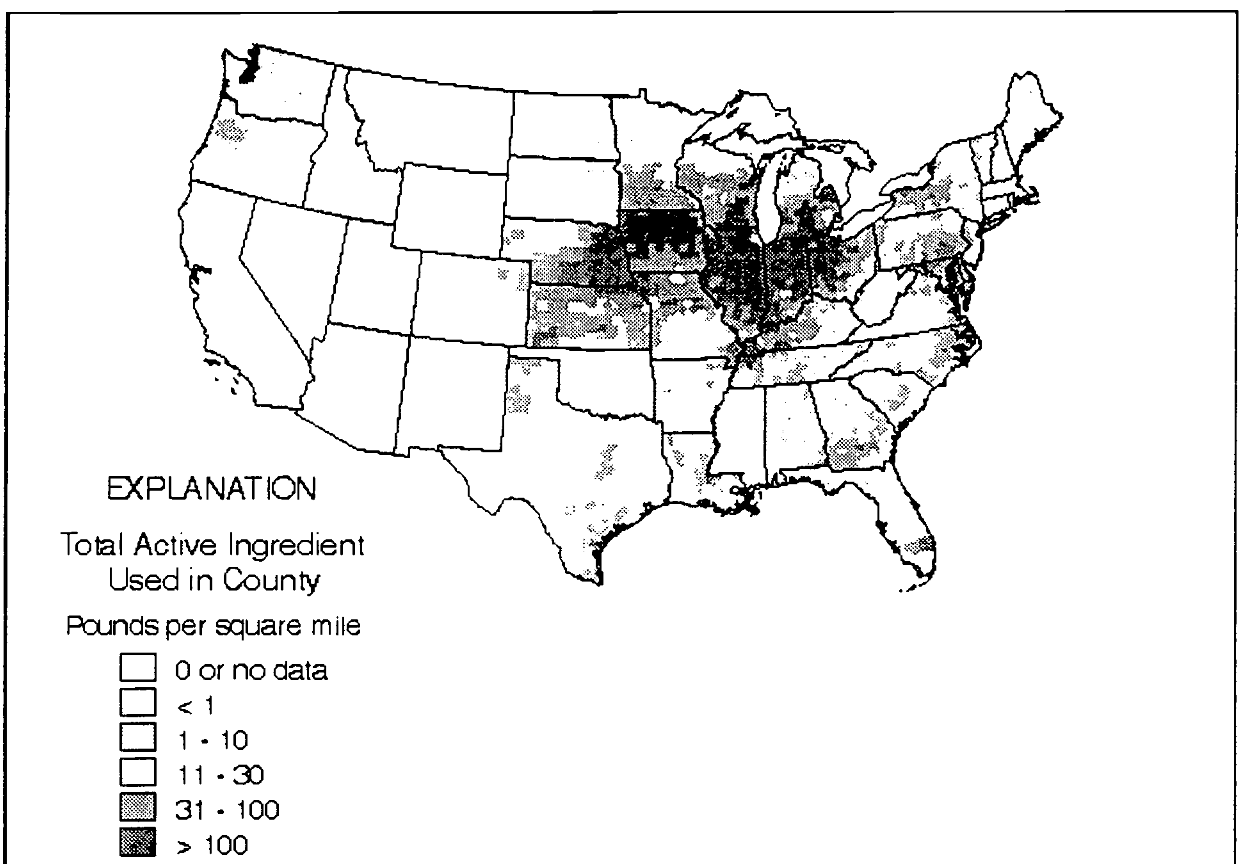
Pesticide losses can be kept to negligible levels with good management, but considerable losses are possible when basic rules are ignored.

Pesticide Registration

All pesticide products in the U.S. must be registered by the EPA. To get a product registered, the manufacturer has to provide evidence that the product will control the pests listed on the label, not injure humans, crops, livestock, wildlife, or damage the total environment, and not result in illegal residues in food or feed. Once a pesticide is identified for market development, a process is started to accumulate a full package of human and environmental safety data that will support product registration and marketing. A registration data package requires a minimum of four to five years of research before the first registered use is approved and marketing may be initiated. Data development for initial registration of a product for a single commodity market may cost more than 10 million dollars. Once a product is registered, it can then be labeled. Pesticides labels are legal documents which explain the legal use of product including basic information on contents and safety. Private applicators must obtain a certification to use restricted use pesticides.

In the U.S., our domestic consumption of pesticides has dropped from $1.2 billion in 1981 to $1.08 billion in 1991. The rest of the world is using and manufacturing pesticides at an ever increasing rate. In 1991, the agriculture market used 76% of the pesticides sold in the U.S., industry and government 18%, and home and garden consumption was 6%. Herbicides accounted for more than 65% of all pesticide sales in the U.S. Atrazine (a corn herbicide) was estimated to have been the most heavily used pesticide in the U.S. in 1991.

ANNUAL ATRAZINE USE (1989-1991)



The U.S. regulatory system requires a great deal of testing before any pesticide chemical is ever allowed to be used in this country. These tests determine among other things, the likelihood of a given chemical to move through the soil to enter water supplies and the potential acute and chronic effects on humans, wildlife, and the environment. Only those products which can be used safely are registered by the EPA.

The following is a list of tests required for pesticides:

- Acute Toxicity—toxic effects produced by short-term exposure.
- Chronic Toxicity—toxic effects produced by cumulative exposure.
- Metabolism—chemical adsorption, distribution, excretion, and metabolism within mammals.
- Sensitization—allergic reaction due to chemical exposure.
- Reproduction—changes in the ability to produce offspring, birth defects, and toxicity to the unborn.
- Mutagenesis—alteration of genetic material though chemical interaction.
- Oncogenesis—formation of cancerous or non-cancerous tumors or lesions.
- Ecological Effects—adverse effects of the chemicals on the health and life cycles of fish and wildlife.
- Environmental Fate—movement and persistence of the chemical in soil, air, water, and in plants. Breakdown by sun, microbes, or plants. Accumulation within plant parts.

Drinking Water Standards for Pesticides

Maximum contaminant levels (MCLs) are legally enforceable drinking water standards. The MCL on each substance allowed in drinking water is based on what humans can consume for a lifetime without adverse effect. These standards are based on the consumption of two liters of water every day for a 70 year lifetime, and that 20 percent of pesticide exposure will be due to drinking water. Certain violations will mean that consumers will have to take immediate action, other MCL violations won't mean your health is at immediate risk. If a violation poses an acute risk to human health, water systems must notify media within 72 hours of discovering a violation. Large safety margins were built into most standards so you won't be harmed if the water exceeds the MCL for short periods of time. The EPA has established, based on health risk considerations that single or seasonal violations of atrazine in drinking water does not present a significant risk to human health as long as the running annual average concentration does not exceed the MCL.

How MCLS are Determined

When evaluating a pesticide that is considered to be non-carcinogenic, or having negligible lifetime cancer risk, the EPA divides the level of exposure which does not produce an observable effect in a test animal (NOEL) by a uncertainty factor to determine a Reference Dose (RfD) which is often called the Acceptable Daily Intake (ADI). The uncertainty factor, which can range from 10–1000, gets higher when there is less information available about the substance's effect on humans. RfDs are used to help set the legal limits for the amount of pesticides that can occur in drinking water.

To determine drinking water levels of exposure, the RfD is converted to a drinking water equivalent level (DWEL). The DWEL is the amount of a pesticide that can be in drinking water without putting a person over the amount they are allowed to be exposed to in one day. The drinking water equivalent level is determined assuming that the average person weighs 140 pounds, and drinks 2 L of water a day. Since the exact exposure from drinking water is not known it's usually assumed to be 20%.

Legal drinking water limits take into account the drinking water equivalent factors and the economic feasibility of removing a compound with the current best available technology. If a substance is a carcinogen, additional safety factors are built into the limit. The final limits that are set are called maximum contaminant levels (MCLs).

Pesticides in Ground Water Throughout the U.S.

The U.S. Geological Survey's National Water Quality Assessment Program began in 1991 with the goal of producing a long-term assessment of the status and trends in the quality of the nation's water resources. They have reported the following findings on pesticides:

- Currently there is insufficient data to provide a statistically representative view of pesticide occurrence in ground water across the U.S. A review of published information on the pesticides in ground water indicates that pesticides from every chemical class have been detected in ground waters beneath agricultural land.
- Often, pesticide use on lawns and golf courses is comparable to or greater than agricultural use, but little information on the occurrence of pesticides beneath non-agricultural land is available.
- The factors which appear to be most strongly associated with pesticide contamination of ground water are the depth, construction, and age of the sampled wells, the amount of recharge, and the depth of tillage.
- Current approaches used for predicting pesticide distribution in the subsurface (computer simulations, indicator solutes, or ground water vulnerability assessments) appear to provide unreliable predictions of pesticide occurrence in ground water and that the models tend to underestimate the distance of pesticide transport.

Pesticides in Sediment and Aquatic Biota

- Forty-one pesticides or their break down products were detected in sediments, and 68 in aquatic organisms.
- The pesticides typically detected were organochlorine insecticides or their metabolites. These findings reflect the persistence of these compounds, and a study bias because they constituted most of the samples analyzed for.
- Nationwide trends of pesticides in freshwater fish but not in sediments have been established which show residue of DDT, chlordane, dieldrin, endrin, and lindanes (organochlorine insecticides) declined during the 1970s, then leveled off during the early 1980s.
- Localized areas of high concentrations of pesticides in freshwater fish exist. Toxaphene (an organochlorine insecticide) residues declined during the early 1980s.

Pesticides in Surface Water

- The annual mean concentration of pesticides in surface waters used as drinking water sources rarely exceeded maximum contaminant levels but peak concentrations of several currently used herbicides exceeded MCLs for periods of days to weeks in streams of the Central and Midwestern U.S.
- Organochlorine insecticides continue to be detected in surface water 20 years after their use was banned or severely restricted. The significance of the observed concentrations of pesticides in terms of human and ecosystem health is not known because there is a lack of data relating environmental exposure to toxicological effects.

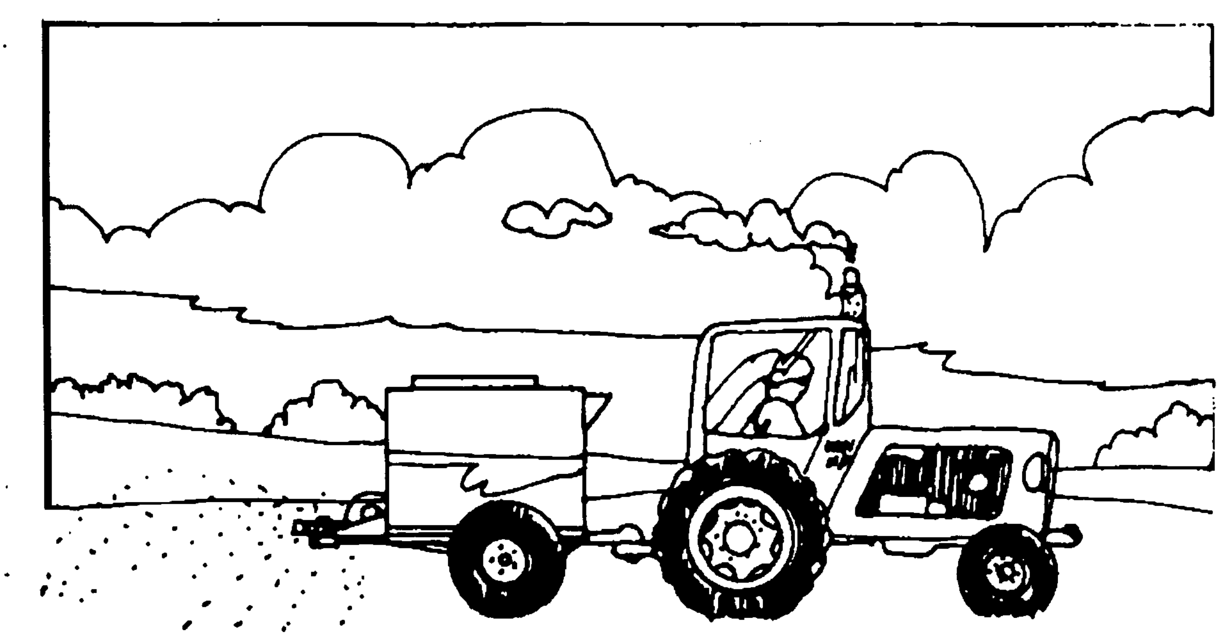
Agricultural Pesticides and Wildlife

What is the Problem?

Until the 1985 Farm Bill, another trend in farming was to cultivate more and more marginal land, including highly erodible areas and drained areas in or near wetlands. This cropland adjacent to wetlands has a tremendous impact on wildlife because agricultural chemicals can enter wetland systems through runoff or drift. For example, in major waterfowl production areas in North Dakota and Iowa, 94 to 100 percent of the wetlands are adjacent to farm fields. Wild animals that depend on these wetlands for food, cover, or brood rearing can be endangered.

Why Should I be Concerned?

Pesticides can affect wildlife in many ways. Some chemicals are toxic enough to directly kill wildlife. Others weaken animals so that they are more likely to die of disease, exposure to harsh weather, or predation. Herbicides can affect the available habitat by killing vegetation, and insecticides can reduce the amount of food by killing non-target aquatic and terrestrial insects. J Wild animals in the "seasonal wetlands"



(wetlands containing water only during spring and early summer) have an especially high risk of exposure to agricultural chemicals because these wetlands are often sprayed in wet years and farmed in dry years.

Birds appear to be more sensitive to commonly used pesticides than mammals. The increased use of agricultural chemicals near wetlands has been blamed for some of the decline in the waterfowl population. Fish also are affected by agricultural chemicals. In the past, trout were the most sensitive to pesticides. Today, farmers are using different kinds of pesticides, and, consequently, specialists are finding that the most sensitive fish now include bluegill and bass. These warm-water fishes are some of the most common and popular species found in ponds, lakes, and streams near agricultural areas.

Where are the Hazards?

Chemical Hazards

Insecticides are generally more toxic than herbicides to wildlife and fish. Although habitat damage can occur, few acute or chronic effects on wildlife are currently known to be connected with herbicide use; however, studies are continuing.

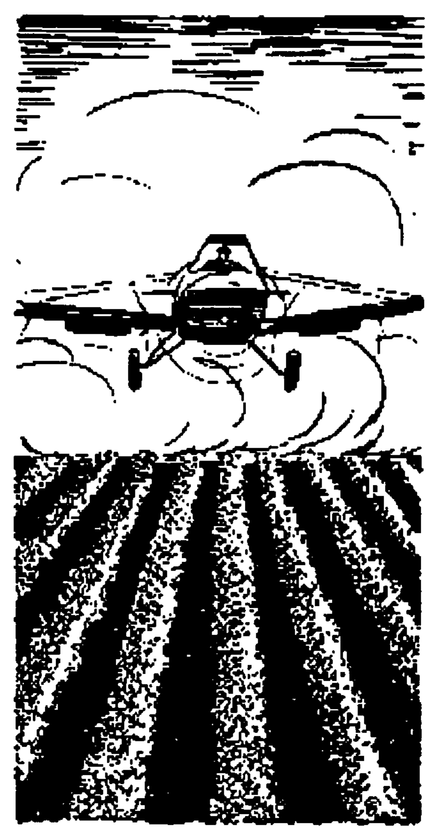
Insecticides in use are primarily organophosphates and carbamates. These chemicals kill insects by damaging their central nervous system and can kill wildlife and fish in the same way. Wildlife and fish can be exposed to a chemical by eating contaminated food, by drinking contaminated water, by breathing the chemical, by absorbing the chemical through the skin, or by swallowing the chemical while grooming. Young birds can die from insecticides by eating or being fed insects that have been contaminated. These are called lethal effects.

Insecticides also can damage the central nervous system of wildlife in such a way that the animal does not die, but shows abnormal behavior affecting its ability to survive or reproduce. In some cases, birds exposed to pesticides are unable to sing properly, and thus cannot attract a mate. Also, some parents fail to tend their young properly, which can lead to the death of the nestlings. These are called sub-lethal effects.

Insecticides also can affect wildlife indirectly by killing insects other than crop pests. Insects are very high in protein, which is necessary for growing birds. The growth of young birds, such as ducklings, is stunted in areas where insecticides are heavily used because they do not have enough insects to eat. Fish also feed on insects, as well as very tiny water animals called zooplankton. Scientists say that fish also may show stunted growth in areas with heavy insecticide use because both the aquatic insects and the zooplankton populations are reduced. This, in turn, affects fish reproduction because the number of eggs a fish can produce is directly related to its size and health.

Many of the contemporary organophosphate insecticides are as hazardous as some of the organochlorines that were used in the past. DDT, an organochlorine, caused eggshell thinning in some birds, including the bald eagle, and led to rapid declines in their populations. Problems like this are called chronic effects and occur when a toxic chemical accumulates in an animal's body over a period of time. Insecticides today are not as persistent; they do not last as long in the environment and thus seem to be less residual in animals. However, they are equally as hazardous in their acute effects—the ability to kill or harm animals in a short period of time.

Another group of insecticides used currently is the pyrethroid insecticides. Some examples of pyrethroids are esfenvalerate (Asana XL), permethrin , and cypermethrin (Ammo). These insecticides are synthetic versions of insecticides that occur naturally. The pyrethroids are in their fourth generation and are still being developed and registered. The application registration of this latest generation on the order of 0.01–0.05 lb ai/A (active ingredient per acre). This is quite low when compared to the rate of 1.0–2.0 lb ai/A for the organophosphates and carbamates.



Pyrethroids have only low to medium toxic effects; birds and mammals can break the chemicals down and pass them through their bodies rapidly. However, fish are less adapted to breaking down pyrethroids and clearing their bodies of them. Also, the fish nervous system seems very sensitive to these chemicals. As a result, pyrethroids are highly toxic to fish. These compounds are labeled as restricted use compounds, and must be used with caution around water.

Application Hazards

Any application method or farming practice that allows considerable drift or runoff is potentially harmful to wildlife. Insecticides often are applied aerially and, when applied near wetlands, can contaminate these areas. In 1987, a routine aerial application of ethyl parathion, an organophosphate insecticide, to sunflower fields adjacent to wetlands in North Dakota led to the death of 96 percent of the mallard ducklings in the wetlands. When the pilot was instructed to do his best to avoid contaminating the wetlands, no more ducklings died than in unsprayed areas. However, aquatic insects and zooplankton in the wetland were killed causing sub-lethal effects in wildlife.

Currently, scientists are studying the hazards involved with granular pesticides, especially to birds. Some birds and small mammals can die from swallowing even a single granule of some granular pesticides. Studies are continuing.

The answer to the crisis of agriculturally polluted water in rural areas obviously cannot be the same as the answer to point source pollution, such as tertiary sewage plants for municipalities and waste recycling for factories. Yet, some of the principles can be borrowed and joined with traditional agricultural management techniques to limit, if not eliminate, agricultural pollution.

Nutrients in Surface Water

The USGS' National Water Quality Assessment Survey found that nutrient concentrations in water usually are related to land use in the upstream watershed or the area over a ground water aquifer. Twelve percent of domestic supply wells in agricultural areas in the U.S. exceeded the EPA MCL of 10 mg/L for nitrate. Nitrate in surface water is highest downstream of agricultural or urban areas. Concentrations are not as high as in ground water and normally don't exceed the drinking water standards. High concentrations in Midwestern states might be accentuated by tile drainage of agricultural fields. Ammonia and phosphorus concentrations were found to be highest downstream from urban areas. If these concentrations are high, they warrant concerns about decreased oxygen in the water, toxicity to fish, and accelerated eutrophication.

Ground water provides drinking water for more than one-half of the U.S. population. Nitrate can persist in ground water for decades and accumulate to high levels as more nitrogen is applied. Areas with well drained soil and high nitrogen input have the highest risk.

Animal Waste Contamination

Animal agriculture can be a source of pathogens (disease causing organisms) in surface waters and ground water. Contamination from pathogenic organisms contained in animal wastes is often the most significant health concern associated with animal agriculture. Health professionals are calling for greater emphasis to be placed on the control of pathogens in drinking water. Types of pathogens in surface and ground water include: bacteria, viruses, and protozoans. Of the three types of pathogens found in animal wastes, the primary concern regarding surface water is the protozoans *Giardia lamblia* and *Cryptosporidium.* These organisms are of great concern because of their ability to live in water for months and to resist common types of disinfection such as chlorination. Proper water treatment and preventing the contamination of drinking water are needed to prevent water contamination.

Bacteria are microscopic single-celled organisms. Bacteria derived from the intestines of warm-blooded animals are usually the ones producing a public health concern. The presence of these bacteria in water indicate sewage or fecal contamination. Coliform bacteria are a group that serve as "indicators" to show if disease-causing agents could be present. Some strains of Coliform bacteria can cause disease. The standard test of bacteriological safety in the United States is the coliform bacteria test. Fecal coliform originates almost exclusively in the intestines of warm blooded animals—this is why farm animals have been identified as potential sources of nonpoint pollution. They've been used for years to indicate the potential of pathogenic organisms in water. They remain a good indicator of bacterial pathogens, but they can't adequately project the presence of pathogenic protozoans and viruses. Both protozoans and viruses can persist longer in the environment than coliform bacteria. Bcause fecal coliform bacteria are believed to die relatively soon after they enter marine waters, their presence usually indicates an active source of fecal contamination. Fecal coliforms can live from less than 1 day up to 5 days in fresh water, survive up to 32 days in wet soil, and live up to 1 year in a cow pie.

Viruses are structurally simple parasites found in plants and animals. Enteric viruses are the ones of concern with respect to drinking water because they are able to enter the body orally. These viruses multiply in the gut and are excreted in large numbers in the feces. Viruses can persist longer in the environment than bacteria and move farther in groundwater than coliform bacteria because of their small size. Monitoring for viruses is expensive and not practical.

Strategies for Agricultural Source Controls

The answer to the crisis of agriculturally polluted water in rural areas obviously cannot be the same as the answer to point source pollution, such as tertiary sewage plants for municipalities and waste recycling for factories. Yet, some of the principles can be borrowed and joined with traditional agricultural management techniques to limit, if not eliminate, agricultural pollution.

Sustainable Agriculture

Sustainable agriculture provides a conceptual framework and key principle to guide future development of farming practices and systems that will protect water quality, other natural resources, and quality of life. Sustainable agriculture is a long-term goal, not a specific set of farming practices. A sustainable agriculture must balance the following outcomes:

- Conserve and enhance resources (soil, water, air, minerals, etc.) both on and off the farm.
- Maintain or improve profits.
- Provide safe, abundant, and high quality food and fiber.
- Improve the vitality of rural communities.
- Be socially acceptable.

Given infinite resources, almost any form of agriculture could be sustainable. However, we have a declining agricultural land base, a limited fresh water supply, a diminishing fossil energy supply, and a growing population. These constraints force us to find ways of sustaining the resources needed for future farming.

Sustainable agriculture is a relative term. It will take shape differently in each diverse crop/product/climate area. Many current farm practices suppress, simplify, or replace biological processes, sometimes incurring greater production and environmental costs. Sustainable farming strategies that can enhance biological process include conservation tillage, diverse crop rotations, improved manure management, increased use of perennial crops, mixed crop/livestock operations, and integrated pest management. These approaches also can reduce the need for some of the current production inputs and can protect the environment and farm profits.

Sustainable agriculture as a concept can encompass other terms that describe approaches to more environmentally sound farming, including alternative, ecological, regenerative, low-input, biological, and organic agriculture. Sustainable implies accounting for all costs associated with the food-fiber system both to society and to growers. These include costs associated with production such as cleaning contaminated water, disposal of food processing and packaging wastes, effects on human health, wildlife, ecosystems, or decline of rural communities. Farmers incur costs of soil erosion through reduced soil productivity and lost nutrients. Short-term profit from farming is essential. But long run costs, such as ground water and contamination have been ignored in determining what is profitable.

Sustainable agriculture offers three general strategies to protect water quality:

1. Improved efficiency includes increased nitrogen fertilizer efficiency and improved pesticide application methods.
2. Substitution of inputs includes using biological controls instead of pesticides or using legumes instead of nitrogen fertilizer.
3. Agro-ecosystem design includes approaches such as intercropping and agro-forestry, which increase biological self-reliance and decrease product inputs and negative environmental impacts.

Sustainable Farming Strategies

No prescriptions or detailed guidelines make or judge whether a farm is "sustainable." However, a number of underlying principles and practices apply. The principles include:

- increased biological diversity.
- recycling nutrients and waste products.
- protecting and restoring natural resources.
- accounting for all costs and benefits of farm practices, including social and environmental costs.
- using information-intensive and site-specific management.
- implementing complementary social and farm policy structures to encourage these principles.

Farming for Profit and Stewardship

Farming practices can be profitable, environmentally sound, and beneficial to the region. Yet many tradeoffs remain in choosing management options. For example, adopting mechanical weed control to minimize herbicide use and potential groundwater contamination can lead to greater soil erosion, a major threat to long-term sustainability. Legumes in dry areas can substitute for fertilizer nitrogen, but at the cost of precious water for the following grain crop. Nitrogen can leach from fertilizer, manure, and legume sources if growers do not consider proper application timing and nitrogen credits. As these tradeoffs are recognized, farmers, researchers, Extension faculty, and industry need a greater degree of teamwork to resolve them.

On-farm testing is one promising strategy for site-specific improvement of sustainability on both large and small farms. Farmers can run properly designed and managed on-farm tests with their own equipment and generate reliable site-specific methods on the farm. Extension, researchers, and industry work together in sustainable agriculture to solve problems in a broader context. Agriculture has a unique opportunity to provide a lead role in creating a sustainable society.

Best Management Practices

The water pollution control efforts have popularized the term "best management practices" (BMPs) to describe a wide range of techniques to reduce agriculturally caused nonpoint source pollution. BMPs are developed specifically for a particular farm or land area to curb nonpoint pollution.

BMPs are either "structural" or "nonstructural." Structural controls (for example, animal waste lagoons) usually attempt to deal with nonpoint pollution problems at their source through artificially constructed systems. They often involve a capital investment and may require special equipment and skills to install. Nonstructural BMPs rely on improved land management practices to reduce nonpoint pollution. They are often integral parts of each farm's animal or crop production system and in most cases must be used continuously as components of the production process. Examples of nonstructural BMPs include the use of conservation tillage and vegetative buffer strips to control erosion. BMPs are discussed in greater detail later in the chapter.

Some Socioeconomic Considerations About BMPs

Technical determinations regarding BMPs are very important. Of equal importance are socioeconomic factors related to the decision maker who manages the land. Some of the significant factors are:

- Size of farm and farm income—research results have consistently demonstrated that conservation is more likely to be applied to larger farms. There also is a consistent, positive relationship between farm income and the use of conservation practices. The need for investment in management, education, and machinery probably causes the lower rate of adoption of conservation tillage by small farmers, not lack of stewardship values.
- Farm tenure—the relationship between farm tenure (ownership) and use of strong conservation methods is less clear. Many studies have found a strong relationship between ownership and adoption of conservation measures, while others have found none. Tenure, however, is a significant factor since absentee landowners may not take an interest in conservation; therefore, the renter is neither encouraged nor required to make use of conservation methods. In addition, many landlords are less inclined to give long-term leases, resulting in a shorter planning horizon for the decision maker on the land.
- Debt service requirements—high debt service requirement is considered to be a negative factor in the adoption of conservation practices. Research indicates that high debt level would negatively affect conservation behavior in two ways: (1) more erosion-prone crops must be planted to satisfy cash flow requirements, and (2) financing for conservations measures is more difficult since these do not provide immediate cash flow benefits.
- Perception of the problem—a farmer may have a serious conservation problem, but action is unlikely unless the farmer perceives it as a problem.
- Perception of economic feasibility—an economically and objectively feasible conservation system may not be perceived as feasible by the farmer, who may therefore choose not to adopt it. Conversely, a conservation practice that appears to be economically infeasible on the basis of objective criteria may, nevertheless, be adopted. Where recommended BMPs were consistent with farmers' preferences, adoption rates of BMPs were high.

Did you know?

Ohio's leading industry is Food and Agriculture. One-in-six Ohioans are employed by Agriculture. Commodity sales account for $8 million annually.

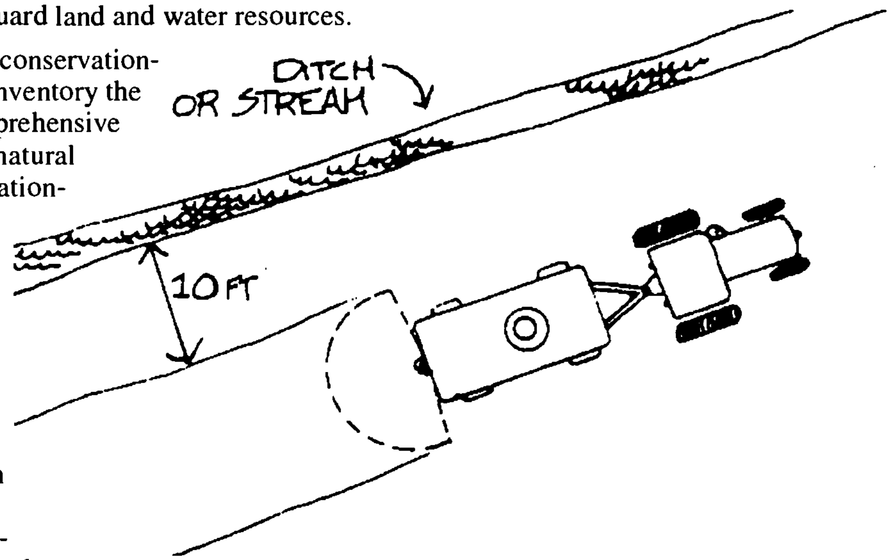
According to 1995 statistics, Ohio has 74,000 farms with an average size of 205 acres.

Land Use Planning

Land use planning is a tool that property owners can use to increase the value and productivity of their property and help identify and plan for pollution reduction. The majority of the land in the Indian Lake Watershed is under private control and ownership. Land owners/operators need to take the responsibility and become good stewards of their soil, water, air, plant, and animal resources. Water quality controls implemented on private property are usually because the owner/operator determined there was a problem and took appropriate action. An owner may be forced into action because of a fine or citation, however, volunteer stewardship ethics usually lead a landowner to action. The Indian Lake Watershed Project is an excellent example of owner/operators utilizing voluntary programs for pollution reduction—over fifty percent of the watershed farms have completed conservation plans to apply a variety of BMPs.

Conservation Plans

Conservation plans are working documents most often developed by the Natural Resources Conservation Service, Ohio Department of Natural Resources, local Soil and Water Conservation Districts, or other qualified organizations to assist landowners. A conservation plan identifies the landowner/operator's objectives for the property and establishes a blueprint to safeguard land and water resources.



To develop a plan, a local conservationist will visit the property to inventory the resources. To develop a comprehensive plan for the whole farm and natural resource system, the conservationist considers soils, topography, type of agriculture enterprise (including livestock), woodland resources, wildlife influences, and proximity to water resources (streams, ponds, wells, lakes). The most important consideration is the owner/operator's goals for the land. A written assessment of needs is developed and presented to the owner/operator considering such factors as operation goals, costs, and incentives. He or she can choose a course of action to solve identified water quality problems. When the land owner or operator's decisions are made, they are recorded along with an implementation schedule in the resource management system plan. One copy is presented to the owner/operator and one is kept in the conservation office. The farm plan is a working document that needs to be understood by the owner/operator so that the plan can be used as a reference.

Farm plans serve an important role in watershed management. By conducting a conservation plan inventory within a watershed, land use managers can identify properties that have the potential to impair water quality and those that are successfully preventing water quality impact.

Financial Incentives and Assistance—Sharing the Cost of Conservation

In recent years, the responsibilities of land ownership and management have become quite complex. Practices that were encouraged twenty years ago or okay just a decade ago are no longer acceptable. As our knowledge and understanding of the environment increases, land management practices must change. To hasten this change, government programs provide financial incentives and free technical assistance.

> "Because we all benefit from BMP implementation, we all should share the cost."

The implementations of agricultural BMPs for water quality protection and conservation of natural resources can be prohibitively costly for individual landowners. Often the landowner realizes no direct benefit from the investment. The benefit is to the environment and our community and society as a whole. Because we all benefit from BMP implementation, we all should share the costs.

There have been many successful financial incentive programs in past years. Due to the constant evolution and change in governmental programs, an attempt to identify all of the current financial incentives and assistance programs would become quickly outdated. Examples of such programs include the Agriculture Conservation Program (ACP), the Stewardship Incentive Program (SIP), and the Conservation Reserve Program (CRP). The ACP, SIP, and CRP are federal cost-sharing programs. The key agency responsible for the administration of cost sharing programs is the USDA Farm Service Agency (FSA).

Practices frequently cost-shared include the following:

- stream protection,
- animal waste control facilities,
- sediment retention, erosion, or water control structures,
- forest stewardship plan development,
- reforestation and afforestation,
- windbreak and hedgerow establishment and maintenance,
- soil and water protection,
- riparian and wetland area protection and enhancement,
- fisheries and wildlife habitat enhancement, and
- conservation farming practices and equipment.

Cost-sharing is available for a wide variety of activities under each of these practices. Technical assistance for implementation of conservation practices is provided by the Natural Resource Conservation Service (NRCS), Department of Natural Resources; Divisions of Forestry and Wildlife, and local Soil and Water Conservation Districts (SWCDs). For information on current federal cost-sharing programs, contact your local SWCD office.

Local jurisdictions, such as a watershed organization, county, or city may obtain grant funds which they can administer as a local cost share program to individuals. A very successful example of a local incentive program was implemented in the Indian Lake watershed (1991–1994) by the Indian Lake Watershed Project.

The Conservation Equipment Buy-Down Program was designed to assist farmers in purchasing new or used conservation equipment. Watershed farmers with currently approved conservation plans were eligible for a 15 percent cost share or a maximum of $4,000 per sign up on equipment purchased through an accredited lending institution. Qualifying equipment included: no-till planters; no-till drills; ridge-till planters; and ridge-till cultivators. Participants could also use funds toward converting conventional drills and planters to no-till systems. Throughout this program, assistance with the purchase of 50 pieces of no-till equipment and 25 chaff spreaders was cost shared. This program can be at least partially attributed for the increase of 6 percent no-till practices in 1990 to over 80 percent in 1996.

The most recent financial assistance program to become available is a Water Pollution Control Loan Fund program administered by the Ohio EPA—Division of Environmental and Financial Assistance. This program provides low-interest loans to eligible applicants for the installation of BMPs necessary to implement conservation plans. Interest rates are usually 2 to 4 percent below the prime lending rate.

Items qualifying for this program include:

- site specific farming equipment,
- rinse pads,
- improved chemical application equipment,
- conservation tillage equipment,
- manure storage facilities,
- manure handling equipment,
- erosion control structures,
- filter strips,
- fencing livestock from streams, and
- other items that are needed to implement a conservation plan.

Maintaining Farmlands

Areas with high densities of development tend to have an increased amount of velocity of water running off the land. Therefore, as people move into an area, increases occur in both the amount of pollutants found in the watershed and the proportion of those pollutants that will reach the stream. For this reason, many rural communities are trying to retain farmlands.

As populations increase, farmland conversion may potentially be a real problem. Growth management planning regulations have community committees looking for ways to preserve farmlands and keep farming a viable business. Many recommendations contain plans for balancing the demands for development and the desire to retain farmland. It's a tall order for areas where residential land prices are at least five times higher than farmland prices. In these areas, market forces do not favor keeping farmland around in the long term.

Options include high-density clustering of homes on a small percent of a farm in return for preserving the larger portion for agriculture. Landowners may be able to transfer or sell development rights to their property and retain the entire farm forever. Some communities are also including "right-to-farm" ordinances to exempt farmers from public nuisance regulations governing noise and smell.

Did you know?

Two percent of our population provides enough food for our country and for people in many countries around the world.

Agricultural Best Management Practices for Everyone

Recommended Pollution Control Practices for Landowners and Farm Operators

The following recommendations are intended for use by people with property or farms in rural areas who are interested in protecting their environment and quality of life. The practices described were developed to protect water quality while improving the productivity and beauty of the land. It is recognized that on many farms there is no excess capital to invest in expensive farm improvement plans. Consequently, many of the practices are those that involve minimal investment and often just entail changing farm management habits.

Use Sustainable Agriculture Strategies

A few special ideas that come out of the sustainable literature include:

- Analyze soil and plant tissue for adequate fertility and feed quality.
- Manage different soils in a field with appropriate levels of fertilizer, herbicides, water, tillage, (site specific management).
- Include different crop families in rotations.
- Maintain a broad genetic base in crops and livestock for disease and insect resistance.
- Use a soil survey to match soil resources with farm enterprise choices and minimize environmental problems.
- Plant windbreaks to reduce erosion potential and conserve moisture.
- Choose appropriate machinery size to conserve fuel and properly schedule operations to avoid soil compaction.

Soil Erosion

Soil erosion is the movement of soil by wind or water. For our purposes we will be concerned primarily with soil erosion by the force of water. Movement of soil by water occurs in three stages. First, individual grains are detached. Second, the detached grains are transported over the land surface. Third, the soil grains fall out of suspension and are deposited as sediment on a new site. When large amounts of sediment are deposited in lakes, streams, and wetlands the use and biological function of these water bodies can become severely impaired. There are four types of soil erosion by water: sheet, rill, gully, and streambank erosion.

Sheet Erosion

Sheet erosion is the removal of thin layers of soil by water acting over the whole soil surface. Raindrop splash and surface flow cause sheet erosion, with splash providing most of the detaching energy and flow providing most of the transporting capacity.

Rill Erosion

Rills are erosion channels small enough to be obliterated by normal tillage operations. Most rill erosion occurs on recently cultivated soils where runoff water concentrates in streamlets as it passes downhill. This water has greater scouring action than sheet flow and it removes soil from the edges and beds of the streamlets.

Gully Erosion

Erosion channels that are too large to be erased by ordinary tillage are called Gullys. Gullies are considered to be active as long as erosion keeps the sides bare of vegetation, and inactive when they been stabilized with vegetation.

Streambank

Sheet, rill, and gully erosion are active only during or immediately after rainstorms. Erosion along streambanks occurs both during and between rainstorms. Streambank erosion is usually most intense along the long shore (outside) of bends. Bank erosion often damages or destroys the approaches to bridges and culverts. Stream bed erosion also causes bridge failure by removing materials that serve as footings.

Impacts

Erosion is a natural process, however, when accelerated by human activity the resulting sedimentation can become a major water pollutant. No other pollutant occurs in amounts comparable to sediment. Streams in the United States carry over 700 times as much eroded soil and sewage. Soil is an important factor in water pollution because of the large volume it occupies, the murkiness it produces, the plant nutrients, pesticides, and other polluting chemicals it carries, and the microbes that may be present. Erosion and the resulting sedimentation of Indian Lake is a primary concern of the Indian Lake Watershed Project. According to sediment surveys conducted by NRCS in 1996, nearly one-third of Indian Lake's water volume has been lost to sedimentation. Sedimentation of the water has threatened fishing, boater access, and other recreational uses of many Ohio lakes including Indian Lake.

Erosion Control BMPs

No till or Conservation Tillage

Tillage practices such as, no-till and conservation tillage, which leaves all residue on the ground during the absence of plant cover will reduce the energy and eroding affects of rain fall and snow melt. With no-till, special planting equipment must be used to drill seeds though the crop residue. No-till can produce other benefits for the farmer such as: lower fuel costs, better moisture retention during periods of low rainfall, and better soil condition. Any tillage practice which leaves at least 30 percent of the soil residue on the surface of the soil can be classified as conservation tillage.

Filter Strips

Filter strips (or buffer strips) are effective BMPs for controlling many types of nonpoint source pollution including sedimentation. Filter strips of grass, trees, shrubs and/or natural vegetation along streams will slow the force of water during and immediately after rainfall events. Sediment, nutrients, and chemicals are filtered by the plants in the filter strip. Filter strips can also provide wildlife habitat and protect streambanks.

Grassed Waterways

A natural drainage way is graded and shaped to form a smooth, bowl shaped channel. This area is seeded to sod-forming grasses. Runoff water that flows down the drainage way flows across the grass rather than tearing away soil and forming a larger gully. An outlet is often installed at the base of the drainage way to stabilize the waterway and prevent a new gully from forming.

Erosion Control Structures

A dam, embankment or other structure built across a grassed waterway or existing gully controls and reduces water flow. The structure drops water from one stabilized grade to another and prevents overfall gullies from advancing up a slope.

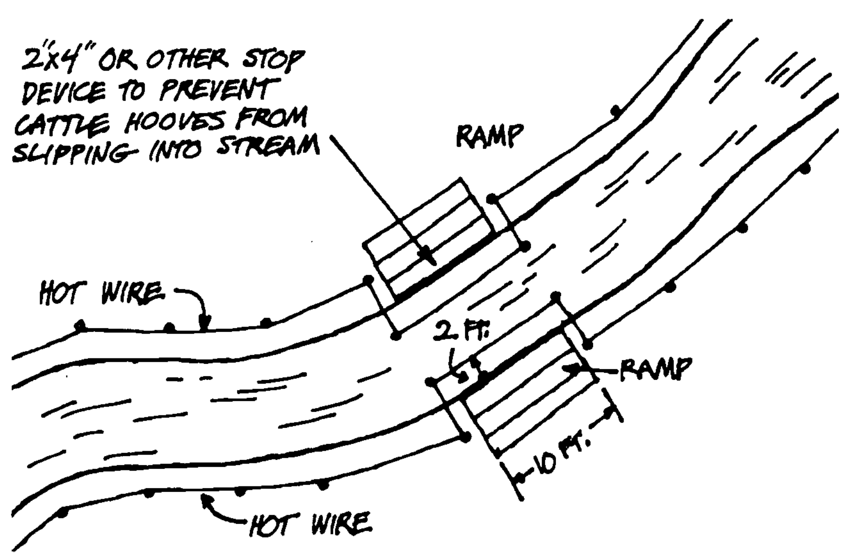
Stream Protection

Grass, riprap and gabions are installed along the edges of stream to buffer the banks from heavy stream flow and reduce erosion. Fencing prevents cattle from trampling banks, destroying vegetation and stirring up sediment in the streambed. A buffer zone of vegetation along the streambank filter runoff and may also absorb excess nutrients and chemicals.

Pasture Management

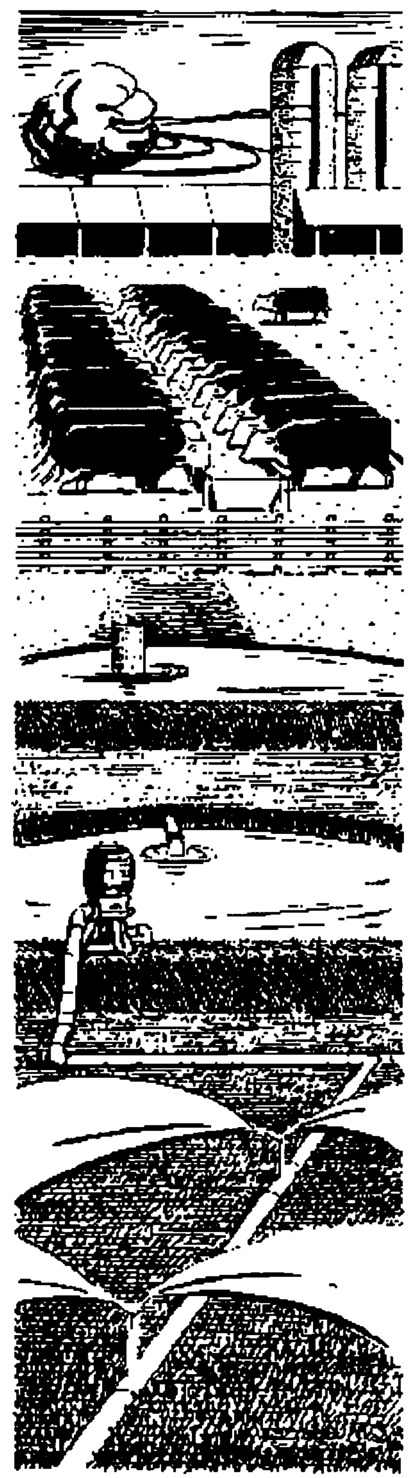
Good pasture management practices improve pasture productivity by increasing both the quality and quantity of forage production. This results in a better weed control, better soil structure, and healthier animals. A well-managed pasture also reduces the runoff of soil, manure, nutrients, and other pollutants from the land, which benefits local water quality.

- Clip vegetation during the growing season to control weeds and remove old growth.
- Drag pasture frequently to spread droppings and promote uniform grazing.
- Apply a thin layer of manure over pasture land each year as a fertilizer. Apply during late spring or summer when rainfall potential is low.
- Control surface water runoff from pastures having a seasonally high water table by installing subsurface drains or ditches **that are protected** from livestock access.



- Fence pastures to keep animals away from surface water, leaving at least a 10-foot strip of vegetation between the fence and water.
- Test soil before reseeding or renovating pastures. Provide adequate pasture liming and fertilization when necessary. Contact the county Extension office or Conservation district for information on soil testing and application rates.
- Intensive livestock use may necessitate reseeding a pasture every two or three years to optimize production. This is particularly true of horse pastures.

- Include legumes in pasture reseeding programs. Legumes add adequate amounts of nitrogen to pastures in a natural way so that pasture growth and quality are improved and the need for yearly chemical nitrogen fertilization is eliminated.
- Keep animals off new seeding for the first year. Fields may be hayed toward the end of the first growing season.
- Graze wet meadows only when they are not water saturated.
- Fence off wetlands to protect them from livestock.
- Maintain pastures with at least three inches of leafy material.
- Develop a nitrogen budget to adjust stocking rates, improve pasture or manure management practices.
- Fence off steep slopes.
- Create a sacrifice area (winter paddock) for use in the rainy season. The area should be on higher ground and well away from streams. It keeps animals from destroying pastures and confines waste to an area that is surrounded by healthy pasture that can filter contaminated runoff.



Overgrazing

Overgrazing is caused by pasturing too many animals on a parcel of land or by letting them graze the same piece of land for too long. Overgrazing reduces plot vitality and survival.

To avoid overgrazing:

- Restrict grazing during winter months when grasses are dormant and can easily be overgrazed.
- Don't let animals graze pastures during periods when soils are wet. This will cause soil compaction resulting in poor aeration and moisture penetration of the soils and will result in reduced plant growth.
- Grass needs to enter the winter month in good vigor. Allow for about 6 inches of regrowth before fall frosts.
- Limit the number of animals you pasture based on the amount of land available and pasture productivity.
- Divide pasture into three or more units and establish a grazing rotation that allows foliage 21 to 28 days of regrowth between grazing periods.
- Bear in mind that the smaller the acreage, the greater the chance for destruction of vegetation, even when ample hay is provided.
- Plan for difference in animals in pasture management schemes. Horses are especially hard on pasture land. They graze plants down to the soil surface, leaving little opportunity for regrowth. Horses also do not graze evenly, and they trample much of the forage area.

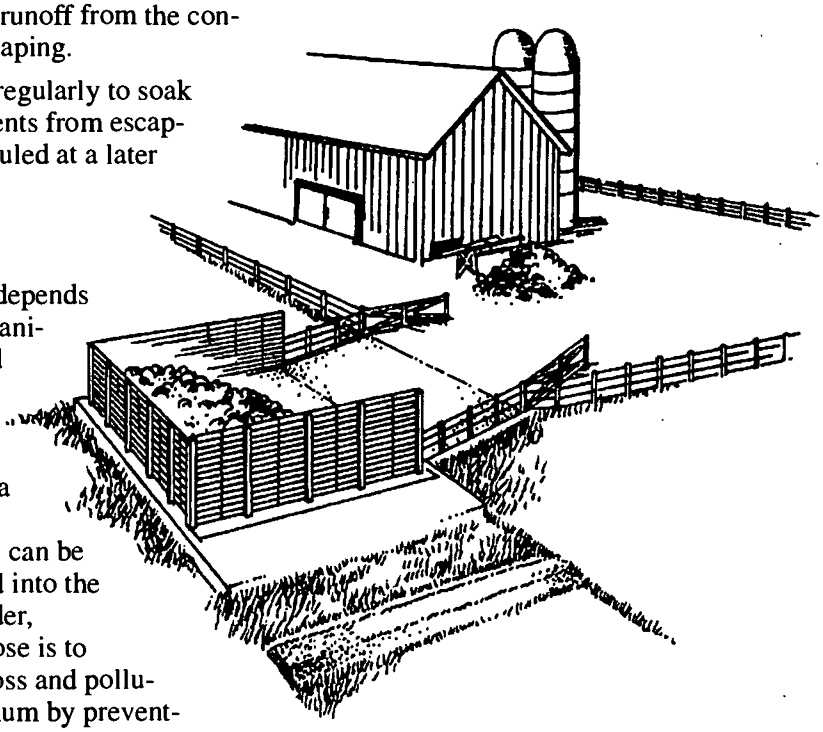
Animal Waste Management

Manure contains high concentrations of bacteria, nutrients, and organic matter. When these pollutants enter surface waters, serious water quality problems can occur. Consequently, animal wastes need to be properly managed; whether the farm contains several thousand animals to small farms with just a few animals. Proper storage and utilization is essential to prevent water pollution problems.

Animal Confinement Areas

Developing a good location for livestock facilities is an important first step. The following items should be considered when looking for the optimum site:

- Locate confinement areas 100 feet or more from any open water course.
- Allow 300–400 square feet per animal for large animals. This translates to 100–150 animals per acre. A paved confined area can hold six times as many animals.
- Divert offsite surface runoff away from confined areas.
- Install gutters and downspouts on roofs to prevent clean water from entering and running through the confined area.
- Install a collection area to trap surface runoff from the confinement area to prevent flow from escaping.
- Add bedding, sawdust, shavings, etc., regularly to soak up excess liquids to help prevent nutrients from escaping. This material can be stored and hauled at a later time or saved to make compost.

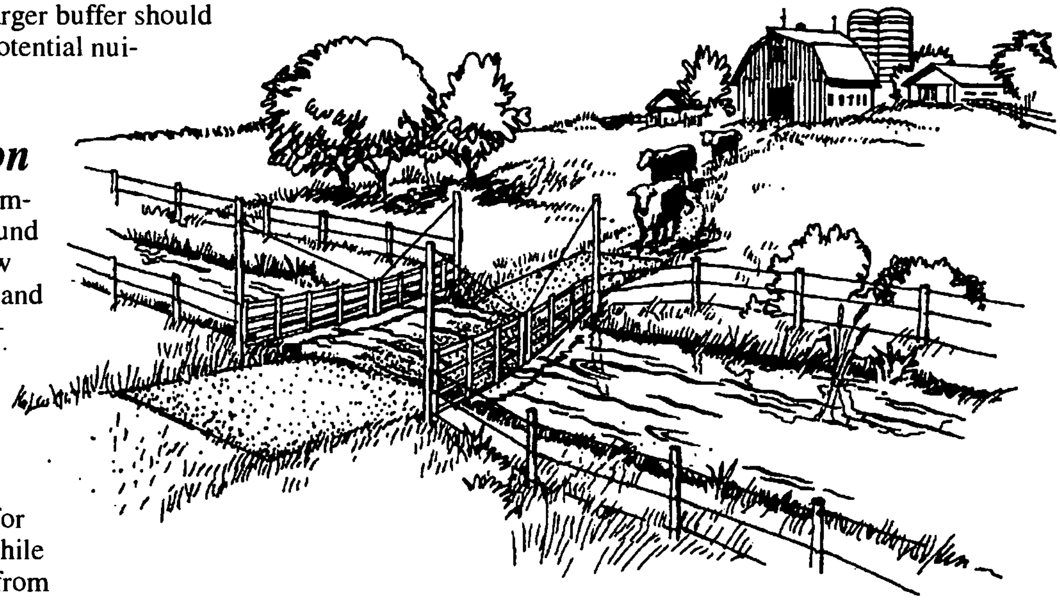


Waste Storage

The type of waste storage structure used depends on the livestock operation (animal species), animal waste management system, and planned field application. Several options exist including earthen storage pond or lagoon system, above or below ground tank, pit under confinement facility, dry staking facility, or a sheltered concrete slab area.
Depending on the consistency, animal waste can be pumped, scraped, hauled, pushed, or flushed into the system. Waste can then be applied by spreader, injection, or irrigation. The structure's purpose is to safely contain the waste and keep nutrient loss and pollution of downstream water bodies to a minimum by preventing runoff. A properly designed structure will save nutrients, allow applications to be done at better field conditions, reduce odors, and increase aesthetic values of the farm. Other items that systems should include are a buffer zone of vegetation to filter any runoff, warning signs for the structure, and safety fencing to keep both animals and people away from the area.

Animal Waste Application

Properly utilizing manure is the final process in a good waste management system. The first step is manure testing. A representative sample will dictate how much manure you will need to apply to meet the crop's needs. Realistic yield goals should be established for the given crop. Apply at a rate that doesn't exceed the crop's use. (See OSU Extension Bulletin 604.) This will prevent excess nutrients from entering surface waters as well as filtering through the soil to ground water resources. Tilling the animal waste into the soil greatly reduces runoff potential. Manure should not be applied on frozen ground or steep slopes. Ten foot (minimum) field buffers are also a good practice to incorporate into the application process. If fields border houses, a larger buffer should be considered to avoid potential nuisance complaints.



Stream Protection

Streamside areas are important to life in and around the stream. Trees and low bushes shade the stream and help maintain water temperatures that are suitable for fish and other aquatic organisms. Streamside vegetation also provides cover and food sources for fish and other wildlife while protecting streambanks from erosion.

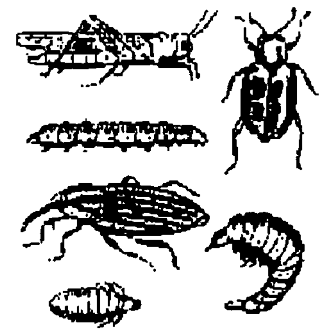
Fencing

Fencing streambanks is a simple and very effective way for landowners to improve water quality in the streams flowing through their farms. Fencing out livestock helps to stabilize banks and reduce erosion. When livestock trample the banks, vegetation is destroyed, leaving the soil unprotected and weak, resulting in collapse of the bank or being washed away by the stream flow. Limiting livestock access to streambanks is one of the best ways farmers can prevent erosion and improve water quality of the stream. Established vegetation (grass and/or wooded) will act as a blanket to protect streambanks against high erosive flows. Vegetation helps to slow the current, reducing the flooding potential as well as the erosive power.

Fencing out livestock promotes modern pasture management. Producers gain more control over livestock grazing areas, which can act as a first step to a more productive pasture system. Stoned lined controlled crossing areas also help to reduce the erosion potential of a stream. The stone prevents stirring of sediments which reduces the turbidity of the water. Farm equipment and animals benefit from a stable crossing site. Fencing across the stream at this point is also important. A stable crossing provides a safe travel lane for livestock, reducing the risk of injury. Limiting livestock access to streams reduces contact with waterborne bacteria, which can cause bovine leptospirosis, mastitis, and other ailments. A pool area can be created to offer a drinking site for livestock. A better alternative would be the use of a piston pump system that draws water up through a hose to a stable point away from the stream banks.

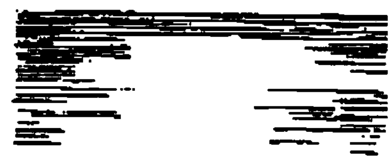
Fencing helps promote wildlife habitat for a variety of birds and upland animals as well. Many species of birds including herons, egrets, bluebirds, mallards, and ringneck pheasants use streamside vegetation for summer feeding or nesting. The quality and variety of wildlife depends on the mix of grasses, trees, and shrubs. Using filter strips with fencing increases the quality of wildlife habitat and the potential water quality protection by trapping sediments and other water contaminants before they reach the stream.

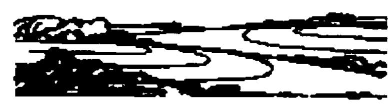
Pesticides and Herbicides



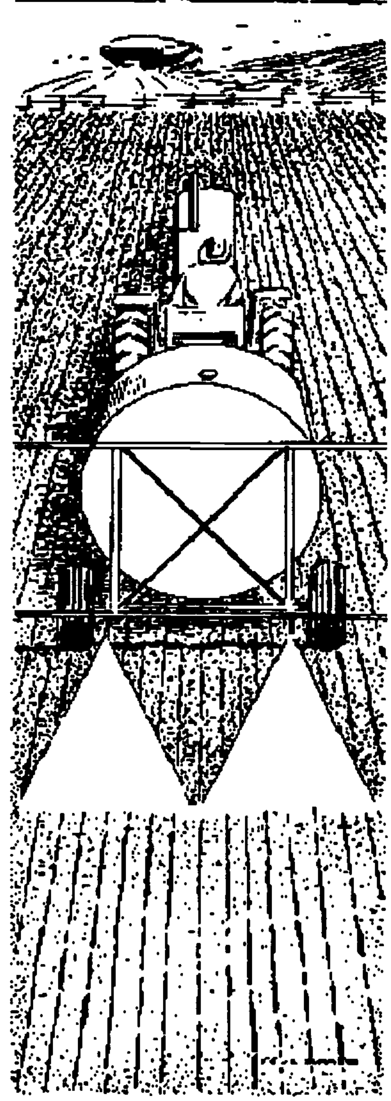
Pesticides and herbicides can be found in most homes and farms. Rat poison, slug bait, lawn and garden weed killers, and crop sprays are all examples of commonly used chemicals. These chemicals can harm or kill much more than the nuisance plant or animal. If pesticides or herbicides are used around the home or farm, it is important to use them with caution and to handle them properly.

Field Mapping to Manage Pesticide Usage





Site-specific field mapping consists of measuring each field into three-acre blocks, noting natural or manmade field markers and religiously completing soil tests for every block. After yield goals and weed problems are figured, a field-by-field inventory is drawn up which lists seed, fertilizer, and chemicals to the gallon, pound, and bag. Trucks and nurse wagons are loaded precisely according to the inventory. By placing precise amounts of chemicals, seed, and fertilizer on the nurse wagon to complete a field, application errors are more likely to be detected. The second half of the double check system involved the tractor operators. They record what is applied, and refer to field markers and acre counters as they monitor application rate. If it doesn't add up, work is stopped. After the spring rush, the information from each operator's log book is compiled and entered into a computer for input rates and cost per block on the field mapping system.



Studies have indicated errors in the amount of chemicals being applied by farmers. Common errors are inaccurate volume marks on the spray tank. In some cases, the volume marks on the tank were unknown. Other common errors were worn nozzles, errors in speed, and inaccurate pressure gauges. Making sure volume marks on the spray tank are correct can easily be checked by making sure the tank is empty and filling a 5- to 10-gallon container repeatedly to establish various levels.

The nozzle buyer's guide or dealer can cross-reference miles per hour, pressure, and nozzle type to determine the flow rate per nozzle. Once the sprayer is calibrated, check boom heights and pattern overlap, flow rate, and speed to avoid over and under application. Spray pattern and nozzle flow should be checked daily.

Integrated Pest Management (IPM)

IPM controls crop pests, uses less pesticide, and saves valuable time and money. The key to reducing pesticide use is frequent inspection, correct identification of pests, evaluation of existing and potential damage based on knowledge of pest life cycles and habits, and integration of nonchemical and chemical methods. Although pesticides may still be an essential part of farm programs, dependence on pesticides can be reduced without reducing profit or production.

Safe Use of Pesticides and Herbicides

- Always consider alternatives to pesticide use.
- Always read the label and follow instructions carefully. Not only do they contain information on application, but they list recommendations for safe disposal. Labels are frequently revised and expanded, so review them every year.
- Try to choose chemicals that are not as hazardous to environment and wildlife.

- Don't apply more than the specified amount. Overuse can be dangerous to your health as well as to wildlife and the environment.
- Never dump pesticides or herbicides into sewers, storm drains, or septic tanks.
- Don't spray in or around waterways and well heads. Use buffer zones of unsprayed crops or grass strips to protect wetlands. The pesticide may contaminate drinking water, harm aquatic organisms, or spread to non-target areas downstream.
- Never spray when rain is likely to occur the same day, and don't water heavily after application. Runoff or seepage from excess chemicals may contaminate water supplies.
- Do not spray on windy days when chemicals may drift from target areas into waterways.
- Be especially careful when spraying in spring or early summer. Many beneficial insects, birds, and animals are much more sensitive to chemicals during their juvenile life stages.
- Obtain a license. If you are a commercial farmer who uses restricted use chemicals regularly, you are required to have a license. Contact Ohio State University Extension to obtain information about pesticide applicator's licenses.
- Apply the pesticide at the appropriate time. Know which growth stage or life cycle of the pest is most affected by the pesticide.

Pesticide Storage and Handling

- Handle sprayers carefully. Many farmers unknowingly may be contaminating ground water on their farm simply by the way they wash their sprayer. Dumping unused chemicals, washing tanks and booms, washing the sprayer off or even letting it sit in the rain can cause a chemical build-up in the soil.
- Worker Protection—follow label guidelines of the use of personal equipment for maximum personal protection.
- Prevent back-siphoning by installing backflow devices such as check valves on the fill pipe between the water source and sprayer. Pumps don't prevent back-siphoning. A drop in voltage or uneven water supply can cause many pumps to "cough" and allow chemicals down the well.

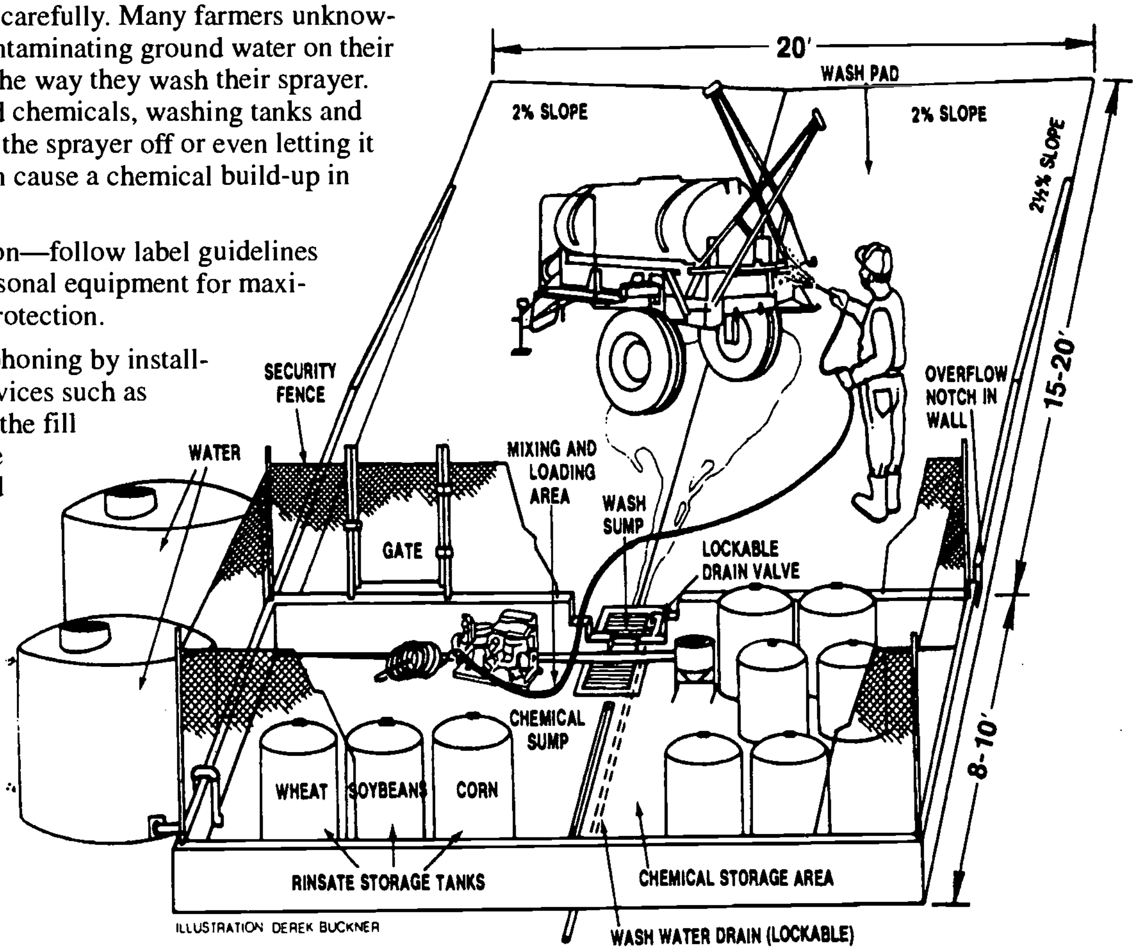


ILLUSTRATION DEREK BUCKNER

- Triple-rinse or pressure-rinse containers to prepare them for disposal, and spray the rinse water back onto the field. Rinse containers as soon as they are emptied so the residue doesn't have a chance to dry out.
- Plan purchases and required inventory carefully for a given crop year. Calculate needs carefully and buy only as much pesticide as you need. Avoid overwintering chemicals whenever possible. Keep records of total amount, rates and dates, and type of chemical applied to each field.
- Store chemicals in a well-ventilated, cool location, preferably with a concrete floor slanting inward with a lock on the door. A retaining wall around the outside will contain spills. Always store chemicals in the original, labeled container. Make sure they are tightly sealed.
- Store pesticides away from fertilizers and animal feeds to avoid contamination and fire hazards.
- Mix and store chemicals at least 50 feet from any well. Some states recommend as much as 200 feet as a buffer zone between mixing/storage areas and wells. It's not always obvious where things will flow after a spill. Subsequent rains can wash chemicals further than one might expect. Maintain the same buffer zone between mixing areas and any surface water such as ditches, ponds, and sloughs.

Safe Disposal of Pesticide and Herbicide Containers

The county OSU Extension Office or Health department can answer questions on the proper disposal of specific material. County Recycling and Litter Prevention office will also provide information on the disposal of waste products.

- Dispose multiple containers in special incinerators or landfills with programs for handling toxic chemical disposal.
- Triple-rinse pesticide containers before recycling, using the rinse water as a pesticide.
- Do not burn containers since burning may cause the release of harmful chemicals.
- Never pour leftover pesticides down a sink or into a toilet.

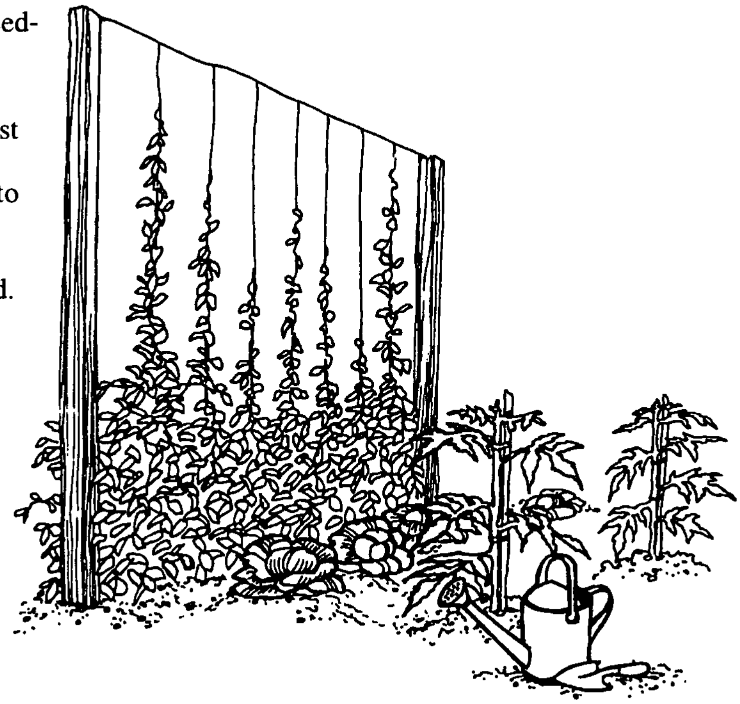
Alternatives to Pesticides and Herbicides

Weed Control Without Herbicides

An herbicide is another form of pesticide. In this case, the "pests" are weeds and other undesirable plants. Herbicides have the potential to do as much damage to water quality as other pesticides. Although the following successful ways to control weeds without the use of herbicides were written for commercial farmers, they are equally applicable to noncommercial farms and home gardeners.

- Determine why weeds are present. Weeds aren't bad plants, just unwanted ones that can have negative consequences on your crop and pocketbook. Their presence may tell you something about the condition of your soil or your current activities. They may be present because of circumstances such as nutritional imbalances, which can be corrected. Current management practices, such as ignoring weeds along the edge of the field, or moving equipment around without concern for transporting weed seeds could be contributing to your problem.

- Make sure you plant into clean seedbeds. Watering seedbeds to germinate weed seeds, then working soil just below planting will give seedlings the best jump on competition.



- Make sure you have a full plant population. Open spaces within the crop area are the most likely places for weed pressure to develop, where non-crop plants have adequate space to attain light and water during their early growth. If you are transplanting, use only healthy plants that will insure a "solid" stand. If direct seeding, use an adequate amount of seed to make sure you have a full stand. (In any case, seed is one of the last places to try to save money.)
- Perform timely cultivation. Don't wait for weeds to become big problems—they are a problem the second they germinate, and the sooner they are dealt with the better. Cultivate frequently, whether weeds appear to be a problem or not. In fact, if they appear as a problem, you aren't cultivating often enough.
- One grower used 5' wide raised beds, with rows on 1" centers. He used only a hula hoe, cultivating every five days, cradling the hoe in his arm and moving quickly down the rows, disrupting germinating weeds before he could even see them. His operation, despite no efficiency-ensuring machinery, was quite profitable, and he never had to hack out large weeds that were affecting his crops.
- If you aren't able to maintain timely cultivations and fall behind, make it a priority to eliminate immature seed heads before they ripen. If you can't keep weeds from affecting this year's harvest, at least make sure they don't get the chance to affect next year's harvest.
- Work just as hard to suppress weed populations outside of the field. A common sight is a clean crop area, while weeds flourish along pipe lines, around pump houses and barns, and along the borders of fields. Next year, their offspring will be in the middle of the action instead of on the sideline.
- Clean all machinery before moving from one field to another.
- Maintain a weed "hit list." If there are weeds that are not yet present on your farm, or present in small numbers, now is the time to make sure they don't get out of hand.
- Cover crop fields when not cropping commercially. Among the many benefits of cover crops is their weed suppression abilities. Planted into fall crops, they can suppress weeds in fields that will be harvested too late for discing or other field work; during the winter they can limit growth potential for grasses and continue to grow in cold weather.

Insect Control Without Pesticides

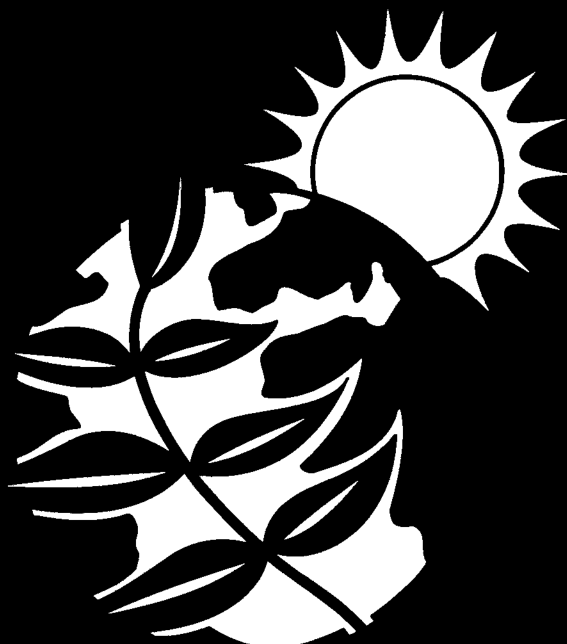
Pesticides that get into surface water such as streams and lakes can be toxic to both humans and water dwelling species such as fish and aquatic insects that fish feed on. Pesticides that leach into ground water can also make it unsafe for consumption. There are many things that can be done to reduce the use of pesticides for crop and vegetables.

- Rotation—change the sequence of plants or crops grown from year to year in the same field.
- Use insect-tolerant or insect resistant varieties.
- Use interplanting or order plantings to isolate insect infestations and therefore reduce crop damage.
- Cultivation exposes insects to weather injury and birds.
- Wire, muslin, or nylon plant cages are useful in small garden plots for excluding insects.
- Encourage birds that feed upon insects by providing cover, suitable nesting sites, supplemental feed and protection from predators.
- Introduce insect predators like praying mantis and lady bugs.

Citizen Roles

- Use BMPs on your property to protect your stream and the watershed.
- Attend field days, seminars, and workshops where new techniques and machinery are demonstrated that help lessen environmental impacts.
- Contact your county OSU Extension office to learn more about Integrated Pest Management and farming to protect water quality.
- Assess your potential impact on water quality by developing a conservation or farm plan. Implement your plan as soon as possible to reduce your pollution impact.
- Become involved with your local watershed project. If a watershed project does not exist, form a local action group to start one.

Yard and Garden



Environmentally Sound Gardening

Yard and Garden: Environmentally Sound Gardening

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Can Gardeners Cause Water Contamination?

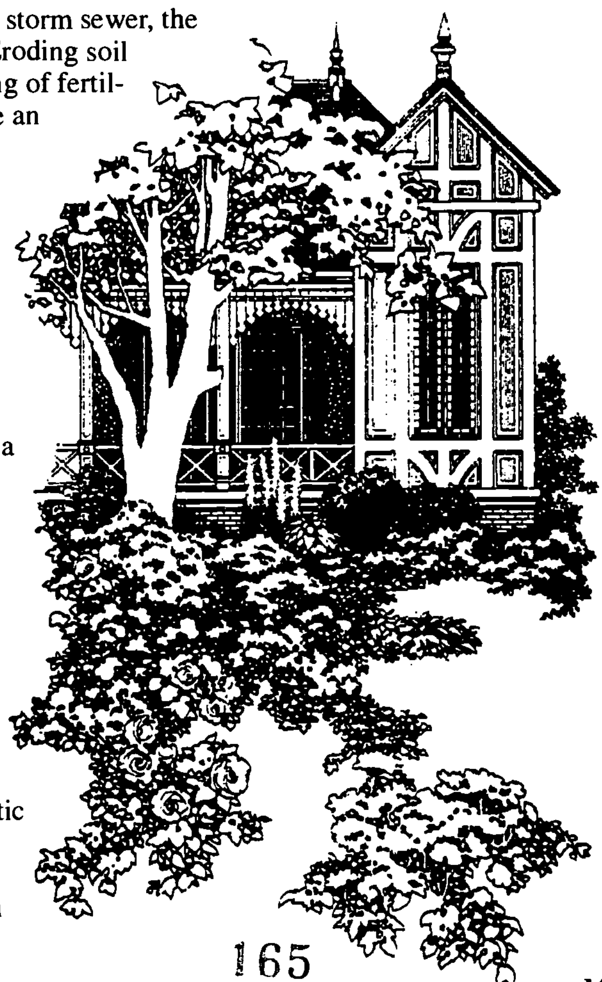
Gardening is generally viewed as a wholesome activity that enhances our environment. But pesticides, fertilizers, and erosion from gardens and landscapes can, under some conditions, contaminate lakes, streams, rivers, the ocean, and groundwater. Since the quality of our water resources affects our quality of life, we must learn how our gardening practices can contribute to water contamination and what we can do to reduce the threat to water quality.

We have long been aware of contamination from point sources such as factories and municipal sewage systems. Recently, we have become more aware of the threat of nonpoint source contamination. Many relatively small, widespread sources can create contamination. Each source by itself may seem insignificant; however, when the sources are added together they could pose a threat.

Hundreds of thousands of homes in Ohio have gardens. Each garden may contribute a relatively small amount of runoff containing soil, chemicals, and fertilizers that flows into our lakes and rivers. Certain pesticides and nitrates (formed from fertilizers and manures) that leach through the soil can contaminate groundwater. Added up, these small contributions may form a sizeable problem. Only when individuals take responsibility and make wise choices can we control nonpoint source contamination.

Why Be Concerned

We all live on a stream. Whether our stream is a natural channel or a manmade one, such as a storm sewer, the effect is still the same. Eroding soil and the runoff or leaching of fertilizers and pesticides have an impact on our lakes and streams. Even sewage treatment cannot remove all pollutants.



Whatever is poured, spread, or sprayed on plants or on the ground may eventually find its way into the watershed. Just because a problem flows away from our property doesn't mean that it is gone. It can come back to haunt us all.

Sediments from erosion can ruin habitats for aquatic life. Residues from lawn and garden fertilizers can over-stimulate aquatic plant growth in shallow lakes and inlets, making water unsuitable for fish and wildlife.

Contamination can make lakes, rivers, and beaches unsafe for swimming and other recreational activities. In many areas, water contamination has decreased populations of fish and shellfish or made them unfit for eating. This worries those people who fish for sport and the commercial fishing industry and consumers.

In short, clean water is essential for human health, wildlife, recreation, and industry.

Environmentally Sound Gardening

Good gardens thrive with good water quality practices. The same simple, practical techniques that improve soil, beautify the landscape, reduce maintenance, and enhance plant health can also protect the quality of our water.

As a gardener, use these keys to protect the quality of our water:

1. Reduce the amount of potentially hazardous substances introduced to the environment.
2. Minimize the amount of water that runs off your property.

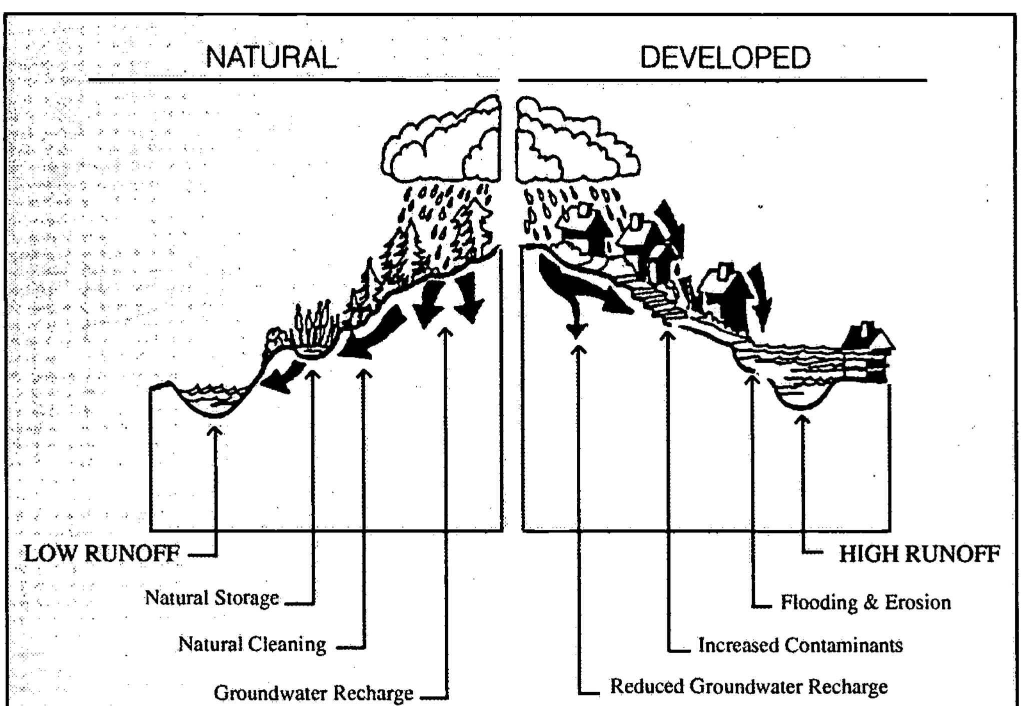
Landscape Design

Landscape Planning

Residential and commercial development on forest and farm land has increased the area covered by buildings and paved surfaces. Our houses and gardens change the watershed in which they are built, causing increased runoff that is larger in volume and that occurs more rapidly after a storm. You, as a gardener, can help alleviate this problem.

ESTIMATED RUNOFF FROM TYPES OF LANDSCAPE

Land Cover	Percent Runoff
Dense forest	10%
Light forest	15%
Lawns	25%
Gravel areas	80%
Pavement and roots	90%



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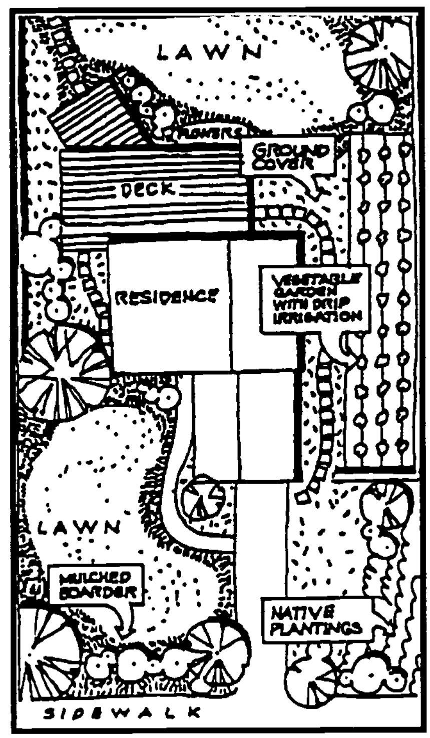
Observe the Water Flow

Start by watching the pattern of water flow on and around your garden. In a heavy rain, does overflow run off, carrying soil with it, exposing roots of plants? When watering, does the water penetrate to plant roots, or does it run uselessly down the sidewalk, driveway, or alley and into the storm drains?

Making Landscape Choices

Choices we make can benefit the beauty of our garden and the quality of our water. Properly selected plants or landscaping features can reduce runoff and minimize the amount of potentially hazardous substances applied to gardens. Plant selection, turf areas, surfaces of walks and decks, and control of water infiltration and flow, all affect water quality.

Consider leaving a portion of your property in native and natural landscaping. If designing a yard, consider incorporating a "Backyard Wildlife Refuge" as part of your landscape design.



Plant Selection

All plants have their own special requirements in terms of sun, moisture, temperature, soil pH, and fertility. A plant living in less than optimum conditions will obviously not be as healthy as it could be under ideal conditions. Selecting plants that suit a site will mean reduced maintenance and better plant health. This should mean less work for you, less reliance on pesticides and less potential to pollute.

Books such as *Right Plant, Right Place* and many OSU Extension publications can help a gardener select suitable plants for special needs. Use of plants in the landscape which are native to the area will respond to the natural climatic conditions and should be considered, along with other suitable plants.

Turf Choices

Turf is used in play and foot traffic areas since most other plants are not resilient enough to resist such activity. It is not wise to grow grass in certain locations:

- In dense shade.
- Where maintenance is difficult, such as narrow, hard-to-irrigate areas.
- Where there is intensive foot or vehicular traffic that kills all vegetation due to soil compaction.
- On a steep slope.

A sound gardening strategy is to balance the amount of turf used in the residential landscape with the area allocated to flower beds, shrubs, trees, or groundcovers. These mix of turf and ornamental landscape plants can help to:

- define the various distinct areas of outdoor activities.
- direct circulation from one area to another.
- give an increased sense of space.
- reduce home heating and cooling costs by planting trees that block the cold winds of winter and provide shade in summer.
- encourage birds, many of which are natural predators of bothersome insects.

- reduce the use of lawn chemicals.
- reduce watering needs.

Selecting Walkways

Concrete and asphalt seal the land, eliminating infiltration, creating runoff in an area that could otherwise soak up the water. Some paving surfaces can offer permeability as well as durability.

Wood Decking

A low deck, with a 2" X 4" board surface, serves as an attractive and functional ground surface. Heights can vary to make a yard more interesting and to suit the terrain. Relative simplicity of construction can mean that it is a do-it-yourself job. Properly designed decking constructed with appropriate material (either cedar or treated wood) will last a long time. Spaced boards allow for the easy infiltration of rainwater. Decks generally shade out most weed growth.

Porous Asphalt

Recent developments in this material have increased its durability to a point comparable to conventional asphalt. It does, however, require a thicker coat. The material allows water to infiltrate rather than run off.

Modular Pavers

This includes such things as stone, brick, and lattice paving blocks. They can be used on any well-drained soil and must be placed on a base of crushed stone or sand.

Pebbles or Gravel

These can make an attractive surface. Be sure to use landscaper's felt or other porous sheeting underneath to help stabilize gravel and to control weeds, while permitting infiltration.

Controlling Runoff

Think about the ultimate destination of rainwater. Runoff from roofs and paved surfaces can be deflected to spread over well-drained soil where infiltration will occur. You can encourage retention and infiltration of runoff by various devices including:

- porous asphalt and lattice or modular pavers installed in low lying areas where runoff may be detained, allowing it to infiltrate the soil more efficiently.
- gravel seepage pits, a Dutch drain, or a series of infiltration beds underlaid by either a gravel or tile drainage system.
- gravel trenches along driveways and pathways.
- terraces.
- spreading runoff across a vegetated land surface.

Lawns

If you have a yard, you probably have a lawn.

Lawns must be carefully managed. In order for lawns to look good, they require a relatively high degree of maintenance. Regular applications of fertilizer, routine mowing, and application of necessary pest control products are essential for good quality turfgrass. Some gardeners, in an attempt to achieve a perfect lawn, may make excessive use of fertilizers and pesticides.

The better you maintain a lawn, the fewer chemicals you will need to apply. Well-maintained lawns provide benefits to the environment.

Suggestions for gardeners for water protection include the following:

- Manage lawns properly so as to minimize the need for pesticides.
- Do not over-fertilize. Apply the required amount at the right time.
- Do not routinely apply herbicide in conjunction with fertilizer.

Lawn Establishment

Planting recommended species and cultivars adapted to Ohio lawn management will go a long way toward preventing problems. Kentucky Bluegrass, perennial ryegrass, and fine fescues will perform satisfactorily in this climate if properly managed. Bent grass and Zoysiagrass are not recommended for home lawns in Ohio.

Table 1. Selected Lawn Grasses

Grass Blend or Mixture	% Weight	Potential Quality of Lawn	Sun or Shade	Amount of Care & Cost of Upkeep	Seedling Rate (lbs/1000 sq ft)
Improved Kentucky Bluegrass Blends[1]	100%	Excellent	Sun	Average to Above Average	1–2
Improved Kentucky Bluegrass — Improved Perennial Ryegrass	80% 20%	Good to Excellent	Sun	Average to Above Average	2–3
Improved Kentucky Bluegrass — Fine Fescue[2]	30–50% 50–70%	Good to Excellent	Shade	Average	2–4
Common Kentucky Bluegrass — Fine Fescue[3]	50–70% 30–50%	Fair	Sun or Shade	Below Average	2–4
Improved Kentucky Bluegrass — Improved Tall Fescue	10–20% 80–90%	Fair to Good	Sun or Shade	Average to Below Average	6–8
Improved Tall Fescue[4]	100%	Fair to Good	Sun or Shade	Average to Below Average	6–8

[1] A blend is a combination of 2 or more cultivars/varieties.

[2] Where improved grasses are used in mixtures (a combination of 2 species like bluegrass and fine fescue), it is recommended that at least 2 varieties of each species be used. Use shade-tolerant bluegrass varieties if available.

[3] Used for low-maintenance lawns.

[4] Use only improved tall fescue cultivars/varieties. Do not use "Kentucky 31" tall fescue.

Lawn Fertility

Maintain the proper level of fertility; avoid over-fertilizing. Formulations containing combinations of slow and quick release components are normally preferable. Use a 5-1-2 ratio fertilizer. Apply 1 to 4 pounds of actual nitrogen per 1000 square feet of lawn annually in several applications. One application should be in late fall. Organic fertilizers, such as composted manure, may be used but are a relatively less concentrated source of nutrients than synthetic chemical fertilizers. When you follow a basic fertilizer scheme, your lawn will be better able to resist the pest problems that exist in Ohio, thus reducing pesticide applications.

Watering Lawns

Keep the lawn properly watered. Tailor your watering to the weather and to soil texture. Lawns on sandy soils will require more frequent watering than those on finer-textured soils. Enough water should be applied each time to wet the soil to the depth of the root zone. You can check this by probing the lawn with a garden trowel. Allow the soil to dry somewhat at the surface between waterings. This will encourage the development of a deeper root system. Proper watering should also allow your lawn to better resist problems.

Lime Applications on Lawn

The application of lime should be made only if recommended following a soil test.

Mowing Lawns

Mow your lawn throughout the year at the recommended height for your species of turfgrass. Grass clippings may be left on the lawn and should reduce the need for fertilizer application. They do not contribute significantly to thatch accumulation. Make sure your mower blades are sharp. Dull mower blades can shred the grass and lead to brown grass leaf tips.

Mowing Heights

Turf-type tall fescue: 2.5–3"

Kentucky Bluegrass, Perennial ryegrass and fine fescues: 2–2.5"

Aeration

Lack of aeration may be one of the reasons that lawns often do not do well. High clay content can lead to compaction which inhibits the infiltration of water and nutrients and indirectly may be the cause of weed problems. Aeration can counter the effects of compaction. It is done by taking plugs out of the lawn, 2.5 to 3 inches deep and 3 to 4 inches apart. This can be done by hand or with a special purpose machine. Aeration allows more water and nutrients to get to the roots.

De-thatching

Heavy thatch restricts water movement into soil and may lead to problems, such as reduced drought resistance. Some species of grasses are more prone to thatch build-up than others. Kentucky Bluegrass lawns may need to be de-thatched occasionally, while lawns with a perennial rye/fescue combination may never require de-thatching. Vigorous hand raking can do the job on small lawns, but special de-thatching machines may be necessary for larger lawns.

Lawn Pests

Bluegrass Billbug and White Grubs are the significant lawn insect problems in Ohio. Monitor the populations of these insects and apply control products only when damage to the lawn is observed.

Weeds

A weed-free lawn is all but impossible to attain. Attempting to achieve it is costly in time and money. Do not routinely apply herbicides in conjunction with fertilizer. Low weed populations can be controlled by spot treating, rather than treating the entire lawn. Healthy, vigorous turf will compete favorably with weeds and moss and reduce the need for herbicides and other chemicals.

Soil and Fertility Management

Drainage

Drainage is the ability of soil to transmit water through the surface and subsoil. Water and dissolved chemicals move very quickly through coarse-textured sandy soils, but much more slowly through finer-textured silts and clays. Adequate organic matter in the soil increases the amount of moisture and chemicals in solution that a soil can hold. This is true for both sandy and clay soils.

Soils that are both well-drained and have good water-holding capacity are the most suitable for gardening. Good soil drainage to a depth of at least two feet is needed for most fruit and ornamental trees and shrubs. Plants on soils with an impermeable layer that prevents downward movement of excess water will have a greater potential for problems and require more maintenance. Soils high in clay must be managed carefully.

Erosion Hurts Your Garden and the Water's Quality

Beating rain and moving water can carry away soil particles, organic matter and plant nutrients. This water-soil-chemical mix finds its way to streams, storm sewers, and lakes. Fine soil particles cause cloudiness in natural waters. Excess nutrients super-enrich rivers, streams, and lakes; and may cause excessive blooms of algae. Pesticides, even in small quantities, may affect the health of fish and those who eat them.

Sound gardening practices can help you control erosion and improve water quality.

The susceptibility to soil erosion depends on:

- Soil cover—its presence and nature
- Soil types—the most erosion-prone soils are silty or sandy
- The grade—moderately to steeply sloping areas are more likely to erode
- Land form—the natural land form or how it was changed by construction

How to Spot Erosion

A gully is obvious evidence of soil erosion. Not all erosion is this easily recognized. Look around your property for these other signs:

- Muddy water on driveways or in gutters following rain or watering.
- Bare spots in lawns.
- Newly exposed tree roots (however, some species, such as maple, grow this way naturally).
- Small stones or rocks becoming exposed.
- Small rills or gullies beginning to develop.
- Build-up of soil in certain areas.
- Soil splashed on windows and outside walls.
- High spots in the soil where it is protected from the impact of rainfall by stones or debris.
- The widening or deepening of stream channels.
- Fallen trees in stream channels.

Prevention and Remedies

Redirect Water

Consider the flow of storm water before attempting any planting on slopes. If water is allowed to gain speed, the runoff may cause severe erosion and prevent plant establishment. Sod swales can provide adequate protection at the top of gentle slopes; earth, masonry, or wood diversions may be needed on steeper grades. The bottom of a diversion channel or swale should be flat and planted with grass. Stone or concrete may be necessary in the center of a channel if water flow causes erosion.

Cover the Soil

Bare soil is the primary cause of erosion. Re-establish vegetation wherever possible, as soon as possible. Grass clippings, straw, wood chips, or any other cover reduces erosion if properly established and maintained. Wood chips can usually be acquired free of charge from tree services. Rent or buy a shredder with your neighbors. In heavy traffic problem areas, such as alongside a driveway, a permanent mulch of stone, bark, or wood chips may be your only answer.

Runoff erosion is best controlled by plants that have dense, fibrous roots which spread throughout the soil. Such a root system tends to stabilize the soil, holds the soil particles together, and loosens the soil along with adding organic matter which increases the soil's permeability. Plant stems or stalks, particularly of grasses, will also help to control runoff erosion by slowing down water as it flows across the soil surface. For the best in runoff erosion control, 70 percent or more of the soil should be covered by plants.

Protect Vegetation

Protect vegetation where high water velocities are expected. For example, use a concrete splashblock at rain gutter outlets and place large rough-edged stones at the outlet of any pipe.

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Plant the Right Vegetation

Get the right kind of plant or plants growing. When re-establishing vegetation you must be certain that the soil, sunlight, drainage, and moisture are adequate to support it.

Observe what plants are growing in similar situations and plant them. There are many plant species that lend themselves to erosion control: cotoneasters, English ivy, low-growing junipers, and turfgrass are some. Close planting and good care will encourage quick establishment and cover. Fertilizing and watering existing vegetation may also help to prevent erosion.

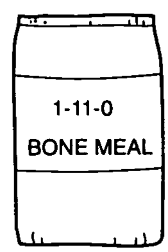
Terrace

Many yards have some slope. The steeper the slope, the greater the potential for erosion and the more difficult its solution. Long slopes should be broken with terraces. Terraces slow runoff, trap sediment, and increase garden space. Select a proper design with adequate foundation and drainage. Consult books on terracing or seek professional advice.

Fertility

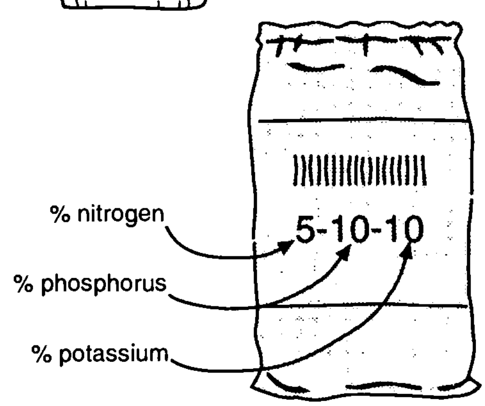
Fertility, the presence of minerals necessary to plant life, may be supplied through either organic or inorganic sources, and gardeners often manage fertility by a combination of both. The complex chemical process which supplies plant nutrients is affected by moisture levels in the soil, by soil temperature, by pH balance, and by microorganisms.

Over-application or misapplication of fertilizers or manure can result in excess nutrients flowing off into storm water or down into the groundwater.



Applying too much fertilizer:

- is a waste of money.
- can damage plants.
- encourages weed growth.
- can pollute our waters.



Avoid over-fertilization by having your soil tested. Call your local OSU Extension county office to find out how to get a soil test. A soil test will identify the level of most of the primary nutrients in your soil which affect plant growth. Fertilizer rates recommended by soil tests and Extension publications allow for optimum growth. It is important not to exceed the amounts recommended.

A complete chemical fertilizer such as 5-10-10 is probably the easiest and least expensive to use. Organic sources of nutrients, such as cottonseed meal, bloodmeal, and bonemeal are available and may be used as well. Plant nutrients can also be supplied using manures, compost, and other organic material. However, because the percentage of nutrients in them is relatively low, fairly large amounts may be required to supply plant needs.

Most trees and shrubs will not require a yearly application of fertilizer. Furthermore, trees growing in fertilized turf may not need additional fertilizer. Over-fertilization can cause fast but weak growth that could be more susceptible to insects, diseases, and drought. Recently installed landscape plants may not need to be fertilized for 6 to 12 months. Do not fertilize woody plants which are making satisfactory growth. However, woody plants which are not putting on adequate growth and whose leaves are poor in color may need fertilization.

Plants make the most effective use of fertilizer if it is applied before or just as the new growth begins in spring. You may then apply a light or moderate amount of fertilizer as needed by your plants. Do not apply fertilizer to woody plants from July through October. This could cause vigorous, tender growth late in the season, which may be killed by cold weather in early winter. Late Fall application of fertilizers if often recommended, but is more subject to loss by leaching than Spring-applied fertilizers.

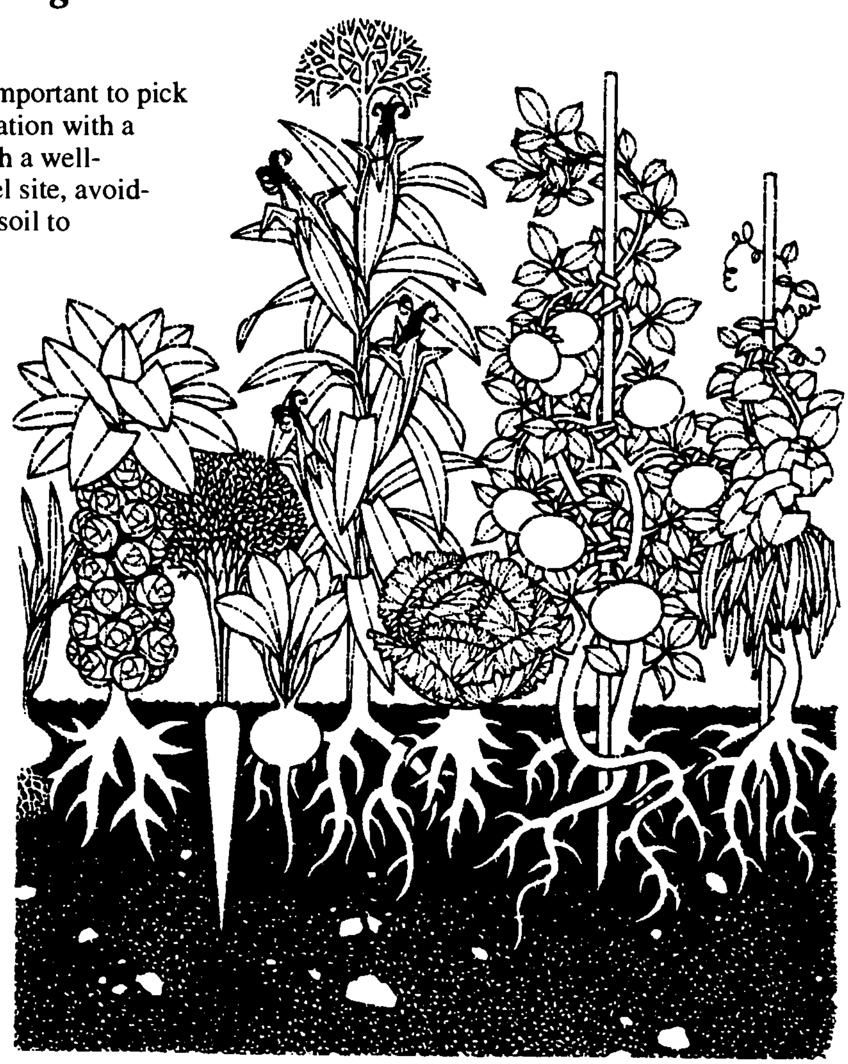
Conditioning

Productivity and workability of soil can be greatly enhanced by mixing in suitable organic material. Organic matter, such as compost, stores moisture and nutrients in the soil, making them available for plant use. Organic matter also acts to prevent rapid changes in the pH (acid/alkaline) balance of soils. In addition, it can buffer the effects of pesticides and other chemicals in the soil. Organic matter helps protect water quality by preventing rapid downward movement of chemicals to groundwater.

Fruit and Vegetable Gardening

Where to Plant

To get the most out of a garden it is important to pick the right spot for planting. Choose a location with a minimum of 6 hours of sunlight and with a well-drained soil. Plant your garden on a level site, avoiding sloping areas which could allow topsoil to wash away during heavy rains.

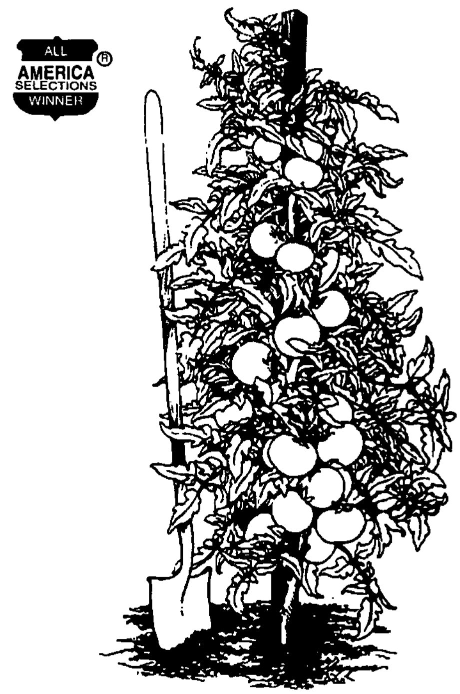


If your garden must be on a slope, then plant across the slope. This way each row acts like a ridge to trap rainfall, preventing soil and nutrients from washing away. On long slopes, it is a good idea to have strips of grass that run across the line of the slope. This helps hold the soil while it absorbs rainfall. The grass strips can also be used as garden access paths. If the spot you want to garden is on a fairly steep slope, terracing will decrease runoff and erosion, and will make it easier on you to work in your garden.

What to Plant

Fruit and vegetable plants need adequate sun, moisture, space, soil temperature, soil pH, and fertility. A plant living in less-than-optimum conditions will obviously not be as healthy as it could be under ideal conditions. Selecting disease-resistant cultivars suited to Ohio and caring for them properly means better plant health and reduced maintenance. Healthier plants mean:

- more food from your garden.
- less work for you.
- reduced pesticide use.
- less potential for pollution and erosion.



Garden Care

Watering

Water only when needed. Vegetable garden soil should be kept evenly moist. The rule-of-thumb is one inch of water per week for most vegetables. This includes water from rainfall. A rain gauge in the garden is helpful to determine how much additional water needs to be applied. Some garden vegetables have critical growth periods during which water should be not be limited.

Some vegetable crops are naturally more deep-rooted and drought-tolerant than others. Generally leafy crops and onion family crops will need the most frequent watering. Root vegetables should also be kept evenly moist (no wet-dry alternation) to prevent tough areas in the roots. Seeds and seedlings need moisture closer to the surface than mature plants, so they need more frequent watering.

Fruit, such as blueberries, strawberries, and raspberries, need adequate moisture at all times during the production season. Full-sized fruit trees should get along with much less watering than dwarf fruit trees, which will need irrigation more often.

Pests

A properly located, planted, and maintained fruit or vegetable garden is likely to have fewer serious pest problems. The following preventive measures will help reduce the presence of pests:

- Choose healthy vegetable transplants and seed potatoes that are certified disease free.
- Choose disease-resistant vegetable and fruit cultivars.
- Rotate crops so that the same or related crop is not in the same place. Repeated plantings of the same plants in the same spot can encourage insect infestation and the buildup of soil diseases.
- Practice good garden sanitation. Weeds; decaying vegetable stalks, vines and fruit; empty pots and bags; and other rubbish may harbor insects, slugs, and diseases.
- Pull out volunteer vegetables such as potatoes, tomatoes, and squash. These too can harbor pests and diseases.
- Time vegetable plantings to avoid peak of insect infestations. Keep a record of when insect problems appear so you can plan future plantings.
- Identify the pest before attempting any control measures.
- Inspect plants for insects and eggs frequently. Pick off and destroy those you find. Check with a flashlight at night, too.
- Some insects can be dislodged with sprays of water. This may be all the control you need for aphids, spider mites, and spittle bugs.

- Place insect barriers over vegetable plants such as screening or floating row covers.
- Protect fruit crops from birds with netting.
- Properly train and prune fruit trees to help reduce disease and insect problems.
- Trap slugs in containers of beer, molasses and water, or use metaldehyde-based baits. They can also be lured beneath boards for capture.
- Avoid using herbicides in a vegetable garden; they are unnecessary. Mulch around fruit and vegetable plants to keep down weeds. Cultivate soil lightly to kill seedling weeds or hand pull weeds before they get larger.
- Use the least toxic control method if you do have a pest problem. Some of these which have the least potential to pollute are Bt products, pyrethroids, insecticidal soaps (toxic to fish), horticultural oils, and sulfur.

Strategies for Controlling Common Vegetable Pests

(•• = very effective; • = somewhat effective; – = not effective or unknown)

	Cultural								Mechanical				Bio.		Chemical	
	crop rotation	trap crop	row cover	variety selection	planting date	tillage	sanitation	reflective mulch	collars	traps	hand removal	hosing/irrigation	predators & parasites	microbial insecticide	standard insecticides	soap or oil
CATERPILLARS																
armyworm	–	–	–	–	–	–	–	–	–	–	–	–	–	•	••	–
cabbageworms	–	–	•	–	–	–	•	–	–	–	•	•	•	••	••	–
corn earworm	–	–	–	–	•	•	–	–	–	–	–	–	•	•	••	•
cutworms	–	–	•	–	–	–	–	–	•	–	–	–	–	•	•	–
European corn borer	–	–	•	–	•	–	•	–	–	–	–	–	•	••	••	–
hornworms	–	–	•	–	–	–	–	–	–	–	•	–	••	••	••	–
squash vine borer	–	–	•	–	•	•	•	–	–	–	•	–	–	–	•	–
stalk borer	–	–	•	–	–	–	•	–	–	–	–	–	–	–	–	–
BEETLES																
asparagus beetles	–	–	–	–	–	–	–	–	–	–	•	–	–	–	••	–
bean beetles	–	–	••	–	•	–	–	–	–	–	•	–	–	–	••	–
Colorado potato beetle	•	••	••	•	••	•	–	–	–	••	••	–	•	••	•	–
corn rootworm beetles	•	–	–	–	–	–	–	–	–	–	•	–	–	–	••	–
cucumber beetles	–	••	•	•	•	–	–	–	–	–	•	–	–	–	••	–
flea beetles	•	•	••	•	–	–	–	–	–	–	–	–	–	–	••	–
Japanese beetle	–	•	•	–	–	–	–	–	–	•	•	–	–	–	••	–
OTHER PESTS																
aphids	–	–	••	•	•	–	–	•	–	•	–	•	••	–	••	•
leafhoppers	–	–	••	•	–	–	–	•	–	•	–	–	•	–	••	•
onion thrips	–	–	–	•	–	–	•	–	–	•	–	•	•	–	•	•
root maggots	•	–	••	–	•	•	•	–	•	–	–	–	•	–	•	–
slugs	–	–	–	–	–	–	–	–	–	•	•	–	–	–	•	–
spider mites	–	–	–	–	–	–	–	–	–	–	–	•	•	–	•	•
spinach leafminer	–	–	•	–	–	•	•	–	–	–	•	–	–	–	•	–
squash bug	–	–	•	–	–	–	•	–	–	•	•	–	•	–	•	–
stink bugs	–	–	•	–	–	–	•	–	–	–	–	–	–	–	••	–

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Most home-owner labeled products will not cause pollution if used according to label directions. Do not mix at a higher rate than indicated on the label. Only purchase the amount you will need during one season. Mix only the amount you will need for one application. Dispose of unused pesticides and pesticide containers according to label directions. Be aware that pesticide labels are legal documents. All pesticide labels state: "It is a violation of Federal law to use this product in a manner inconsistent with its labeling."

Fertilizer

Fertilizers are to supplement the nutrients already in the soil. Gardeners frequently apply too much fertilizer, which may damage plants, affect water quality, and cost you money. Apply fertilizer according to soil test recommendations. When using chemical fertilizers, apply in bands along the vegetable rows rather than broadcasting. This can improve crops and save fertilizer.

Recycling Garden Wastes

Gardening, like many other things we do, creates wastes: grass clippings, prunings, and leaves. Unlike many wastes, these can be processed in the garden to create a valuable resource. If we treat them like garbage, we are cheating ourselves and our garden of a valuable soil amendment.

Keep Garden Waste Out of the Water

Large bodies of water are often looked upon, by those who live near them, as a handy bottomless garbage pit. If we wastefully dump these valuable materials in a river, lake, or stream, we are endangering the health of these water bodies and those plants and animals that live in them.

Why Not Throw Garden Wastes Into the Water?

- Plant materials need oxygen to break down, so the process competes with fish and other aquatic animals for the limited oxygen supply.
- Some plant materials contain chemical components that can alter balance in aquatic environments.
- Wastes can create obstructions and dangers to boats, divers, and swimmers.
- It is illegal! Regulations forbid dumping anything into any body of water.

Using Garden Wastes

Mulching

Garden wastes, such as leaves, can be applied directly to the soil as a mulch. Mulches reduce the need for watering, while helping to control weeds. Grass clippings are best used after being dried. (Note that herbicide-treated grass clippings should not be used as a mulch.) Woody plants and prunings can be run through a chipper. If you don't want to buy your own chipper, purchase it with a few neighbors or rent one.

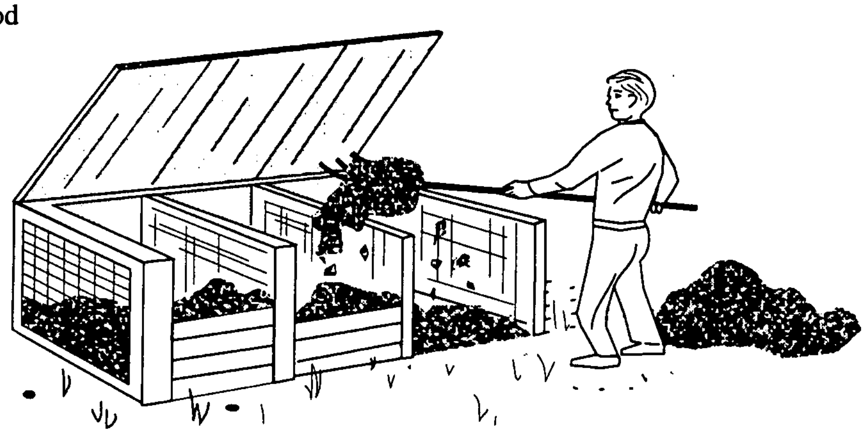
Four or five layers of newspaper serves as an effective mulch for garden plants, especially newly planted strawberries. Cover the newspaper with straw or wood chips to reduce the white glare and prevent it from blowing away or decomposing too rapidly.

Composting

Compost improves your soil. Finished compost can loosen a heavy soil, making it more porous and allowing better aeration and water infiltration, while a sandy soil will hold moisture and nutrients better. Adding compost will help better hold moisture and nutrients. This should cut down on the amount of water that runs off your land, thereby reducing the threat of pollution. The added benefit for you is that the more water your soil holds, the less water you need to apply. Compost-enriched soil makes a healthy home for many beneficial creatures, insects, worms, and microorganisms.

Information about composting is available through your OSU Extension county office. Some good references for the home composter are also listed in the reference portion of this chapter.

Compost can also be used as a mulch, by itself or combined with other organic materials, such as bark or wood chips. Compost can be worked into the soil when preparing flowerbeds, vegetable gardens, or new lawns.



All leaves are compostable, including oak, rhododendron, and even conifer needles. Since smaller pieces break down faster, shrub and tree prunings and other large pieces of plant material should be run through a shredder/chipper. Tree leaves tend to form a mat and can also be shredded by running over them with a rotary lawn mower.

Plant material treated with herbicide, including grass clippings, must be properly composted for at least a year to eliminate potential herbicide problems. In addition, do not compost diseased plant parts, perennial weeds (such as morning glory and quackgrass), or weeds with seeds.

A carefully managed compost pile should be free of odor, insect, and rodent problems. Compost piles are not garbage heaps. Health authorities now caution against adding kitchen wastes, especially meats and oils, to home compost because they may attract rats and other vermin.

Watering

Plants Need Water

Proper watering is essential to a healthy garden. A plant is 75–90 percent water. Water is necessary for plant functions such as photosynthesis and transporting nutrients within the plant. If water is applied properly in correct amounts, you will save on your water bill while protecting water quality.

Overwatering can wash away soil, pesticides, and nutrients. These may eventually find their way into the watershed, a loss to your garden and a hazard to aquatic life.

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Ways to Water

The method you use can make a difference.

Hand Held Watering Can or Garden Hose

This method is only appropriate for containers or a small bed because even a small garden will require a great deal of time and patience to hand water properly. Perforated cans may be sunk into the ground next to plants and filled with water which will percolate slowly into the soil.

Sprinklers

Sprinkler irrigation of shrub and tree plantings may generate considerable runoff. Keep the water pattern even by moving the sprinkler frequently and overlapping about one half of each pattern. Do not apply water faster than soil can absorb it. Be sure the sprinkler is not watering the sidewalk, street, or other paved surface where water will be wasted.

Soaker Hoses

There are a variety of special soaker hoses. These can reduce runoff and evaporative losses and generally do not cost more than normal garden hoses. Perforated plastic hoses or soaker hoses should be placed with holes down (if there are holes). Lay hose along one side of the crop row or underneath mulch; water will slowly soak into the soil without wetting foliage.

Trickle and Drip Systems

Trickle or drip irrigation is very efficient since it applies water to each plant's roots zone at a rate consistent with the plant's moisture requirements. It can reduce water use by as much as 50 percent to 80 percent compared to overhead irrigation. Another advantage of these systems is that foliage stays dry which reduces the potential for foliar disease problems.

When to Water

Water only when needed. A good rule of thumb in watering plants is to fill the entire root zone with water and then allow the soil to dry out partially before the next irrigation. The amount of drying depends on the plant species and size, and weather conditions.

A small or newly established plant will need watering before very much soil drying takes place. Seeds and seedlings should never be allowed to dry, so they need more frequent watering. A vegetable garden should be kept evenly moist. When a lawn gets too dry it will show a loss of resilience; footsteps will remain instead of bouncing back.

Don't water according to the calendar or by relying on an automatic timer. If you use an automatic system, then install a moisture detector to trigger waterings. Try not to water on windy days or during the heat of the day, especially with sprinklers, when considerable water may be lost to evaporation. Morning watering is fine for lawns and most other plants. The water will then be there when the plants need it and foliar disease problems can be reduced compared to night waterings.

How Much Water to Use

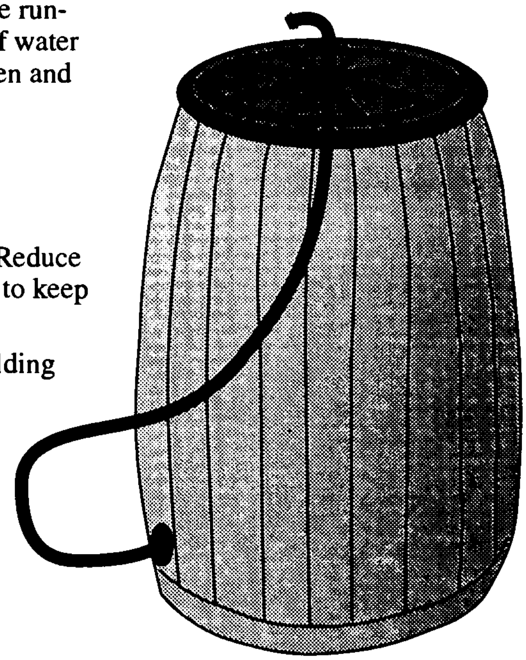
A hose running for 1 hour can use about 375 gallons of water.

Too much water, especially in poorly drained soils, can be damaging.

Do not apply water faster than the soil can absorb it. Turn off water at the first sign of saturation and turn it back on later if water did not penetrate the whole root zone. Generally, the rule is not to apply more than one half inch of water per hour; more rapid application can cause runoff. Use small tin cans to measure the amount and distribution of water being applied using a sprinkler system. The lawn and most garden and landscape plants can use an inch of water per week.

How to Reduce the Need to Water

- Select low water use plants.
- Allow the lawn to go dormant during the heat of summer. Reduce watering to one half inch every 2–3 weeks. This is enough to keep turfgrass crowns, rhizomes, and roots hydrated and alive.
- Add organic matter to the soil. This increases the water holding capacity of both sandy and clay soils.
- Store rainwater in a 55 gallon barrel collected from the roof. A hose tap can be mounted at the bottom.
- Design your landscape to consolidate plants requiring more irrigation; azaleas and rhododendrons, for example, could be grouped in one area.



Pest Management

Pests

Pests are organisms we don't like: plant, insect, or animal. When most people think of pests they think of insects, but fungi, viruses, bacteria, weeds, rodents, and other organisms can be as destructive as insects. They may all compete with us for food, inflict injury, or just be annoying. Pests can be controlled without undue damage to our natural waters and our environment as a whole.

A pest-free garden is expensive, impractical, and actually undesirable. The goal should be to keep pest populations below the level at which they cause unacceptable damage. Allow a low level of pests to survive in order to maintain a population of their natural enemies.

Know Your Garden

What is going on in your garden? Inspect your plants for insect damage and disease often; try it at night with a flashlight too. You will learn a lot about what goes on in your garden. Remember that most insects are helpful; few are harmful. We certainly can tolerate some harmful insects without significant damage.

Good gardening is based on understanding nature's interactions. Don't turn to chemicals at the first sight of a weed or insect. The more often we use garden chemicals, the greater the risk we run of endangering our health and environment.

By looking at the pest problem realistically you can:

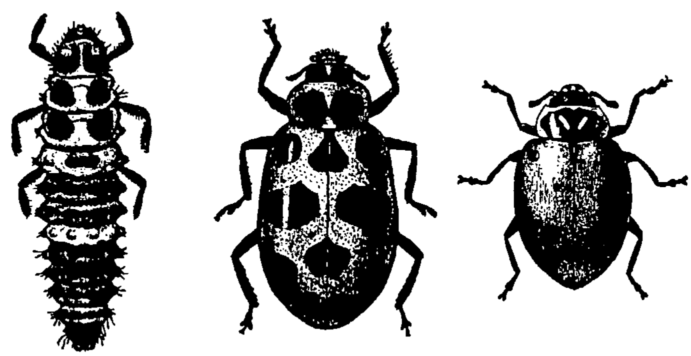
- save money by buying fewer pesticides.
- save time by not controlling what doesn't need to be controlled.
- protect the watershed by introducing less pesticides into our environment.

Keep a Healthy Garden

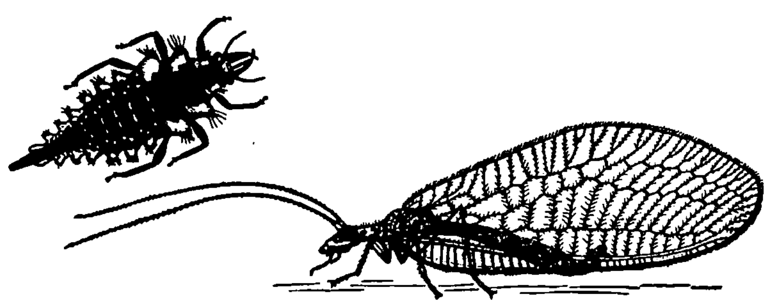
Good management prevents problems. Make your garden a healthy place for your desired plants and an unhealthy place for pests. Here are some ways:

- Select appropriate plant species. Plant disease and insect-resistant cultivars.
- Provide proper level of moisture. Water enough to maintain healthy plants. Design landscapes to conserve soil moisture.
- Maintain correct level of fertility. Test your soil. Don't over- or under-fertilize.
- Rotate vegetables and other annuals so that the same or a related plant does not occupy the same area every year. Rotations can reduce insect infestation and the buildup of soil diseases.
- Keep your garden clean. Rocks, wood, weeds, and debris provide great hiding places for slugs and insects.
- Time plantings to avoid peak of insect infestations. Sometimes the most destructive phases of an insect's life are brief and predictable.
- Encourage naturally occurring beneficial insects and other animals. These are your garden's best friends.

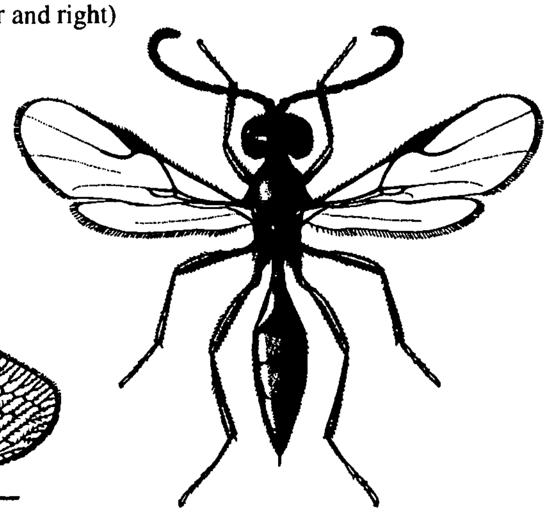
BENEFICIAL INSECTS THAT FEED ON PESTS



Lady betle larva (left) and two types of lady beetle adults (center and right)



Lacewing larva (left) and adult (right)



Parasite wasp that attacks aphids

When There is a Problem

Identify the Problem

Don't jump to conclusions. Read up on the specific pest and/or take a sample to your local OSU Extension county office, garden center, or nursery. Did a past experience with this particular pest require control?

Determine the Problem Potential

Decide whether the current problem is likely to become serious enough to justify some kind of treatment. Many times the problem has already run its course and no further damage may occur. Sometimes the damage will be minimal. Decide what can be tolerated.

Select the Least Toxic Approach

Try the simplest and safest first.

Observe Results

Record your results for future reference.

Non-Toxic Control Methods

Insects

- Prune out insect-infested areas of plants.
- Cover susceptible crops with floating row cover or nylon screen. This will protect them from insects that are difficult to control by other means.
- Use insect traps where appropriate.
- Handpick insects off plants.

Disease

- Plant disease-resistant cultivars.
- Rotate annual plants.
- Allow adequate space between plants and prune for good air circulation.
- Time watering so that foliage dries by nightfall.
- Prune off diseased areas of plants.

Slugs

- Place beer in containers to effectively attract and kill slugs.
- Overturn clay pots or place flat boards next to the plants to lure slugs. Check frequently and kill collected slugs.

Weeds

- Hand pull; cultivate with a hoe where appropriate.
- Use mulches generously.

Beneficial Insects

- Choose the right plants and you can encourage beneficial insects—those good bugs that feast on such garden pests as aphids and whiteflies—to stop and stay awhile in your garden. See Appendix B for a list of 15 plants that attract beneficial insects.

Pesticides

Pesticides (insecticides, fungicides, and herbicides) are chemicals used to kill pests. They can have an impact beyond their intended target if used improperly. Pest populations are more likely to become resistant to pesticides when the same ones are repeatedly used against them. Chemical pesticides are only one of several control options that should be considered.

As an alternative to insecticides, encourage insect-eating birds and beneficial insects in your yard. Attract birds by providing tree cover and food throughout the year. Nesting boxes and water sources will encourage their residence. Spiders, ladybugs, and lacewings are effective insect pest predators. Learn to recognize and respect these insects. You can even purchase and release them onto your land, although they may not take up permanent residence there.

If You Use Pesticides

Chemical controls should not be applied according to a predetermined calendar schedule. Time treatments to be most effective and least disruptive to naturally existing controls. Insects should be dealt with when you see them, not when they have departed and left the damage behind.

Choose the Right One

If you are unsure, then seek good advice. Choose the least toxic alternative. Some examples of less toxic pesticides are pyrethroids, insecticidal soaps, horticultural oils, and Bacillus thuringiensis (Bt), and IGRs or insect growth regulators. Buy the smallest quantity available and mix only the amount needed to avoid disposal problems.

Check the Label

Re-read the label each time you use a pesticide; don't trust memory. Make sure your pest and plant are listed. Newer labels may have added use restrictions.

Mix Correctly

Don't use rough estimates. Follow label recommendations. More is not better; it can hurt your plants, your family, and the environment. Extra dosage does not mean extra effectiveness and, in fact, it may give poorer results. Excessive amounts may even damage or kill plants. Do not mix more than you need.

Do Not Ignore the Possibility of Spills

Clean up spills right away. Your chemical storage area should have a non-porous floor, without a drain, so spills can be easily cleaned up and properly disposed of. Set up a barrier to contain spills. Never flush down with a hose. Do not allow pesticide to go down a drain. Soak up liquid spills with such material as cat litter, box granules, rags or newspaper. Carefully sweep up spilled powders. Scrub wood, cement, or tile surfaces with a small amount of mixture of water and strong household detergent. Place all contaminated materials into a plastic bag, seal and, then dispose of properly.

Apply Thoughtfully

Take safety precautions as recommended on the label. Don't apply pesticides:

- when it is windy or raining.
- where it is likely to go into any body of water, channel, or drain.
- when the soil is saturated.

Dispose of Leftover Pesticide Safely

Managing leftover pesticide is extremely difficult and must be done with care. The best practice is to only mix as much as you need. Use it up as directed on the label. Do not pour leftover pesticides down any drain or storm sewer.

Store Properly

Store in original, closed, well-labeled containers. Keep on strong, secure shelves in a locked cabinet.

Treat Empty Containers Properly

Triple rinse or pressure rinse empty containers, use the rinse water as you would a pesticide. Do not pour pesticide contaminated rinsewater down the drain. Follow label directions for disposal.

Further Reading

Applehof, M. (1992). *Worms eat my garbage.* Kalamazoo, MI: Flower Press.

Craven, Scott R., and Ellarson, Robert. (1992). *Landscape Plants that attract Birds.* Madison, WI. University of Wisconsin-Extension Bulletin G1609.

Curtis, C. R. (1995). *The Public & Pesticides: Exploring the Interface.* National Agricultural Pesticide Impact Assessment Program. USDA.

Dickson, N., Richard, T., and Kozlowksi, R. (Undated). *Composting to Reduce the Waste Stream: A Guide to Small Scale Food and Yard Waste Composting.* (NRAES-43). Ithaca, NY: Northeast Regional Agricultural Engineering Service.

Ferguson, N. (1984). *Right Plant, Right Place.* New York: Summit Books.

USEPA. (1995). *Citizen's Guide to Pest Control and Pesticide Safety.* EPA 730-K-95-001. EPA, Washington, DC 20460

National Wildflower Research Center Clearing House Fact Sheets. National Wildflower Research Center Clearing House, 4801 La Crosse Ave., Austin, TX 78739. 512-929-4200.

Butterfly Gardening Resources

Creating a Wildlife Garden

Gardening and Landscaping with Native Plants

Recommended Species for Ohio (Wildflowers)

Wildlife Gardening Bibliography

Ohio Nursery & Landscape Association Publications. ONLA, 2021 E. Dublin-Granville Rd., Suite 185, Columbus, OH 43229. 614-431-2452. For purchase in quantities only.

Common Insect Pests and Disease of Ornamental Trees and Shrubs

Landscape Plants for Ohio

Perennial Plants for Ohio

Ohio State University Extension Publications:

HYG 1002-97	*Fertilizing Landscape Plants*
HYG 1050-96	*Ground Covers for the Home Landscape*
HYG 1055-88	*Landscape Plants for Use in Dry Areas*
HYG 1134-94	*Functional Uses of Plants in the Landscape*
HYG 1151-94	*Gardening and Landscaping with Wood*
HYG 1189-93	*Composting at Home*
HYG 1223-92	*Selecting and Planting Annuals Outdoors*
HYG 1236-92	*General Maintenance of Herbaceous Ornamentals*
HYG 1242-92	*Perennials for Specific Sites and Uses*
HYG 1243-92	*Herbaceous Ornamentals for Shade*
HYG 1601-95	*Fertilizing Vegetable Garden Soils*
HYG 1602-92	*Improving Soils for Vegetable Gardening*
HYG 1643-94	*Drought Resistance in the Home Landscape*
HYG 2122-96	*Commercial Suppliers of Beneficial Organisms*
HYG 2205-94	*IPM for the Home Vegetable Garden*
HYG 4002-90	*Annual Grass Weed Control in Lawns*
HYG 4006-90	*Fertilization of Lawns*
HYG 4008-93	*Thatch: The Accumulation in Lawns*
HYG 4011-92	*Turfgrass Species Selection*
HYG 4020-93	*Lawn Mowing*
HYG 4025-88	*What to Look for in a Lawn Care Service*
HYG 4026-90	*Lime & the Home Lawn*
HYG 4027-91	*Lawn Grass Cultivar Selection*
HYG 4028-93	*Interpreting a Soil Test for Lawns*
HYG 4029-96	*Managing Turfgrass under Drought Conditions*
HYG 4030-96	*Growing Turfgrass in the Shade*
HYG 3045-96	*How to Care for Tree Wounds*
HYG 5117-94	*Pesticide-Contaminated Clothing Needs Washing Care*
Bulletin 271	*Your Lawn*
Bulletin 504	*Insect and Mite Control on Woody Ornamentals and Herbaceous Perennials*
Bulletin 591	*Growing and Using Fruit at Home*
Bulletin 845	*Selecting and Planting Trees*
Video VT53	*Master Gardener Series: Home Lawn*
Video VT52	*Master Gardener Series: Backyard Composting*
North Central Regional Bulletin 641	*Insect Traps for Home Fruit Insect Control*
North Central Regional Bulletin 461	*Ornamental Grasses for the Midwest*

Original Washington State publication reviewed and revised by William Pound, Extension Turf Specialist, Marianne Riofrio, Extension Associate and Dr. Mary Ann Rose, Extension Landscape Specialist, Department of Horticulture & Crop Science, The Ohio State University.

Additional Resources

Additional Resources

Prepared By:
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Agriculture and Natural Resources
Ohio State University Extension

The following section contains a list of just a few available resources providing additional water quality and watershed information. Contact your local library and/or OSU Extension office for assistance in locating these resources. A list of government agencies that can assist with providing information is also included.

Catalogs

1. 1997 Environmental Products Catalog. Terrene Institute.

Includes projects/resources; teacher, community, and professional kits; watershed note cards; books; fact sheets; posters; databases and more.

2. National Publications Catalog for 1996. U.S. Environmental Protection Agency.

Lists every EPA publication on a wide range of topics from Acid Rain to Wetlands.

Grants

1. Environmental Grant-Making Foundations 1995 Directory. Environmental Data Research Institute.

Over 700 pages of foundations and other organizations supporting environmental programs, including water quality.

Groundwater

1. A Community Guide to Groundwater Guardian, 1997 Edition. The Groundwater Foundation.

Information kit includes 40 page program guide, groundwater guardian fact sheet, membership guide pamphlet, products catalog, 1 copy of the Journal of The Groundwater Foundation, and 1 copy of the Water Education Newsletter.

2. Groundwater and the Ohio Wellhead Protection Program. **Video**. Ohio Department of Natural Resources.

A mother and her two children talk to Ohio's experts to learn about groundwater use and protection. Describes the Ohio Wellhead Protection Program and what communities and individuals can do to protect the water supply. (20 min.).

Maps

1. Division of Surface Water Watersheds. (October, 1996). Ohio EPA.

Color coded map indicating boundaries of OEPA's 93 watersheds and basins. No political boundaries or cities are indicated on this map.

2. Percent of Stream Miles Meeting Aquatic Life Uses in Ohio Watersheds. (October, 1996). Ohio EPA.

Color coded map indicating percent of streams meeting aquatic life uses in each of OEPA's 93 designated Ohio watersheds.

Outreach Education

1. Walk Your Watershed: Festival Organizing Kit. Water Environment Federation, T. G. F.

Brief but contains valuable ideas for doing your own watershed festival. Includes a sample program, evaluation tool and press release.

Urban Runoff

1. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Terrene Institute.

Very technical manual; gives a good review of water quality impacts of urban runoff and institutional control measures. Includes 3 case studies.

2. Storm Water BMP's. U.S. EPA

17 fact sheets covering topics from catch basin cleaning to spill prevention.

3. Urbanization and Water Quality: A Guide to Protecting the Urban Environment. Terrene Institute.

General overview of water quality problems caused by urban runoff and methods to control them. Includes a list and description of related federal pollution control programs.

Water Quality

1. BMP's for Preventing Contamination of Ohio's Ground and Surface Waters. OSU Extension.

Excellent overview of sources of water quality degradation and BMP's for controlling them. (1991).

2. Citizen's Guide to Understanding Ohio's Surface Water Quality Standards. Ohio EPA.

Very general and brief (8 pages) introduction to water quality standards and why they are important.

3. Help Water Quality. OSU Extension for the Indian Lake Watershed Project.

For landowner audience; discusses residential BMP's for protecting water resources and enhancing wildlife habitat.

4. Ohio's Water, Ohio's Future. 1994 Final Report for the Governor's Blue Ribbon Task Force on Water Resources Planning and Development. State of Ohio.

An evaluation of the organizational, technical, financial and planning infrastructure for water in Ohio with recommendations for improvement.

5. Vegetative Filter Strips for Improved Surface Water Quality. Iowa State University Extension.

Describes vegetative filter strips, their uses, and how they work. Document includes a worksheet for educational activities.

6. Water Watch: What Boaters can do to be Environmentally Friendly. National Marine Manufacturers Association.

Boater BMP's.

7. Water Sampling in Lakes and their Tributaries. **Video**. NYS Federation of Lake Associations, I.

Details materials and methods for water quality monitoring in lakes and their tributaries. (20 min.).

Watershed Management

1. Clean Water in Your Watershed: A Citizen's Guide to Watershed Protection. Terrene Institute.

A step-by-step guide for local citizens' watershed conservation groups.

2. Connecting Ohio Watersheds Conference Proceedings.

Reviews various aspects of watershed management (program formation, education, monitoring, evaluation, etc.) through case studies of Ohio projects.

3. Know Your Watershed: A Guide for Watershed Partnerships. Conservation Technology Information Center (CTIC).

Information packet which includes 7 factsheets, leaflets, and a 'Partnerships for Watersheds' video to help local watershed protection groups get started and grow.

4. Lake Smarts: The First Lake Maintenance Handbook. Terrene Institute.

"A do-it-yourself guide to solving lake problems" including weed and algae control, wastewater and sediments.

5. Maintaining and Improving Water Quality in the Big Darby Creek Watershed: Agricultural and Urban Nonpoint Water Pollution. O.S.U.

Overview of rural and urban contributions to water quality problems in the Big Darby and efforts to control them.

6. Managing Resources for a Sustainable Future. The South Carolina Department of Natural Resources.

A recent (1996) study of the economic and natural resources of the Edisto River Basin in South Carolina using geographic information systems technology. Includes a summary of recommendations for the sustainable management of those resources.

7. A Watershed Approach to Urban Runoff: Handbook for Decisionmakers. Terrene Institute.

Practical guide to controlling contamination from urban runoff.

8. Partnerships for Watersheds. **Video**. CTIC.

An excellent introduction to the watershed concept and strategies for developing local partnerships to manage watersheds. Includes a case study of the Indian Lake Watershed. (13 min.).

9. Managing Lakes through Community Participation. **Video**. Federation of Lake Associations, I.

A thorough but practical guide to forming a lake management association. Individuals share their real life experiences in overcoming common obstacles to a successful lake/watershed management project. (25 min.).

10. Watershed Restoration Management: Physical, Chemical, and Biological Considerations. Proceedings of the 1996 AWRA Annual Symposium. American Water Resources Association.

A 500+ page collection of papers covering a wide variety of topics, all relating to the restoration of watersheds in forested, agricultural, and urban settings. Not just for the technophile, this also has some good information about educational aspects of watershed management.

11. We All Live Downstream. **Video**. Oregon State University Agricultural Communications.

Examines how local residents and government officials are working together to control non-point source pollution in Oregon's Tualatin River. Includes examples of BMP's for farmers and public education ideas. (28 min.).

12. Luck Isn't Enough: The Fight for Clean Water. **Video**. University of Connecticut Cooperative Extension.

Introduction to the concept of non-point source pollution with recommended BMP's for urban dwellers and municipal officials. (12 min.).

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Getting Your Feet 'Wet' On the Internet

Try out some of these sites on the Internet:

OSU Extension(Environment)
http://www.ag.ohio-state.edu/~ohioline/lines/ennr.html#water

U.S.D.A.(water quality projects)
http://info.aes.purdue.edu/agronomy/hua/us_hua.htm

U.S.E.P.A.(home page)
http://www.epa.gov/

(watershed tools directory)
http://www.epa.gov/OW/watershed/tools/

(N.P.S. pollution info. exchange)
http://www.epa.gov/OWOW/NPS/npsie.html

U.S.G.S. (Water resources info.)
http://h2o.usgs.gov/

Soil and Water Conservation Society
http://www.netins.net/showcase/swcs/

Water Quality Information Center
http://www.inform.umd.edu:8080/EdRes/Topic/AgrEnv/Water

Ag. and Water Resources Information
http://inform.umd.edu:86/EdRes/Topic/AgrEnv/Water/.www.html#1

Know Your Watershed
http://www.ctic.purdue.edu/kyw/kyw.html

National Watershed Network
http://www.ctic.purdue.edu/watershed/watershedoptions.html

National Extension Water Quality Database
http://hermes.ecn.purdue.edu:8001/server/water/water.html

Global Rivers Environmental Education Network (GREEN)
http://www.igc.apc.org/green/index.html

Nonpoint Education for Municipal Officials (NEMO)
http://www.lib.uconn.edu/CANR/ces/nemo1.html

- U. S. Environmental Protection Agency, Region 5. 77 West Jackson Blvd. Chicago, Illinois 60604. (800) 621-8431. Wetland & Watershed Section (312) 353-2308. This agency is the primary regulatory agency at the federal level responsible for implementation of various environmental laws including the Clean Water Act.

United States Government, Executive Branch agencies, administered by the U. S. Department of Agriculture (USDA):

- Farm Service Agency (FSA), P. O. Box 2415, Washington, D. C. 20013; (202) 720-6221. This federal agency was formerly known as the Agricultural Stabilization and Conservation Service (ASCS). It administers the Conservation Reserve Program, Wetlands Reserve Program, Water Bank Program and Forestry Incentives Program, among others.
- Forest Service, P. O. Box 96090, Washington, D. C. 20090-6090; (202) 205-0957. This agency administers activities on National Forests and National Grasslands. The Forest Service cooperates with state and private landowners to apply sound forest management practices, to protect forest lands against fire, insects and diseases, and to distribute planting stock. It also conducts research in forestry and wildland management.
- Natural Resources Conservation Service (formerly Soil Conservation Service). NRCS personnel, housed in each Soil and Water Conservation District office, provide technical assistance with watershed projects, flood protection and erosion prevention.

United States Government, Executive Branch agencies, administered by the Department of the Interior.

- U. S. Geological Survey. National Center, Reston, VA 22092; (713) 648-4000. This research agency publishes maps and reports about our nation's physical features and its mineral, fuel and water resources.
- National Park Service. Interior Building, P. O. Box 37127, Washington, D. C. 20013-7127; (202) 208-4747. The NPS administers parks, monuments and other recreational areas of historical and natural value. It also administers study and grants programs.
- Office of Surface Mining Reclamation and Enforcement. Interior South Building, 1951 Constitution Ave., N. W., Washington, D. C. 20240; (202) 208-2553. This office establishes standards to regulate the environmental effects of coal mining, to support state implementation of regulatory programs and to promote reclamation of previously mined areas.
- U. S. Fish and Wildlife Service. This is the lead agency in the conservation of migratory birds, threatened and endangered species, certain marine mammals and sport fishes. Ohio is in Region 3, Great Lakes-Big Rivers Regional Office, 1 Federal Dr., Federal Bldg., For Snelling, MN 55111.

State Agencies

- Extension Service. Ohio State University Extension, based at Ohio State University in Columbus, has offices throughout Ohio (see directory). A staff of agents in each county, district specialists and state specialists conduct informal educational programming in the form of workshops, field day demonstrations, and programs in schools and communities. OSU Extension publishes educational information as fact sheets and bulletins, and offers training materials as videotapes and slide programs.
- Ohio Department of Agriculture, 65 S. Front St., Columbus 43215; (614) 466-2732. ODA administers agriculture laws and regulations.
- Ohio Department of Natural Resources. Fountain Square, Columbus 43224; (614) 265-6565. ODNR is charged with providing for the preservation, conservation, utilization and enjoyment of our natural resources. The Division of Forestry provides a service forestry program to private landowners and wood-using industries. Trained wildlife experts are available from the Division of Wildlife to prepare wildlife management plans and provide technical assistance to landowners wishing to improve wildlife habitat. Other areas covered by ODNR include recycling and litter prevention, natural areas and preserves, oil and gas, parks and recreation, public information and education, soil and water conservation, reclamation, and water.
- Ohio Environmental Protection Agency. 1800 WaterMark Dr., P. O. Box 163669, Columbus 43216-3669; (614) 644-3020. As the state regulatory agency, Ohio EPA has jurisdiction over air, waste water, drinking water, hazardous waste and land pollution control. Five district offices operate throughout Ohio.
- Soil and Water conservation Districts provide technical assistance to landowners and local governments in the area of land-use practices that protect soil and water resources. SWCD has an office in each Ohio county. Look in the county government pages of your phone book.

Local Contacts

- Farm Service Agency — Logan County.
  338 C.R. 11, Bellefontaine, OH 43311; (513) 592-8896.
- Indian Lake Watershed Project. 324 C. R. 11, Bellefontaine, OH 43311-9748; (513) 593-2946.
- Natural Resources Conservation Service — Logan County.
  324 County Road 11, Bellefontaine, OH 43311; (513) 593-2946.
- Natural Resources Conservation Service — Hardin County.
  P. O. Box 436, Kenton, OH 43326; (419) 673-0456.
- Natural Resources Conservation Service — Auglaize County.
  13888 S. Dixie, 25A, Wapakoneta, OH 45895; (419) 738-4016.
- OSU Extension — Logan County 117 E. Columbus, Suite 100, Bellefontaine, OH 43311; (513) 599-4227.
- OSU Extension — Hardin County, 1 Courthouse Sq., St. 40, Kenton, OH 43326; (419) 674- 2297.
- OSU Extension — Auglaize Co. 208 S. Blackhoof St., Wapakoneta, OH 45895; (419) 738- 2219.
- Ohio Dept. of Natural Resources, Division of Forestry.
  304 Patrick Ave. Urbana, OH 43078; (513) 653-4106.
- Indian Lake State Park , 12774 St.Rt. 235 North
  Lakeview, OH 43331; (937) 843-2717.

Master Watershed Steward Program Policies

Purpose

The Master Watershed Steward (MWS) Program is a first-time venture originally funded in part by 319 nonpoint source pollution grant funds and with continued funding by the Indian Lake Watershed Project. The program is supported by The Indian Lake Joint Board of supervisors, Logan, Hardin, and Auglaize County Natural Resource Conservation Service; Logan, Hardin, and Auglaize County Soil and Water Conservation Districts, The Ohio Department of Natural Resources; Indian Lake state Park; the Logan, Hardin, and Auglaize County Extension offices, and The Ohio State University Extension. Its purpose is to educate volunteers and utilize their expertise to teach people more about the importance of water quality and watershed management to the environment and to our quality of life. It is hoped that this program and its volunteers will lead to future public education and public involvement efforts to preserve, conserve and improve the quality of our water resources. The MWS program is dedicated to stewardship of the Indian Lake watershed and the protection and wise use of all naturall resources.

Master Watershed Steward volunteers will receive formal education from the OSU Extension covering a wide range of pertinent watershed and water quality topics. To become a Master Watershed Steward, the volunteer must complete the education program, pass the required exams, and volunteer a specified number of hours to Extension.

Training

The formal training program is the responsibility of the Extension professionals managing the program. Instructors are the Ohio State University faculty, Extension Specialists, Extension Associates, County Extension Agents, experienced Master Watershed Stewards, and other qualified experts.

The training program provides a balanced, integrated practical course in watershed management. Core topics are: Orientation to Extension and the MWS Program; Local Water Quality Issues; Hydrology; Stream, Lake And Wetland Ecology; Geology and Soils; Water Quality Monitoring; and Implementation of Best Management Practices to Improve Water Quality. Additional topics, based on local needs, may be part of the curriculum.

The principal resource for the training will be the *Master Watershed Steward Manual* that includes the core topics and material appropriate to Watershed Stewardship in Ohio. Core training is held during a 3 - 6 month period, with advanced training or in-service provided during the year in accordance with local needs and resources.

Attendance

Each MWS volunteer is expected to attend every class session. The volunteer is responsible for initiating provisions to make up any missed sessions. A limit on the number of allowable absences may be made by the MWS coordinator.

Examinations and Quizzes

Every volunteer must pass any quizzes and examinations with a cumulative average of 70 % or better. There may be closed-book exams that test the volunteer's knowledge of broad watershed management principles, open-book exams to test the volunteer's abilities to retrieve information from reference materials, as well as practical hands on exams to demonstrate the volunteer's knowledge of monitoring techniques.

Certification

Upon successful completion of the MWS educational program, each volunteer will receive a Master Watershed Steward Intern card. Upon fulfillment of the volunteer commitment the participant will then receive an official Master Watershed Steward certificate and name badge.

Volunteer Commitment

The Master Watershed Steward course consists of a minimum of 30 hours of instruction. An equivalent number of significant volunteer hours is required to become a certified Master Watershed Steward. The required volunteer hours should be completed within one year of completion of the MWS course.

Each Master Watershed Steward will have a completed Application, signed Master Watershed Steward Volunteer Agreement, signed OSU Extension Standards of Behavior and a service record on file at the local Extension office. This information is treated confidentially. Volunteers' records are kept in separate files in a secured place and are only accessible by trained extension staff. It is the responsibility of the volunteer to make sure that the information on their application (i.e. address, driver's license number) and their service record is kept current and accurate. This is necessary for liability reasons and for the protection of the volunteer as well as program staff .

Use of the Title

The title "Master Watershed Steward—Ohio State University Extension" is to be used only and exclusively in The Ohio State University (OSU) Extension MWS Program in which the trained and certified Master Watershed Stewards perform specific public services. Master Watershed Stewards' are advised not to advertise their name or place of business, nor be listed on the advertisements of business places as Master Watershed Stewards. Since The Ohio State University is a source of unbiased, research-based information, appearing as a commercial activity, having association with commercial products, or giving implied University endorsement of any product or place of business is improper.

The training and experience gained by functioning in the Master Watershed Steward Program are valuable and may be rightfully listed and featured as qualifications when seeking employment. Once employed, and while serving as a paid employee, or self employed, Master Watershed Stewards should NOT display credentials or give the appearance of being a Master Watershed Steward at the place of business.

Monitoring Policy

Biological, chemical, and physical monitoring of waterways will be conducted by volunteers only at locations with prior approval by the MWS Coordinator. Master Watershed Steward volunteers are required to have written permission from the landowner to monitor at locations on private property.

Recertification

Once an individual has completed the necessary requirements and is certified as a Master Watershed Steward, this does not mean that s/he is automatically a Master Watershed Steward for life. Master Watershed Stewards must be recertified each year to remain on the "active" list and maintain the Master Watershed Steward title.

Master Watershed Steward Recertification is achieved by fulfilling the following requirements:

1. Donating a minimum fifteen (15) hours of volunteer service each year, and
2. Completing a minimum of six (6) hours in-service training by any of the following options:
   - participation in State, Regional, National or International Watershed Conferences.
   - participation in county-sponsored advanced training sessions.
   - participation in any other programs approved by the local coordinator for recertification.

Dismissal of a Master Watershed Steward Volunteer

Repeated and consistent disregard for the policies and guidelines established by the Ohio State University Extension and the Ohio Master Watershed Steward Volunteer Program are grounds for dismissal as a Master Watershed Steward Volunteer.

If it is deemed necessary to dismiss a volunteer, the volunteer must be informed in writing by the Master watershed Steward coordinator of the termination of his/her volunteer status. This notice of dismissal will become part of the volunteer's confidential file.

Ohio Master Watershed Steward Volunteer Application

(All sections must be completed for consideration as a Master Watershed Steward volunteer)

General Information:

Name: ____

Mailing Address: ______________________________________

______________________________ County ______________

Length of time at this address (years):______ If less than one year at this address, list your previous address:

____

____

Driver's License Number[1] ______________________________

Social Security #[1] ____________________________________

Date of birth (mo/day/yr): ______________________________

Phone: Day (   ) ________________ Best time to call: ________

Evening (   ) ______________ Best time to call: ________

Have you participated in Ohio State University Extension activities or programs previously? (list most recent involvement)

____

____

____

____

Volunteer Interest:

Why are you interested in becoming a Master Watershed Steward volunteer?

____

____

____

What is your water quality philosophy? ________________________

____

____

____

____

[1]This information is used as a means of identification and is necessary in order to ensure your coverage under OSU Extension Personal Liability Insurance for Extension volunteers. All personal information is confidential.

Previous Work Experience:

(List current or most recent experience first)

Employer	Position Title	Year

Other special skills, training, interests(i.e. birdwatching, crafts, computer graphics, etc.): ____________________

____

____

Previous Volunteer Experience:

(List current or most recent experience first)

Organization	Volunteer Role	Year

Type of activities in which you are interested:

- ❑ Stream and Lake Restoration Projects
- ❑ Committee Member
- ❑ Lake Monitoring
- ❑ Stream Monitoring
- ❑ Public Presentations
- ❑ Working with Adults
- ❑ Newsletter
- ❑ Working with Children
- ❑ Writing News Releases
- ❑ Train other volunteers
- ❑ Administration
- ❑ Data Management
- ❑ Program Planning
- ❑ Data Collection (i.e. watershed land uses, lake user surveys, etc.)
- ❑ Other Interests ____________________

Indicate days and times you are available to volunteer:

Monday	❑ morning	❑ afternoon	❑ evening
Tuesday	❑ morning	❑ afternoon	❑ evening
Wednesday	❑ morning	❑ afternoon	❑ evening
Thursday	❑ morning	❑ afternoon	❑ evening
Friday	❑ morning	❑ afternoon	❑ evening
Saturday	❑ morning	❑ afternoon	❑ evening

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We frequently have many more applicants than volunteer positions, and consequently must choose among equally qualified individuals. Please explain why you think you would make a good Master Watershed volunteer: ______________________________

____

____

____

Personal References:

Have you been convicted of a misdemeanor or a felony in the last seven years? __________

If yes, please give date, nature and disposition of offense. __________

____

____

Please note: A criminal record will not necessarily prevent an applicant from being a Master Watershed Steward volunteer; a criminal record will be considered as it relates to specifics of the volunteer position for which you are applying.

References:

Name two persons not related to you who have knowledge of your qualifications. Please provide complete addresses and phone numbers.

1. Name: ____________________ Relationship: __________

Address: ______________________________

Phone: Day ( ) ____________ Evening ( ) ____________

2. Name: ____________________ Relationship: __________

Address: ______________________________

Phone: Day ( ) ____________ Evening ( ) ____________

I authorize the contact of listed references. I understand that the misrepresentation or omission of information requested is just cause for non-acceptance as a Master Watershed Steward volunteer trainee. If accepted as a volunteer, I agree to abide by the policies of Ohio State University Extension and the Ohio Master Watershed Steward Program and to fulfill the volunteer responsibilities to the best of my ability.

____

Applicant Signature   Date

Please return the application by the date indicated in the cover letter. Contact us if you have any questions or wish further information. Thank you!

Return to: Ohio State University Extension, Logan County
117 E. Columbus Avenue, Suite 100
Bellefontaine, OH 43311

Master Watershed Steward Volunteer Agreement

The title **Ohio Master Watershed Steward** is to be used only and exclusively in conjunction with activities associated with The Ohio State University Extension Master Watershed Steward Volunteer Program.

I will identify myself as a Master Watershed Steward only when engaged in unpaid public service in an Ohio State University Extension sponsored or approved program.

I will not appear as part of a commercial activity, have association with commercial products, or give implied Ohio State University or Ohio State University Extension endorsement of any product or place of business while serving as a Master Watershed Steward Volunteer.

In such service, I will follow policy dictated by Ohio State University, Ohio State University Extension, and the Master Watershed Steward Volunteer Program coordinator.

I have read and understood the Ohio Master Watershed Steward Volunteer Program Policy Statement and agree to give The Ohio State University Extension 30 hours of volunteer service in approved programs in exchange for 30 hours of water quality and watershed management training.

Signature of Volunteer ______________________ Date ____________

Ohio Master Watershed Steward Standard of Behavior

This Standards of Behavior is a contractual agreement accepted by volunteers who commit to the Ohio Master Watershed Steward Program. The standards shall guide the volunteers' behavior during their involvement with the Master Watershed Steward Program. Just as it is a privilege for Ohio State University Extension to work with individuals who volunteer their time and talents to the Master Watershed Steward Program, a volunteer's involvement in the program is a privilege and a responsibility, not a right.

The Ohio Master Watershed Steward Program provides unbiased, research-based educational programs accessible to all Ohio residents. The primary purpose of this Standards of Behavior is to ensure the safety and well-being of all Master Watershed Steward participants (i.e., target audiences, professionals and volunteers.)

Ohio Master Watershed Stewards are expected to function within the guidelines of Ohio State University Extension and the Ohio Master Watershed Steward Program. Ohio Master Watershed Steward volunteers shall be individuals of personal integrity.

The Master Watershed Steward volunteer will:

- Uphold volunteerism as an effective way to help meet the water quality needs of Ohio residents.
- Uphold an individual's right to dignity, self-development, and self-direction.
- Accept supervision and support from professional Extension staff while involved in the program.
- Accept the responsibility to represent their individual watershed Master Watershed Steward Coordinator and the Ohio Master Watershed Steward program.
- Represent the Watershed Steward Program with dignity and pride by being positive mentors for those they work with.
- Conduct themselves in a courteous and respectful manner, with fairness, honesty and integrity.
- Respect, adhere to, and enforce the policies and guidelines established by their individual watershed Master Watershed Steward Coordinator , the Ohio Master Watershed Steward program, and Ohio state University Extension.
- Abide by the OSU Extension Youth Protection Policy; not abuse any program participant by physical or verbal means; and report such abuse, if observed, as outlined in the Youth Protection Policy.
- Not commit a felonious criminal act.
- Comply with equal opportunity and anti-discrimination laws.
- Perform duties in a responsible and timely manner.
- Report immediately any threats to the volunteer's emotional or physical well-being to the Extension professional coordinating the Master Watershed Steward program.
- Accept the responsibility to promote and support the Master Watershed Steward program activities in order to develop effective watershed based programs across the state and nation.
- Conduct water quality monitoring and use sampling equipment in a safe and responsible manner.

I have read and understand the Standards of Behavior outlined above. I understand and agree that any action on my part that contradicts any portion of these standards is grounds for suspension and or termination of my volunteer status with the Ohio Master Watershed Steward program.

Signature of Volunteer ______________________ Date ________

Signature of Extension Professional ______________________ Date ________

Screening and Training of Extension Personnel and Volunteers

1. Volunteers (age 18 and over) working directly with youth and having two or more contacts per year with youth will acknowledge by signing the Ohio 4-H Volunteer Standards of Behavior that they have read, understand, and agree to abide by the Youth Protection Policy and Guidelines.

   Extension personnel and staff will acknowledge by signing the attached Agreement Form that they have read, understand, and agree to abide by the Youth Protection Policy and Guidelines.

2. At the discretion of each County Chair and appropriate staff, a criminal record check pertaining to any prior child abuse, felony, domestic violence, petty theft, etc. may be conducted and placed in his/her personnel file prior to the involvement of any or all potential Extension personnel and volunteers who work with youth.

3. All Extension personnel, staff and volunteers will be provided appropriate materials and orientation on the following:
   a. Youth Protection Policy and Guidelines of Ohio State University Extension,
   b. Identifying signs of possible child abuse and/or endangerment, and
   c. Legal requirements for responding to the suspicion of child abuse.

Youth Protection Policy and Guidelines

Ohio State University Extension The Ohio State University

Relationship With Youth

4. Extension personnel, staff and volunteers will endeavor to provide safe and healthy programs for youth. In cases of illness or injury, youth will be treated on site by an appropriate health care provider or taken to an appropriate health care provider if necessary, when a parent or guardian is not available for consultation.

5. Extension personnel, staff and volunteers are encouraged to avoid, where possible, being alone with a single youth, including sharing sleeping quarters with non-related youth.

6. Extension personnel, staff and volunteers will not, under any circumstances, discipline youth by the use of physical punishment or by failure to provide the basic necessities of care, such as food or shelter.

Reporting Procedure

7. According to Ohio Revised Code Section 2151.421 anyone may report child abuse or neglect to the Children Services Board. In addition, this law also imposes upon the following persons a legal reporting obligation by stating that such persons "when acting in their official or professional capacity are required by law to report knowledge or suspicion that a child under eighteen years of age or a physically or mentally handicapped child under twenty-one years of age has suffered or faces a threat of suffering any physical or mental wound, injury, disability, or condition of a nature that reasonably indicates abuse or neglect of the child:
   - attorney
   - physician, including a hospital intern or resident, dentist, podiatrist, practitioner of a limited branch of medicine or surgery
   - registered nurse, licensed practical nurse, visiting nurse, other health care professional
   - licensed psychologist, licensed school psychologist
   - speech pathologist or audiologist
   - coroner
   - administrator or employee of a child day-care center, administrator or employee of a certified child care agency or other public or private children services agency
   - school teacher, school employee, school authority
   - social worker
   - person rendering spiritual treatment through prayer in accordance with the tenets of a well-recognized religion."

8. Although Ohio State University Extension professionals are not listed in number seven, O.S.U. Extension encourages all Extension personnel, staff and volunteers to report forthwith, either by telephone or in person, suspected cases to the Children Services Board, the County Department of Human Services exercising the Children Services function, or a Municipal or County Peace Officer in the county in which the abuse or neglect is suspected to have occurred. (Ohio Revised Code Section 2151.421 (A) and (B)).

9. When Extension personnel, staff or volunteers file a report as described in paragraph eight, such person shall then immediately inform:
   - either the Agent responsible for the program, and/or the County Chair, or their immediate supervisor about the incident so reported.

This information shall proceed through Ohio State University Extension administration until the District Director, the appropriate Assistant Director, Associate Director and Director have been informed of the situation.

10. Ohio law provides that anyone reporting suspected child abuse or participating in a judicial proceeding resulting from such reports, is immune from any civil or criminal liability that otherwise might be imposed as a result of such actions when taken in good faith. (Ohio Revised Code Section 2151.421(G)).

11. A person who knowingly makes or causes another person to make a false report that alleges that any person has committed an act or omission that resulted in a child being an abused or a neglected child is guilty of a misdemeanor of the first degree. (Ohio Revised Code Sections 2151.421(H)(3) and 2921.14).

12. Extension personnel and volunteers will be familiar with and follow the reporting procedure described by Ohio law, including reporting the names and addresses of the youth and his/her parent(s) or the person(s) having custody of the youth, if known; the youth's age and nature and extent of known or suspected injuries, abuse or neglect or of the known or suspected threat of injury, abuse, or neglect; and any information that might be helpful in establishing the cause of the known or suspected injury, abuse, or neglect (Ohio Revised Code Section 2151.421(C)).

13. Extension personnel, staff and volunteers shall not contact the parent(s) and youth involved in a reported suspected child abuse incident unless instructed to do so by appropriate legal authorities.

14. When an incident that involves Extension personnel, staff, or volunteer is reported to Children Services Board, the County Department of Human Services exercising the Children Services function, or the appropriate Municipal or County Peace Officer, the immediate supervisor in consultation with the appropriate Extension administrator, will remove the person from all activities involving direct contact with youth until the matter is resolved.

15. Extension personnel, staff and volunteers will handle suspected child abuse information in a confidential manner. Involved Extension personnel, staff and volunteers will discuss matters pertaining to suspected abuse with only the immediate supervisor and the Children Services Board, the County Department of Human Services exercising the Children Services function, or the appropriate Municipal or County Peace Officer.

This policy has been approved by the Ohio State University Extension Administrative Cabinet, in consultation with Gary E. Brown, Assistant Attorney General, Office of Legal Affairs, The Ohio State University.

8/05/92

Master Watershed Stewards

Prepared and Compiled by:

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Suite 100
Bellefountaine, Ohio 43311-2053

Reference Sources:

Significant portions of material were adapted from the following resources:

Ohio State University Extension Master Gardener Program

The Washington State University Cooperative Extension Clallam County office and the Sequim Bay Water Quality Projects BAY WATCHERS Program.
WSU Extension
Clallam County Courthouse
223 East Fourth
Port Angeles, Washington 98362

Izaak Walton League of America Save Our Streams
707 Conservation Lane
Gaithersburg, MD 20878-2983
(301) 548-0150

Ohio's Scenic River Stream Quality Monitoring Citizen Action Program
Ohio Department of Natural Resources
Division of Natural Areas and Preserves
Scenic Rivers Program, Building 1889
Fountain Square Court
Columbus, Ohio 43224

This program was developed through the cooperation of The OSU Extension Logan and Hardin County offices and the Indian Lake Watershed Project.

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March, 1997

Indian Lake Watershed Project

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List of Contributors:

A significant portions of this document were written, adapted and edited by the following individuals.

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William K. Bruce	Geneva M. Garver	Richard Nisonger	Harvey Riebel
Kristi D. Comer	John Krock	Diane Norris	Vicki Smith
Chris Dewitt	Gregory L. Nageotte	Garis E. Pugh	James Taylor

ter Conservation Districts within the watershed, and representatives from local interests including agriculture, business, the local water dept., lake residents, and the Indian Lake State Park. The Joint Board receives and disperses funds, determines programming priorities and provides project direction.

An interagency implementation team consisting of individuals from NRCS, Division of Forestry, OSU Extension Service, Soil and Water Conservation Districts, and a Project Administrator contracted by the Joint Board provide technical support and implement programs.

The Programs

The Indian Lake Watershed Project provides a diverse array of incentive and education programs funded through various federal, state, and private sources in order to promote the adoption of Best Management Practices (BMPs) to reduce the sedimentation and eutrophication of Indian Lake and its tributaries. The following is a partial list of programs which have been or are currently being implemented in the watershed as of June 1996. A more complete list of programs is available in the "Indian Lake Watershed Project Long Range Management." Copies of the plan are available at local libraries, Ohio State University Extension office, and the Indian Lake Watershed Project office. (See Resource Agencies page).

Filter Strip Establishment

- 255 acres (42 miles with 50 foot average width)

Streambank Restoration

- 1580 feet applied

No-till Equipment Buydown

- 50 pieces of equipment

No-till Farming

- 80% of row crop and small grain acreage
  (6% prior to project implementation)

Integrated Crop Management

- 18 long-term agreements
- 3200 acres

Grassed Waterways

- 62.7 acres

Grade stabilization structures

- 36 structures

Critical area planting

- 4 acres

Tree Planting

- 17 acres

Pasture/Hayland Planting

- 1,625.9 acres

Precision Farming Systems

- 11 farms

- 5000 acres

Intensive Grazing Systems

- 40 acres

Livestock exclusion fencing

- 30,000 feet

Stream Monitoring

Education and Community Involvement

Stewardship Ethic

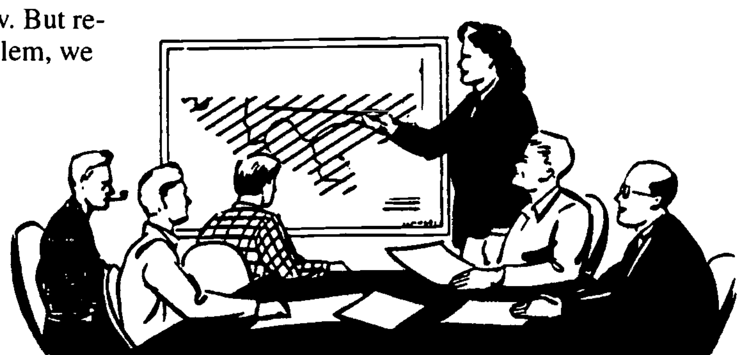
The Master Water shed Stewards (MWS) program is based on the concept that people will not knowingly do things that will pollute water. Yet everyday, as we go about living our daily lives, we do things that contribute to the water contamination.

You have joined the MWS program because you want to do something about water quality. No point in letting the news reports and magazine coverage drive you to despair; even the most "intractable" environmental problems march toward a solution when citizens get involved.

Few of us can do anything to keep million-barrel oil tankers on course through pristine waters. All of us can do something, every day, to ensure that fewer tankers are needed. None of us can stop the need for growth to facilitate increasing population. All of us can help reduce our own impact on the environment.

The volunteer program you are joining seeks to empower the individual to stop activities that contribute to water pollution. In other words, we want to foster a clean water ethic in our volunteers and, through them, in our communities. The program starts by providing background information about water and water pollution. By understanding the basics of hydrology, groundwater, geology and soils, stream, lake, and wetland ecology, agricultural practices, water quality monitoring techniques and other similar topics, you will understand how pollution occurs. Then you will learn what is being done to control pollution. Finally, you will be given tips about how you-as an individual and as a water quality volunteer can help protect and improve the water quality in our own community.

The 1990s have brought a new awareness that institutions alone can never solve the problems that culminate from the seemingly inconsequential actions of millions of individuals. Your trash, your neighbor's cows, his neighbor's septic system—all make the water less pure for the children of today and tomorrow. But remember: as much as we are the root of the problem, we are also the genesis of its solution.



Recording fish populations is another method of determining water quality, because fish species have different pollution tolerances. For example, trout need oxygen levels of at least 7.0 mg/l and are considered intolerant of pollution. Carp, on the other hand, can withstand lower levels of oxygen and are very pollution tolerant. Fish such as carp can accumulate toxins in their flesh. Thus, even though a fish looks healthy, it may contain toxic chemicals at levels that are hazardous to humans who consume the fish. Half of the states in the United States have published advisories against eating certain fish species caught in certain rivers, lakes, bays and reservoirs. However, because fish are mobile, they are not the only indicators of water quality at a particular location.

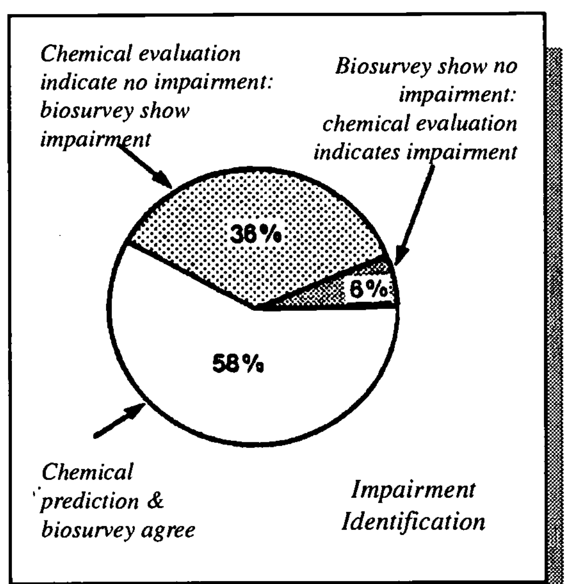
Macroinvertebrates, on the other hand, complete the larval stages of their life cycle within a few meters of the streambottom. Although macroinvertebrates may float a few feet downstream at night (a process called drift) they are generally stable in population within several yards and are not as mobile as fish. Because they are so stable, macroinvertebrates can indicate water quality and land use effects on the stream at the specific monitoring location.

Algae are another measure of water quality. Excessive algae covering most rock surfaces in riffle areas indicate nutrient pollution. High nutrient levels in the water from land runoff and sewage can cause excessive growth of algae, depleting the stream's oxygen supply when it breaks down and decomposes. Excessive algae also blocks light to underwater plants and invades the macroinvertebrates' habitat.

The type of algae present also indicates relative water quality since algae types vary in pollution tolerances and nutrient (ie. nitrates and phosphates) needs for growth. For instance, Cladophora glomerata is a clean water indicator, but Oscillatoria indicate polluted water. Algae identification techniques are useful, but are beyond the scope of this manual.

Aquatic plants, often referred to as submerged aquatic vegetation (SAV), also can be monitored as water quality indicators. Aquatic plants are important to the stream ecosystem by producing oxygen for the stream during photosynthesis and providing habitat and food for fish. For example, duckweed is a free-floating aquatic plant often found in good quality water.

Chemical Water Monitoring



Chemical monitoring also can be conducted by volunteers. Easy-to-use chemical monitoring kits that include parameters, such as dissolved oxygen, pH and hardness, can be obtained through the Hach or LaMotte companies. However, sophisticated monitoring is usually required to determine the presence of toxics and heavy metals. Analytic instrumentation and a controlled laboratory setting usually are required. Thus, the scope of chemical monitoring may be limited by cost or technical requirements.

In addition, measuring water chemistry in a stream will indicate the chemical makeup of the water at the particular moment the water is sampled. Dissolved oxygen rates differ depending on location in the water body, the time of day and temperature of the water. Thus, a range of different values could be obtained depending on the time of testing and sampling location.

Chemical monitoring will not always indicate the presence of water pollution. A 1988 study done by the Ohio Environmental Protection Agency indicated that the presence of a water pollution impairment in a stream was not detected 36 percent of the time using chemical monitoring alone. This means chemical monitoring showed impairment in only 64 percent of the cases in which the stream was polluted. However, using biological surveys indicated the presence of an impairment problem 94 percent of the time. Six percent of the time only chemical monitoring was able to show impairment. According to the 1990 EPA publication, "Biological Criteria: National Program Guidance for Surface Water", biological monitoring can identify impairments from contamination caused by sediments, unknown or unregulated chemicals, nonchemical impacts and altered physical habitat. Biological monitoring also can detect impacts from cumulative pollution or other impacts that periodic chemical sampling is unlikely to detect.

> "... the presence of a water pollution impairment in a stream was not detected 36 percent of the time using chemical monitoring alone."

To conduct chemical monitoring, equipment is needed from either Hach, LaMotte or other suitable companies to conduct the tests. These companies are recommended because they provide simple kits that can be used by nonscientists. Chemical kits may be purchased or borrowed, see your Master Water Steward coordinator for further information. Because the instructions for performing the tests vary depending on the chemistry kit, instructions for conducting chemical monitoring are not included in this manual.

Ideally, volunteers can measure physical, biological and chemical aspects of rivers or streams to gather a complete picture of the water quality. The stream survey form found at the end of this chapter includes spaces to record chemical test results, habitat characteristics and stream biology.

Stream Quality Survey Instructions

Stream health can be assessed by stream macroinvertebrates, organisms such as insects and crayfish large enough to be seen by the unaided eye. Many stream dwelling organisms are sensitive to changes in water quality, and their presence or absence can serve as an indicator of environmental conditions. Macroinvertebrates are easy to find. By following the technique below and filling out the Stream Survey, the stream's water quality can be diagnosed. Before choosing a site to monitor you should follow these rules:

Before monitoring:

1. Check with state and county agencies to make sure the area is not a survey area used by government agencies (over-monitoring may harm the stream).
2. Always contact local landowners and obtain written permission before monitoring to avoid trespassing. Ask for permission to cross private land. Most landowners will give permission for the study and may even want to help you conduct your survey.
3. Make sure that someone knows the date, time, and location of the monitoring so in case of injury, someone will realize you are missing or late in returning. Monitoring with a partner or group is best so someone can go for help in an emergency.
4. Make sure to know the phone number and location of the nearest medical center to the monitoring site and the location of the nearest phone. Know local emergency numbers from memory (i.e. 911, sheriff or fire department).
5. Pack a first aid kit

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get a clear picture of a stream and consult with a Extension Agent or state biologists from Ohio Department of Natural Resources or Ohio Environmental Protection Agency to discuss the findings.

Studying the Find

Check another spot about a quarter mile upstream. If there is a decrease in water quality, check the stream for new discharge pipes, evidence of erosion, farm runoff, and other possible sources of stream pollution.

Macroinvertebrate Count and Water Quality	
If you find:	**Look for:**
Little variety of insects, with great of each kind	Water overly enriched with organic matter
Only one or two kinds of insects in great abundance	Severe organic pollution
A variety of insects, but only a few of each kind, or no insects, but the stream appears clean	Toxic pollution

Stream Problems and Their Impact on Stream Organisms

1. *Physical Problems* may include excessive sediment from erosion, street runoff, or a discharge pipe. Sediment may create poor riffle characteristics; contribute to excessive flooding, reduce flow, change temperature, and smother aquatic life. The result is usually a reduction in the number of all animals in the study area.
2. *Organic Pollution* is from excessive human or livestock wastes or high nutrient enrichment from farm or yard runoff. The result is usually a reduction in the number of different kinds of insects and an increase of collectors/scrapers (such as the caddisflies).
3. *Toxic Pollution* includes chemical pollutants such as chlorine, acids, metals, pesticides, and oil. The result is usually a reduction in the number of insects.

When considering land use as the controlling factor in stream quality, look not just at the area visible from the stream, but at all the land draining to the stream - the watershed. If the stream drains an intensely developed area, do not be surprised if no organisms are found. Should this be the case, consider visiting a forested or agricultural tributary or ditch for a sampling comparison. It may be surprising the different types of organisms found.

Pollution sources causing poor or fair stream quality include sewage treatment plants, industries, construction sites, sewer overflows, landfills, and mining operations. A pollution source can be identified by sampling the stream at one-quarter mile intervals upstream from the initial sampling point (where a pollution impact is suspected) until quality improves. The pollution sources should be located somewhere between the point where degraded conditions were first found and the point where water quality improves.

Explanation of Survey Form Questions

The stream survey form asks a number of questions about the land and vegetation surrounding the stream. These questions will help characterize the quality of stream habitat and its ability to support a healthy population of stream organisms. The land use information will also paint a picture of the stream for other people who might review the survey form. Guidelines for correctly answering these questions are given below. Questions where the answer is obvious are not explained.

Record answers based on the area that is upstream from the monitoring site. Generally, always record the data for the area that can be seen. For land use information, include land uses for one mile upstream from the site or the section of stream being monitored (ie. one-quarter mile).

Surface Water Appearance: You can check more than one of the colors listed, but not all of them. Note if strange colors are present throughout the stream or only in one section, such as immediately below a discharge pipe or highway runoff culvert.

Stream Bed Deposits: Record the general overall appearance of the stream bottom. If the stream bed does not have any apparent coating, note it as other and write in "normal".

Algae: Algae feels slimy and you will notice it while rubbing rocks during monitoring. A great deal of algae may indicate a nutrient enrichment problem. Sometimes there is more algae in the Spring after snowmelt releases extra nutrients to the stream. However, note the amount of algae present in the stream to make sure it is not increasing over time.

Questions about stream banks and vegetation: Remember to look at both sides of the stream's banks. When questions ask for a percentage, use the information for both the left and right bank and combine values. For instance, if one side of the bank is completely bare from erosion while the other side is well-vegetated, record the percent of bank coverage as 50% (one half is covered and the other is not).

When recording total percentages of shrubs, grasses, and trees, look at both sides of the bank. However, if one side has artificial structures such as rock rip rap or concrete you will have to account for such ground cover. For instance, if the left side of the bank is not vegetated you cannot have more than 50% of shrubs, grasses and trees total when you add those values together.

Bottom composition: This question refers to the 3 x 3 foot area of stream sampled for rocky bottom sampling techniques with a kick-seine net and is best answered before disturbing the site. You do not have to fill out this question when using the muddy bottom sampling technique. Simply check off the number of scoops taken from each of the four types of muddy bottom stream habitats found in the next question on the survey form (muddy bottom only).

The organisms collected are most abundant in riffles composed of predominately cobble-sized stones (>70% cobbles is a good riffle habitat). Start with the largest rocks first when recording bed composition. If you don't have any boulders (rocks > 10 inches), write 0%. Record the amount of cobble-sized stones and continue until the percentages equal 100%. A typical riffle in a medium gradient stream might be recorded as 5% boulders, 65% cobbles, 15% gravel, 10% sand and 5% silt. Ranges are given on the survey form for the rock sizes. For the smaller rock sizes, remember that silt feels like talcum powder and sand feels gritty. If riffle had 40% silt, 10% gravel and no cobbles, either find another station to monitor or switch to the muddy bottom sampling technique.

NOTICE

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