Introduction

On Earth, all living things have moved through self-renewing life cycles, have depended on air and water, have grown and died. All these life-forms are tied together. To survive, they all—plants, animals, birds, insects, and organisms too small to be seen without a microscope—need air, water, soil, and sunlight in some form.

All life-forms are closely linked and depend on one another for their existence; this is called the "web of nature." If one strand of the web is damaged or destroyed, the other strands will feel the result in some way. If the web is strong, with all parts working well, a wholesome environment on Earth will flourish for people and all other living things.

It takes the attention and help of many people to keep Earth's environment in good working order to support its growing population, which must have air, water, food, clothing, shelter, and living space.

Our Responsibility to Learn

We all have a place in the great web of nature and should be concerned about what happens to the soil, water, and all things we call *natural resources*. We all have a duty to learn more about the natural resources on which our lives depend so that we can help make sure that these resources are used intelligently and cared for properly.

Conservation isn't just the responsibility of soil and plant scientists, hydrologists, wildlife managers, landowners, and the forest or mine owner alone. It must be *your* duty, too. To enjoy

woods, wildlife, and flowers; clean water; natural open spaces near our homes; and a good food supply, then you, too, must be a conservationist.

To be a natural resource conservationist, you must have a good knowledge of those natural resources. The Soil and Water Conservation merit badge will introduce you to the fascinating world of soil and water—and to the plants and animals that share Earth with us. To understand soil and water conservation as a whole, we must first study parts of it. This is why soil and water are discussed separately first, before they are considered as an inseparable whole. As you learn more about soil and water conservation and carry out your conservation projects, you will begin to see that it is nearly impossible to separate soil and water as parts of Earth's natural resources.

As you begin work on your Soil and Water Conservation merit badge, discuss the requirements with your counselor. Your counselor can help you choose projects that you can do readily and from which you can learn the most, depending on where you live.

soil. A self-renewing compound of rock and mineral particles, organic material, living organisms, air, and moisture.

What Is Soil?

We walk, play, travel, and build on it. You call it dirt and don't think much about it, but your life and that of all other creatures depend completely on the relatively thin layer of soil that has developed on most of the land surface of Earth. If you look closely at some soil, you'll see many bits of rock, mineral crystals, plant roots, decayed leaves and other materials, worms, tiny living and dead plants and animals, water, and air. Though the proportions vary, all soil consists of mineral and organic matter, water, and air.

> Recognizing how important soil is in the web of nature, Charles E. Kellogg, a soil scientist and chief of the Soil Survey for almost 40 years, wrote that "essentially, all life depends upon the soil. . . . There can be no life without soil and no soil without life; they have evolved together."

Understanding how soils form, how soils differ, and how plants use soil will help you better understand and appreciate the importance of soil in everyone's life.

Physical and Chemical Changes

Most soils developed largely from various kinds of rocks. Over thousands of years, the forces of nature—sun, wind, rain, frost, glacial ice, chemical and biological reactions—break rocks into smaller and smaller pieces. The sun warms the rock and the rock expands; at night the rock cools and contracts. This expansion and contraction opens tiny cracks in the rock. Moisture from rain or snow gets into the cracks and helps force the rock pieces farther apart. More water enters to repeat the cycle.

The forces of nature helped shape these rock formations in eastern Utah.

Nature's forces slowly crumble rocks into mineral particles of clay, sand, and silt.

After some pieces have broken off the rock, the wind blows them, or running water grinds them, against other rocks. Huge glaciers that once moved across the northern United States twisted and shifted and ground up tremendous quantities of rock, greatly changing the landscape.

Chemical reactions also help advance the decay of rocks. Falling rain picks up a little carbon dioxide from the atmosphere and, when joined with hydrogen, forms a weak acid—yet one powerful enough to dissolve certain mineral salts. These dissolved substances cause other chemical changes to occur in the rocks.

Soil Formation

The crumbling of rock is a destructive process while soil formation is a building process. Finely ground or splintered rock will not become soil until it begins to surge with life. Living and once-living plants and animals—organic matter—help give soil a physical structure that admits moisture and air and helps the soil retain them. To remain alive, soil must keep its structure.

As bits of crumbled material and moisture collect on a rock, simple plants called lichens begin to grow. After some time, water, decaying lichens, and more bits of mineral matter

Plants are the real makers of soil. At the same time, chemical reactions are happening, and bacteria, fungi, worms, tunneling and burrowing insects, and other organisms are active. Thus the formation of a simple soil begins.

Entirely different soils can come from the same rocks.

collect in the rock crevices. Soon, microscopic forms of plant and animal life begin to make the crevices their home. Mosses begin to grow on the rock, and later the seeds of larger plants germinate in this loose earth material; these weeds, grasses, and other plants grow, die, and decay, thereby supplying organic matter.

The shape, or *topography*, of the land on which soil develops helps determine the soil's quality. The topography—steepness of slope, direction of slope, elevation—determines the patterns of water movement and accumulation as well as the amount of the sun's heat that reaches the surface of the land.

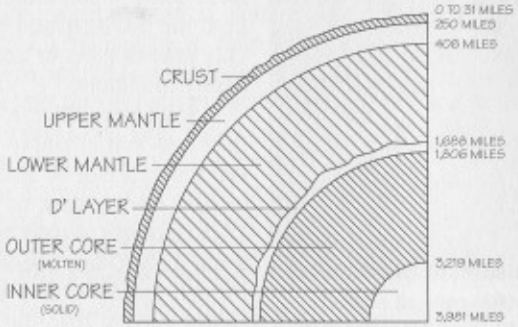
To build just 1 inch of the surface soil could take 100 years; in places where the climate is dry and cold, an inch of surface soil might not develop in 1,000 years. This is why it is so important to care for the soil we have.

Rub two pieces of rough rock together vigorously to get an idea of how long it would take for physical forces to break down rocks into the material from which soil develops. You have to rub a long time to get even a spoonful of tiny particles!

The Many Kinds of Soil

Soil scientists have identified more than 70,000 kinds of soil in the United States. Climate, parent rocks, plant and animal life, topography, and time all affect the development of soils and cause soils to be different. Particularly important is the climate, especially temperature and the amount of rainfall. Climate determines not only how fast and in what way rocks are broken into fragments, but, more importantly, what kinds of plants grow in a particular place. In turn, the kind of plants that grow, as well as how fast dead ones decay, and the kind and activity of soil organisms determine the kind of soil that develops.

Peat is a kind of soil that consists almost entirely of organic matter. You will usually find it where there were once lakes, ponds, or marshes.



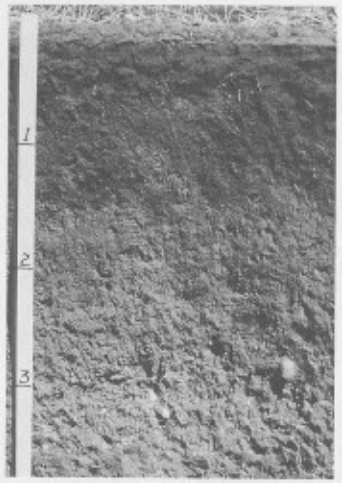
By looking at a cross section of Earth, we would see that the outer layer—the soil—is very thin compared with the diameter of the whole planet. Soil depth actually ranges from many feet, where wind and water have deposited soil materials over time, to less than an inch in places where the climate and other factors have hindered soil development or where soil loss has occurred because of carelessness or natural disasters.

The Soil Profile

Soil has three dimensions. It is bounded on the top by the surface of the land, on the bottom by rock material, and on the sides by other soils. A cross section of soil in a newly cut road or the excavation for the basement of a new building will show definite layers. This succession of layers from the soil surface down to broken, weathered rock is called a *soil profile*. The different layers are known as *horizons*.

Each horizon differs in one or more properties, such as color, texture, structure, porosity (how many pores it has—tiny holes that let in moisture), and chemical content.

In some places, if the cut for the soil profile is deep enough, you can see solid rock called bedrock below the soil's parent material.



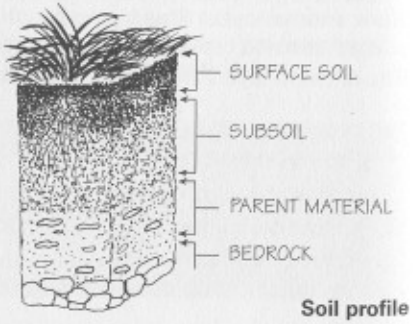
A soil profile can tell a great deal about the past climate of an area and about the plants that grew there many years ago.

The soil profile—all of the soil horizons taken together—carries the soil's history. For instance, the profile of the particular type of soil that develops in a forest looks much different from the profile of soil where only grasses grew or under desert conditions.

Soil layers differ in thickness and in color—surface soils can be black or dark brown, gray, or red. Organic matter usually makes a soil dark. Other layers in the soil profile usually are lighter in color than the surface soil. Their colors—yellow, red, white, or maybe even somewhat blue—come from rock and from chemical reactions that have happened over a long time.

Soils may look the same on the surface, they can be quite different underneath. To better understand the differences, look at several different soil profiles exposed along steep road banks or in construction excavations or grading activities. Explain some of the things you see and have learned about soil to other Scouts, your leaders, friends, or family members.

Most soil profiles include three *master horizons.* The top layer—the one we usually think of when we use the word *soil*—is called *surface soil.* From it, many plants get most of the moisture and nutrients they need to survive. Below the surface soil is a layer called *subsoil,* and then another layer called *soil parent material,* which is largely loose and partly decayed rock that might some day develop into soil.



Soil profile

Three Sizes of Particles

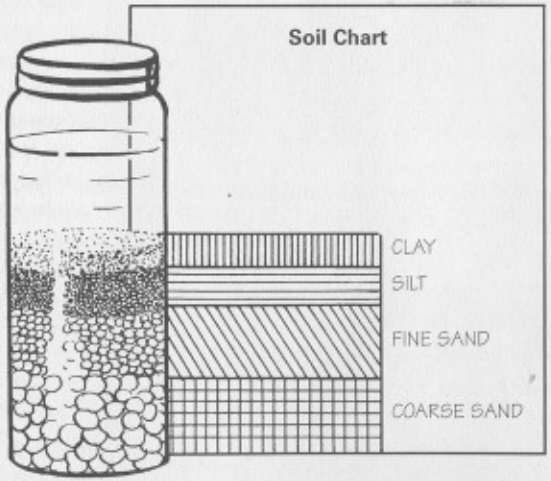
Another characteristic of a soil is the size of the solid particles it contains. In describing soils, the different-sized particles are called *sand, silt,* and *clay.*

Take some soil between your fingers. If it feels coarse and gritty and you can just barely see individual particles, it must contain a large proportion of sand—particles that range from 0.05 to 2.0 millimeters in diameter.

Fine soil feels smooth like flour. Moisten some and work it into a thin ribbon between your thumb and forefinger. If the ribbon breaks off near your fingers each time, chances are the soil is largely silt—particles ranging from 0.002 to 0.05 millimeters in diameter. You cannot see the individual particles without using a strong magnifying glass.

Does the soil between your fingers feel like fine powder when dry? After you moisten it, does it make at least an inch-long ribbon before breaking when you work it between your thumb and finger? If so, you have mostly clay—particles smaller than silt and less than 0.002 millimeters in diameter.

When soils experts refer to soil texture, they are talking about the size of the soil particles. When a soil is identified as a *loam* (this term refers only to the size of particles it contains), it means that the soil contains a relatively even mixture of sand and silt and a somewhat smaller proportion of clay. This generally is a desirable quality in soil.



Try this experiment. Fill a jar two-thirds full of water and pour in a cup of soil. Shake it vigorously and then let it stand for several hours. Hold a piece of paper against the side of the jar and draw a diagram of the layers to make your own soil chart. Do the layers look like these? Explain why the largest particles settle on the bottom.

Naming Soils and Soil Surveys

A *silty clay loam* soil contains a fairly high proportion of clay particles—27 to 40 percent—with the remainder being sand and silt-sized particles.

Soils usually are named after the towns or localities near where they were first defined. Because several soils in the same locality might have similar texture, descriptive words are added to give specific soil names, such as Miami silt loam, Houston sandy clay, or Mohave sandy loam.

Soils vary widely in their ability to support plant life and in how well they are suited for building. To manage a soil intelligently and care for it properly, people must know something about its characteristics. This is the reason for making *soil surveys*—inventories of soil resources that show the extent and location of different kinds of soil.

The soil scientist bores holes in the soil with a boring tool called an auger, usually to a depth of 3 to 5 feet. By studying this soil core and the exposed soil profiles, the scientist can determine many soil characteristics and thus can outline on aerial photographs the boundaries of different soils. Samples of the soil are sent to laboratories for chemical and physical tests that cannot be made in the field.

When this research on the soil is completed, all the measurements, observations, and test results are published in the *soil survey*. This report includes maps showing the boundaries of different kinds of soil; the description, name, and classification of each soil in the area; and the information that landowners, conservationists, engineers, and others who will work with the soil need to determine possible safe uses of the land and how it needs to be cared for when used for different purposes.

Soil samples can be extracted easily and quickly with a hydraulic soil probe.

Soil surveys—published reports you can find at the office of a local soil conservation district, the county extension service, or a major library—also are available on CD-ROM. Digital soils information can be found on the Web site of the U.S. Department of Agriculture's Natural Resources Conservation Service. The NRCS helps people conserve, maintain, and improve our natural resources and environment.

Using a Soil Survey

Soil surveys have been completed on more than 90 percent of all land in the United States. Usually, these reports cover one county. From this report, you can learn the names and the characteristics of some of the soils in your part of the country.

Many people find published soil surveys useful. The surveys contain information called *soil interpretations*. People who want to use the land for different purposes need to know about different characteristics of the soil. For example, a soil might be good for growing crops, but a pond built on it might never fill up because the water drains away too quickly.

Paying attention to soil interpretations can help builders and landowners avoid this kind of disaster. Soil slippage and swelling caused this house to break apart.

Soil interpretations tell whether land can be used in a certain way or something about how to manage a tract of land for a use that has already been determined.

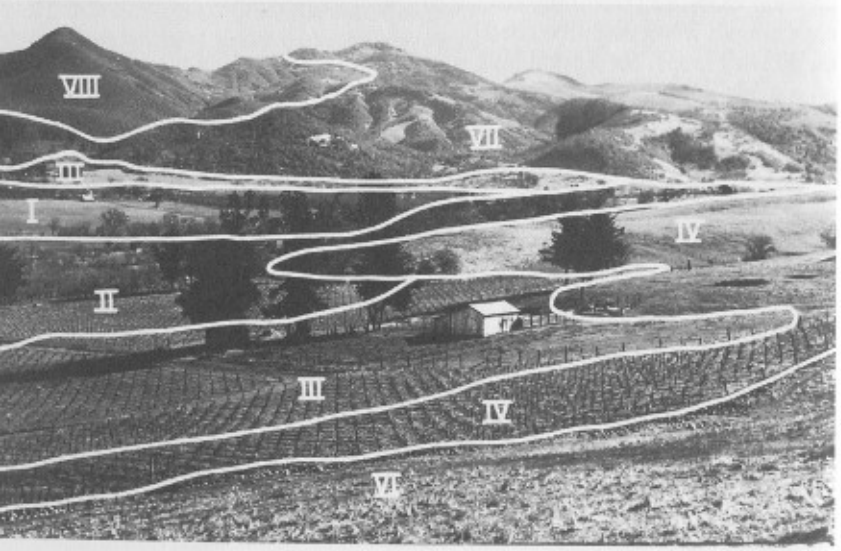
Soil interpretations can help homeowners learn what kinds of plants they can expect to grow successfully, but more is at stake than growing things where office buildings, homes, factories, airports, highways, and other land uses are planned. Some soils give excellent support to buildings; others sink or slide under weight. Foundations or even the upper parts of buildings can shift or crack if they are on soils that expand when wet or shrink when dry. Septic systems for the disposal

of household wastes work well in soils with good drainage characteristics, but some soils dry so slowly or have such high water tables during certain periods of the year that septic systems cannot be used. And some soils contain minerals and chemicals that quickly corrode gas, water, or electric conduits or cause concrete to disintegrate.

Land-Capability Classification

The most widely used soil interpretation is the *land-capability classification*. This system classifies individual soils according to their capabilities and limitations, such as crops that will grow there, or the risk of erosion damage if they are mismanaged. Farmers, ranchers, and others use this classification scheme to help them develop conservation plans for their lands.

The United States has eight separate classifications of land. The risks of soil damage and the limitations to use of the land increase from class I to class VIII. For example, land in capability class I is the best for farming. It is almost level and not subject to erosion; generally it is fertile, and there are no problems with water management. Land in capability class VIII is not suitable for crops, grazing, or forestry; it may be extremely dry, wet, sandy, stony, and steep, rough, or badly eroded. Desert areas, swamps, some rugged mountains, and sand dunes are examples of land in this class.



Find out whether a written conservation plan is available for the property on which your Scout camp is located. If such a plan exists, study its soil and land-capability maps. Using what you have learned so far, determine whether the land has been used to its best capabilities. Are there areas where the plan hasn't been followed? If so, what can you do about it?

Many people use soil-survey information, including city and regional planners, engineers, Scout camp officials, highway departments, farmers, tax assessors, construction contractors, architects, utility companies, and landscape architects.

Plant Nutrients

The land resources of the United States total nearly 2 billion acres (National Resources Inventory, 1997). We use only about 5 percent of the total for such purposes as cities, roads, homes, parks, railroads, airports, camps, and industrial plants. About 377 million acres produce crops, while 526 million acres are devoted to pasture (120 million) and range (406 million). Another 809 million acres are in forests and federal lands.

An acre is about the size of a football field.

Why are some lawns greener and more lush than others? Why do some gardens and orchards produce tastier vegetables and fruits? Why are crop yields on some farms much larger than on ones nearby? There may be several reasons, but an important one is the presence or absence of nutrients that plants need for growth and development.

Whenever we remove plants from the land, we take away nutrients that could be used in future plant growth. If the plants are allowed to decompose there, nutrients usually are added to the soil as the dead plants again become part of the organic matter in the soil. But in most cases, we harvest crops. We take vegetables and flowers from gardens. Cattle graze on grass. We cut hay to feed the cows that provide our milk.

When animals eat plants grown on soil that doesn't have the right nutrients, and when people, in turn, eat the products supplied from animals, no one gets the nutrients needed for best growth and health. Improper or careless use of soil causes plant nutrients to rapidly deplete. Also, water moving downward through certain soils carries soluble plant nutrients into the subsoil where plant roots cannot reach them. This is called leaching.

Most plant nutrients are located in the topsoil.

Plants Need a Balanced Diet

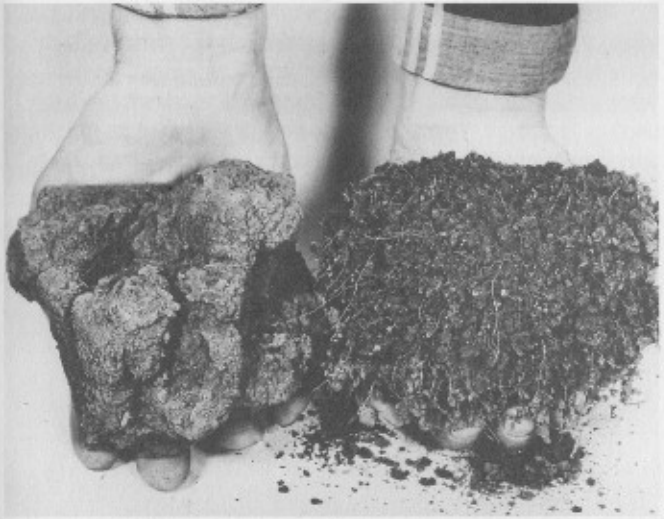
Fertile soil can supply the complete dietary needs of a growing plant. The three principal plant nutrients are nitrogen, phosphorus, and potassium. Plants usually need only exceedingly small or trace amounts of sulfur, calcium, iron, manganese, magnesium, molybdenum, boron, copper, zinc, and several dozen other chemical elements, but they must have them. A plant that lacks an essential nutrient will show physical signs of the deficiency. Chemical soil tests help determine how much of which nutrients are needed for the best growth of different kinds of plants.

As far back as around 200 B.C., even the Romans knew how to maintain soil fertility: crop rotation (planting different crops on a piece of land in a planned sequence), adding lime to soils to reduce acidity, adding manure, growing legumes (peas, beans). These methods all are still used today. For centuries, people who lived along the banks of rivers and streams have recognized that the annual floods that covered their land with sediment-rich water led to better crops. In 1699, John Woodward experimented by growing plants in water containing differing amounts of sediment. He found that the plant growth improved as the amount of sediment in water increased.

Plants usually can get adequate amounts of carbon, hydrogen, and oxygen from water and air.

Fertilizers

Early American colonists received help from Indians who insisted that one fish be planted with each seed. The decomposed fish supplied the growing plant with nitrogen and phosphorous. In some places, seaweed has been used for centuries as a fertilizer for crops. By the late 1880s, research into fertilizers picked up. Scientists focused on the essential elements in fertilizers, the best time for application, and fertilizer formulas.



These soils were found only 25 feet apart but have very different structures. The soil on the left came from a cultivated field; the soil on the right, from uncultivated fencerow (land occupied by a fence and the area surrounding it on either side). The loose, crumbly soil, *right,* can absorb water 20 times faster than the compacted soil on the left.

Loose and crumbly soil has many pores for water and air—it has good structure.

Gardeners often make a *compost pile* and use the decayed organic material from it to fertilize and improve the soils in which they grow flowers and vegetables. Leaves, grass clippings, dead garden plants, vegetable scraps, and other raw organic material placed in a pile and kept fairly moist usually will rot and make useful compost for mixing into the soil within about six months.

Composting is all about turning your organic garbage and waste into rich fertilizer, which helps keep the soil in your yard healthy and landfills less full. Some people even use worms to help speed up the process, a method called vermiposting. To find out more about composting, see the *Gardening* merit badge pamphlet.

nutrient tonnage. The actual weight of the nitrogen, phosphorus, and potassium produced.

To fertilize gardens and crops of high value such as tobacco and cotton, naturally occurring and readily available materials—cottonseed meal, dried blood, fish meal, guano—were used. Animal manure and crop residues also have been used as fertilizers. These materials help replenish plant nutrients and supply organic matter essential for maintaining desirable soil structure.

Since the early 1920s, use of manufactured fertilizers has become increasingly common. Most fertilizers supply one or more of the nutrients—nitrogen, phosphorus, and potassium—that plants use the most. As people developed plants that yielded much larger quantities of food and animal feed—hybrid corn, for example—they had to supply these plants with the nutrients necessary for high production. Thus, the total nutrient tonnage of manufactured fertilizer used in the United States increased almost eight times from 1945 to 1977, from 2.8 million tons to more than 22 million tons. Fertilizer usage in the United States has fluctuated by only 2 to 3 percent around this total since the 1970s.

Today, fertilizer research, processing, and manufacturing is a $6 billion business.

Homeowners and farmers must apply the proper fertilizers for the plants they want to grow. For example, grass on lawns usually needs a greater amount of nitrogen than other nutrients. Soybeans, a crop plant that has the ability to take nitrogen from the air and, with the help of certain bacteria, store it in little nodules, or lumps, on its roots, will on most soils produce a much greater yield if fertilized with phosphorus.

Maintaining a proper balance among the available plant nutrients in the soil also is important; if any one is deficient, plant growth will be limited.

Rotating Crops

People learned long ago that rotating crops—growing different crop plants in a planned sequence—was important in good soil management. Crop rotation has many benefits. Insects cannot stay in the same field to dine on their favorite crop year after year when crops are rotated. On many soils, it is easier to maintain a good soil structure when shallow-rooted and deep-rooted plants are alternated. On sloping land, erosion can be greatly reduced by rotating crops.

A soils expert tests a soil core to determine its pH—how acidic or alkaline it is. On the pH test scale, the number zero represents an extremely strong acid reaction, 14 represents an extremely strong alkaline reaction, and 7 represents a neutral reaction. This information tells landowners what will grow best in the soil and how to increase or decrease its acidity.

Very few plants will grow in soils with a pH higher than 10 or less than 3.5. Roses, most annual flowers and vegetables, and most lawn grasses should have a slightly acid to neutral soil. Farm crops thrive best in soils ranging from pH 6.0 to 8.0.

"Sweet" or "Sour" Soil? You may hear gardeners or farmers remark that they have a "sweet" or a "sour" soil. This has nothing to do with taste. "Sour" is used to describe a soil that is *acidic,* while "sweet" refers to an *alkaline* soil.

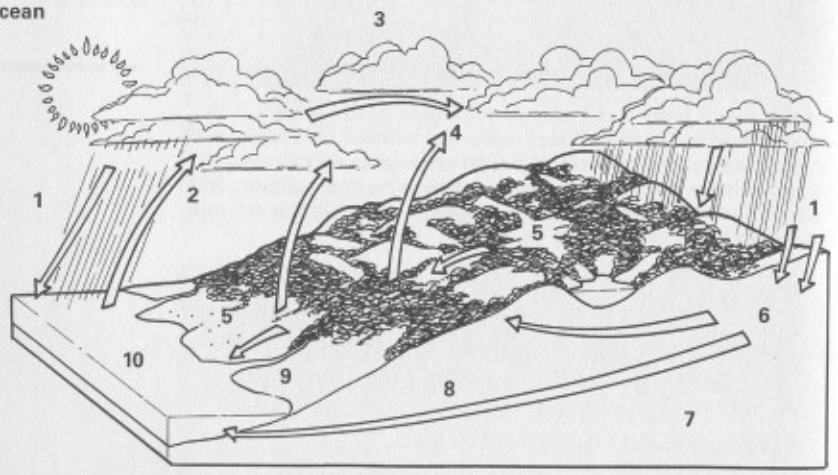
How Water Behaves

Of all the natural resources necessary to the existence and comfort of all living things on Earth, water is the best-known. We know that water falls on Earth as rain, snow, sleet, or hail. But there are many things you might not know about water.

To understand more about water, we must learn about the water cycle, or *hydrologic cycle*, the process by which water travels from the sea through the air by means of clouds, and falls on Earth to return again over the surface or underground to the sea and start the cycle all over again.

We must manage the land to manage water. If we are to manage land and water intelligently, we need to know how and why water behaves the way it does.

1 Precipitation
2 Evaporation
3 Condensation
4 Transpiration
5 Runoff
6 Infiltration and percolation
7 Aquifer
8 Groundwater movement
9 River
10 Ocean



The Water Cycle

The Hydrologic Cycle

Let's begin with the sea, where the sun's energy draws up into the atmosphere most of the water that travels through the hydrologic cycle. This process is known as evaporation.

Much of the moisture evaporated into the air soon falls back into the sea during storms, but winds eventually do carry air masses with moisture in them over land. A small part of the moisture, or *water vapor*, in the air at any time might be visible to us as clouds, fog, or mist. When the water vapor in clouds condenses, we get the rain, snow, sleet, or hail that falls on Earth—called *precipitation*.

As air masses move across the land, the air picks up more moisture. Water from lakes, ponds, rivers, and even from birdbaths and puddles on the sidewalk, evaporates and returns moisture to the air. The soil itself gives up moisture as winds move across it.

Another way moisture gets into the air is from living plants. Moisture absorbed largely by plant roots from the soil and other plant parts from the atmosphere moves into the air during the plant's life. This release of water vapor from plants is called *transpiration*.

Evaporation is one of nature's ways of purifying water, because most of the dissolved substances in it, such as the salt in seawater, remain behind when water evaporates.

To see transpiration happening for yourself, try this experiment. Place an airtight, transparent plastic bag over a common potted houseplant and tie it fairly tightly around the plant stem near the surface of the soil. Then set the plant in the sunlight. Soon you will see drops of water collecting on the inside of the plastic bag.

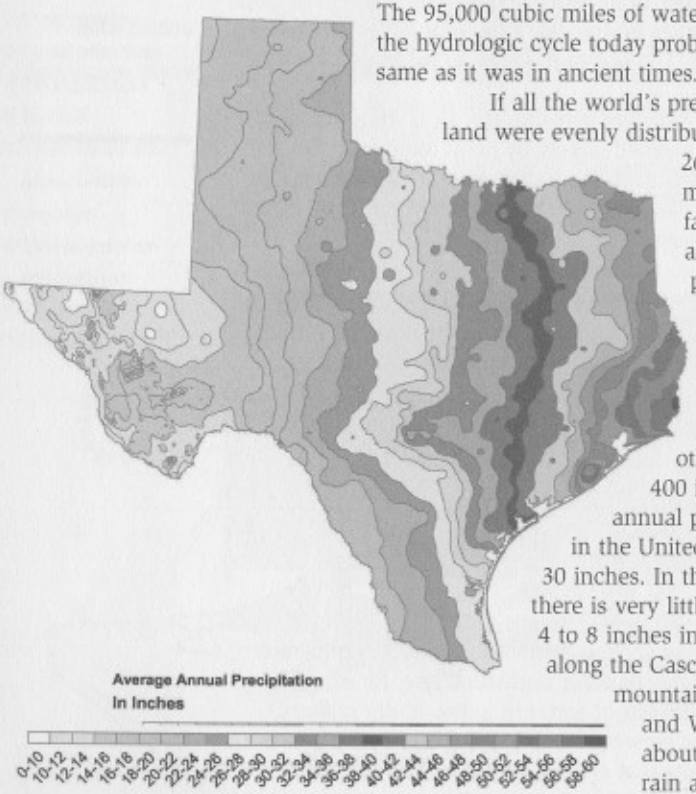
Different plants transpire greatly different amounts of water depending on factors such as humidity, moisture, temperature, and wind. A large oak or other hardwood tree, for example, can transpire 500 gallons of water in a day. In dry country, where moisture for growing crops and for other purposes is badly needed, plants that are not considered useful but that transpire large quantities of water sometimes must be removed to conserve severely limited water.

Chemical reactions return small amounts of water to the atmosphere. People, animals, and plants return some through the process of respiration (breathing), and the combustion, or burning, of fuels in cars and furnaces returns additional amounts.

Evaporation and Precipitation in Balance

Evaporation and precipitation are the most significant processes in the endless hydrologic cycle that is always at work over Earth's entire surface. The amount of moisture in circulation has remained about the same throughout the ages. The 95,000 cubic miles of water in circulation in the hydrologic cycle today probably is about the same as it was in ancient times.

If all the world's precipitation on land were evenly distributed, about 26 inches of moisture would fall annually on all land. But precipitation is not evenly distributed. Some places get less than an inch and others more than 400 inches. Average annual precipitation in the United States is about 30 inches. In the arid West, there is very little rain—probably 4 to 8 inches in a year. And along the Cascade Range of mountains in Oregon and Washington, about 100 inches of rain and snow fall each year.



Precipitation maps like this one of Texas show the area's average precipitation.

To get some idea of the quantities of water involved in the cycle, pretend that an ordinary bathtub filled to the top represents all the water in the oceans. Compared with that, the amount of water circulating in the hydrologic cycle would fill an ordinary water glass about two-thirds full.

Water and Soil Working Together

Infiltration and Percolation

On Earth, precipitated water either soaks into the land or runs off over the surface and is called *runoff*. To satisfy their many wants and needs, people must control the water that falls on the land. This means using and managing the land so that in most cases the maximum amount of moisture enters the soil. We can do our part to help water more readily enter the soil by keeping plant cover on the ground, slowing runoff, maintaining or increasing organic matter in the soil, maintaining good soil structure, and by using other conservation practices.

The entry of water into the soil is called *infiltration*, and the rate at which water penetrates the surface of the soil is the *infiltration rate*.

In the time of Christopher Columbus, a family used 3 to 5 gallons of water a day for all its personal needs. In the United States today, it takes about 1,900 gallons a day to support each person for bathing, watering domestic animals, air conditioning, food preparation, all manufacturing processes, irrigation for crop production, and all other purposes. You can understand why people now are much more concerned with water supply and water control and use than they were even in your great-grandparents' day, when the average use per person was about 95 gallons a day.

After penetrating soil that is already wet, water may continue moving downward through the soil by *percolation*. Percolation, the major means by which groundwater supplies are replenished, is important, for many cities obtain all their

Not all water that enters the soil percolates through it. Some becomes part of the soil itself though chemical and physical action as it soaks into clay and silt particles and the pieces of decayed and decaying organic matter we call *humus*.

water from wells. In many places, water for irrigating crops also is pumped from deep in Earth.

In nature, there may be a layer of rock or of hard soil through which water passes slowly or not at all. If this layer is not far from the surface, it may keep water from percolating deep into Earth, thereby limiting the space for water storage in the soil.

Water percolates through different soils at different rates. To illustrate this, put sand in a small flowerpot that has a hole in the bottom. Pack clay soil in an identical pot. Then pour water into each pot until it flows through the sand and clay and out the bottom. Notice the difference in the length of time it takes for water to begin to trickle through the bottom of each pot.

The percolation rate is important to those who need to know how fast the soil absorbs water. For example, a septic tank system for the disposal of household wastes won't function if water cannot percolate through the soil fast enough. People who irrigate gardens and crops partially determine the amount of water they need on the basis of how quickly the soil absorbs water. Water that percolates through the soil might carry certain impurities, such as chemicals and bacteria, so those who get water from shallow wells need to know how fast and from what sources water percolates underground.

The percolation rate in this soil was so slow that outflow from a septic tank system rose to the surface instead of draining away underground.

Capillary Action

Another form of water movement in the soil is *capillary action*. In this process, water moves in all directions. After rain has percolated through soil, a thin film of water that clings to soil particles and remains in tiny soil pores helps dissolve plant nutrients so that plants can use them. This capillary action is the source from which the fine hairs on plant roots absorb water.

It could take capillary action several weeks to move water upward in dry soil only about 3 feet. Once dryness breaks the film of capillary moisture on soil particles, water cannot move by capillary action again until the moisture supply is renewed and the film reestablished. Since this takes time, capillary action might not move water available after a long dry period to the plant roots soon enough to save wilting plants.

To demonstrate capillary action, get a flat pan and fill it with an inch of water. In it, place a clay pot filled with a common houseplant growing in soil that has been allowed to become quite dry. Within a few hours you will see that the surface of the soil in the pot is moist. By capillary action, water has risen through the soil in the pot.

The Water Table

Soil that is too wet can be as damaging to plants as soil that is too dry. In some places, a major problem is moving water off the land so that it will not settle there to waterlog the soil, thereby cutting off the air to plant roots and to small soil organisms that need oxygen. When the *water table*—the level

Water From Snow and Water-Supply Forecasting

Rainfall determines the amount of stream flow in most parts of our nation, except for the West, where the winter snows in mountainous regions are the great reservoirs of water that determine the volume of stream flow. The water that comes from melting snow is vital to plants, people, and wildlife that live hundreds of miles away in dry country where little rain falls.

During a typical snow season, from January to June, surveyors travel more than 50,000 miles to measure the depth of the snow to help determine the snow's water content and the amount of moisture in the soil below the snow.

below which the soil is filled completely with water—is only a few inches below the soil surface, the growth of plant roots is restricted and many plants cannot grow. Where the water table frequently rises to within a few feet of the surface, water can seep into basements. When some soils become much wetter than usual, they slip and settle, cracking plaster and shifting building foundations.

Because people need a fairly constant supply of water for many different uses, dams and reservoirs are built to control and store water from the melting snows for later use.

But snowfall varies from year to year, and the storage capacity of reservoirs is limited. To plan wisely for the stream flow they can expect, people use information from snow surveys, which measure snowfall. From that, and other factors, they can predict the stream flow for the coming season. Those who manage reservoirs that store floodwaters can release enough water from the reservoirs early to make room for the water from rapidly melting snow upstream, and thus control a flood.

When they know they will have less water than usual:

- Cities can limit water use early in the season and perhaps avoid water rationing.
- Farmers can plan to plant fewer acres of water-thirsty crops and thus avoid having crops on some acres die for lack of water.
- Hydroelectric plant operators can plan to use other power sources to produce electricity.

Forecasting the flow of rivers and streams is important everywhere. However, it is difficult to predict because rain runs off the land soon after it falls, and we do not know how much rain will fall. Still, rainfall, stream flow, and groundwater records accumulated over the years help experts determine the expected flow from larger streams and rivers. These records also help forecasters predict accurately the possibility of flooding downstream caused by heavy and widespread rainfall many miles upstream.

The runoff that collects in creeks and streams and eventually flows from rivers into lakes and reservoirs is the source of most of the water we use. It is also the source of nearly all water that wildlife uses.

Causes and Effects of Erosion

Soil erosion by water can occur where and when there is enough rain or melting snow and ice so that water quickly runs off the surface of the land.

You have watched the force of moving water from a hose or hydrant push dirt—even pebbles and rocks—off a driveway or sidewalk. Rain and running water act on the bare soil in a garden, on the site where a new building is being constructed, in a farmer's field, or on a cutbank along a highway in the same way as the stream from a hose. The process by which beating rain and moving water dislodge and carry soil particles, organic matter, and plant nutrients to a new location is called *soil erosion by water.*

Wherever you live, you have seen the wind pick up and carry dust and larger particles of loose materials from one place to another. You may have observed that there usually is more dust and dirt in the air when it hasn't rained for a long time. Where does the wind best pick up and deposit dust, dirt, and sand particles? Close to trees or buildings, or out in open streets and spaces?

Whenever wind moves across a bare or poorly covered soil surface, especially if the land is dry and the soil contains mostly fine and loose particles, soil blowing, or *soil erosion by wind,* occurs. Severe wind erosion occurred in the Great Plains region in the 1930s. Then, the wind carried dense clouds of surface soil more than 1,500 miles east to the Atlantic coast. The drought broke in 1938, when life-giving rain returned.

Huge clouds of blowing soil during the "dust bowl" days of the 1930s were called "rollers."

Natural Erosion

Cut by water

Weathered

Glaciated

Geologic Erosion

Natural, or geologic, erosion began when the air first stirred and the rain first fell on Earth. It continues today and is especially noticeable in dry regions where there is little vegetation, and infrequent but intense rains carve hills and scour valleys. Geologic erosion usually moves so slowly that, when there is much native plant cover, soil is built up and seldom destroyed, and in a lifetime one could scarcely see the change it brings.

Throughout the ages, geologic erosion has shaped Earth's face; it helped crumble rocks to form soils, and it wore away mountains to make broad plains and valleys.

Accelerated Erosion and Sediment

Our concern is the accelerated erosion of soil that occurs as a result of the activities of people. Soil and water conservation projects help control the rate of this kind of soil erosion, which has been called the greatest scourge the world has ever known. It affects everyone.

You may have seen a muddy creek or river. You don't want to play in it and you certainly don't want to drink from it. In

Accelerated Erosion

Damage from flash snowmelt

Washout in a road ditch

Gullied hillside

Erosion from poor farming methods

many small streams, sediment fills the deep pools that provide a refuge for fish during the dry season. Sediment often damages the spawning beds of game fish, ruins their eggs, and reduces their food supply. Fish eat the worms, insect larva, and other small aquatic animals that feed on microscopic plants in the water—but muddy water filters out light and so interferes with the growth of microscopic plants. It has caused oysters to disappear from the Chesapeake Bay, affecting commercial fisheries.

Sediment removal makes water purification much more expensive for many cities and towns. As a result, water bills go up. Sediment in water also causes costly wear on machines, as in hydroelectric plants.

Even more important and costly is the sediment that fills lakes, reservoirs, navigation channels, harbors, and roadside ditches. Reservoirs lose storage capacity each year as a result

Sediment is caused by soil particles that are moved and deposited by wind, water, or glaciers.

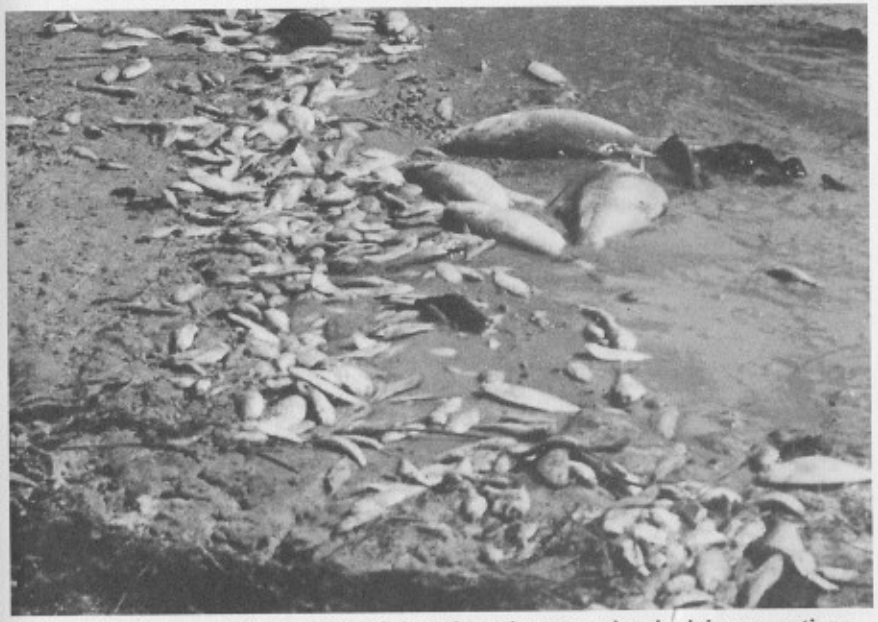
Sedimentation can quickly cause small ponds to become nothing more than mud holes; some ponds have filled with sediment in only a couple of years.

In large amounts, such as caused by accelerated erosion, sediment can be a pollutant and create costly problems. This small reservoir is slowly becoming filled by sediment.

of sediment. Eventually, the sediment must be removed or a new reservoir constructed. Some city water reservoirs have been filled completely with sediment in fewer than 30 years.

When flood-prevention and other types of reservoirs are built, allowance must be made for the sedimentation. Each year, more than half a billion cubic yards of sediment must be dredged from harbors, streams, and navigation channels in order to keep these vital routes open and useful for water transportation. Much of the cost of sediment removal is passed on to taxpayers.

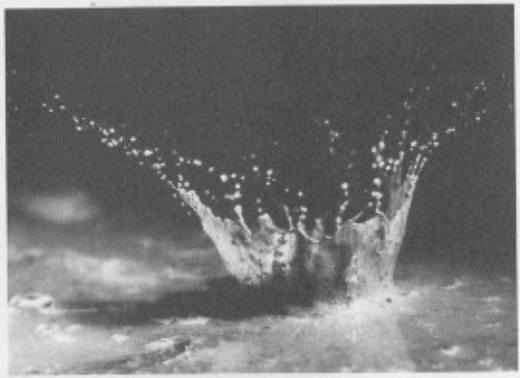
Each year, more rivers flood because sediment chokes stream channels. In addition to floodwater damage, sediment can damage streets, houses, automobiles, parks, camps, and machinery. Much of this sediment has to be removed by hand. Rain and wind also spread sediment over cropland, destroying crops and making the soil less useful for growing plants. Drainage and irrigation ditches become less effective as they are clogged with sediment. Thus, sediment reduces the amount and quality of crops.



Sediment in rivers and lakes can kill fish and require expensive dredging operations.

Now you can understand how polluting sediment affects everyone in some way. Because all sediment stems from erosion, which destroys the usefulness of the land, we need to know more about how erosion occurs, how to recognize it as it starts, and what to do about it.

Soil Erosion by Water



The force of a single raindrop won't move much soil. But when billions of raindrops together hammer against bare ground, they tear clumps of soil apart and separate the tiny particles from each other. As they bounce into the air after striking the ground, the raindrops carry some soil particles with them; these bits of soil gradually move downhill. This is called *splash erosion*.

After a rain, you can see evidence of splash erosion in the small bits of soil that cling to the walls of buildings, the leaves of plants, and picket fences.

Sheet erosion is happening wherever muddy water moves off bare ground without cutting channels in the soil.

Whenever rain falls or snow melts so fast that the water cannot soak into the soil, a sheet of water collects on the surface and moves downhill. On sloping land with little vegetation, such as a new building site, an overgrazed pasture, or a newly plowed field, the combined action of beating raindrops and flowing water continuously washes away thin layers of surface soil. This is called *sheet erosion*. The damage caused by sheet erosion often is not apparent until much of the surface is washed away.

As water moves over the land surface, collects in little streams, and continues to run down a slope, it tears away more soil particles until it carves small, irregular channels called *rills*. Called *rill erosion*, it can be erased by smoothing over the land surface as a farmer does when cultivating, yet the soil is gone.

On much sloping land, the small rills join somewhere on the slope to make larger channels. As more water collects in these channels, its force is increased; it begins to rip away larger and larger pieces of soil. When water falls over a sudden drop, it begins to cut into the slope itself. When larger channels form, there is gully erosion. It takes more than ordinary cultivation to fill in gullies, for they are so deep that machines usually cannot cross them. These destructive gullies often are a sign that sheet and rill erosion have been going on for a long time.

Three kinds of soil erosion by water: sheet erosion *(top)*, gully erosion *(left)*, and rill erosion *(right)*.

Soil Erosion by Wind

The sand dunes we see in some desert areas and near the shores of some lakes and oceans are obviously results of wind erosion. The wind-shifted sands of these dunes are hard to control. Because plants cannot easily be established there, the sand often continues to advance and cover even larger areas. Much more serious wind erosion occurs, however, wherever loose, small soil particles are moved by the wind.

Soil blowing usually starts on land that has few plants and sandy soils. Once soil blowing starts, it tends to spread. The wind picks up a few loose soil particles, and when these strike bare ground, they blast loose other particles that in turn are bounced and swept along the ground surface, causing further erosion. The blowing soil particles can cut off tender, growing plants at the ground surface. Or they can cover both growing and dead vegetation with drifts and mounds of dust or sand. When the growing plants are cut off, the soil they protected from the wind will erode. If high winds continue for a long time, the soil blowing can spread over an entire community.

Wind erosion

Gullies leave gaping channels in the land, feed huge amounts of sediment into creeks and reservoirs, divide fields into areas too small to be useful, and cut deep scars into steeply sloping land where new buildings are being erected.

Though a natural disaster can remove all the plants from an area and expose the surface soil to the ravages of wind and rain, the area affected is very small compared with the area people have carelessly used and left unprotected.

Erosion, Plants, and People

Why hasn't all the soil been splashed, washed, and blown away by this time? You can discover the answer to this question. Have you ever seen dust blowing from a lawn that has a thick grass cover? Have you ever seen mud splash up after a rain from soil covered with grass? The grass broke the force of the falling water, and its roots held the soil tightly in place.

In the same way, plants break the force of falling raindrops. Their roots help water enter the soil by keeping it porous. They hold the soil particles together so that moving water cannot break the particles apart and carry them away. Plants also slow down running water, thereby allowing some time for it to soak in. Plants growing closely together protect the soil from strong winds. The tops of the plants slow down the wind, and the roots help hold the soil in place.

If we are to continue to live and to enjoy life on Earth, we must conserve the land.

Soil erosion often is called a disease of civilization because nearly all of it is the result of the activities of people:

- Cutting down forests and making no plans for new growth
- Growing crops and leaving the soil bare part of the time
- Erecting buildings and leaving the soil unprotected during construction
- Overgrazing, thereby killing the vegetation
- Building highways and railroads without protecting their banks
- Crowding wildlife so that they destroy the vegetation in their search for food
- Trampling the grass and other plants to death in recreational areas
- Destroying trees and grass through careless use of fire
- Stripping the land surface to obtain fuels and minerals from the earth
- Using the soil improperly for any purpose

Soil erosion is commonplace on undeveloped land.

Problems of Runoff

When erosion reduces the depth of the surface soil, runoff generally increases. When runoff increases, soil erodes more rapidly, accelerating the cycle. But plants help soil absorb water and protect the surface soil from the erosive action of water.

When we use, remove, or change the kind of plants on the land, we usually change the quantity and quality of runoff. For example, if trees and grass are cleared from an area for housing, we know that more water will run off the land more quickly and the runoff will be muddy. After the houses are built, the streets are paved and community facilities are erected, much of the soil on the area that was cleared is covered with hard surfaces. Runoff from this built-up area can be as much as 10 times greater and will occur much more quickly than when the land was covered with trees and grass.

Polluted Runoff

Water running off the land picks up many pollutants as it moves. This is one of the main sources of what is called *nonpoint source pollution* (NPS); that is, the pollution doesn't come from a specific source, such as an industrial site or sewage-treatment plant. The U.S. Environmental Protection Agency points to several pollutants:

- Excess use of fertilizers, herbicides, and insecticides
- Oil, grease, and toxic chemicals that run off through our cities
- Bacteria from livestock manure, pet wastes, and faulty septic systems

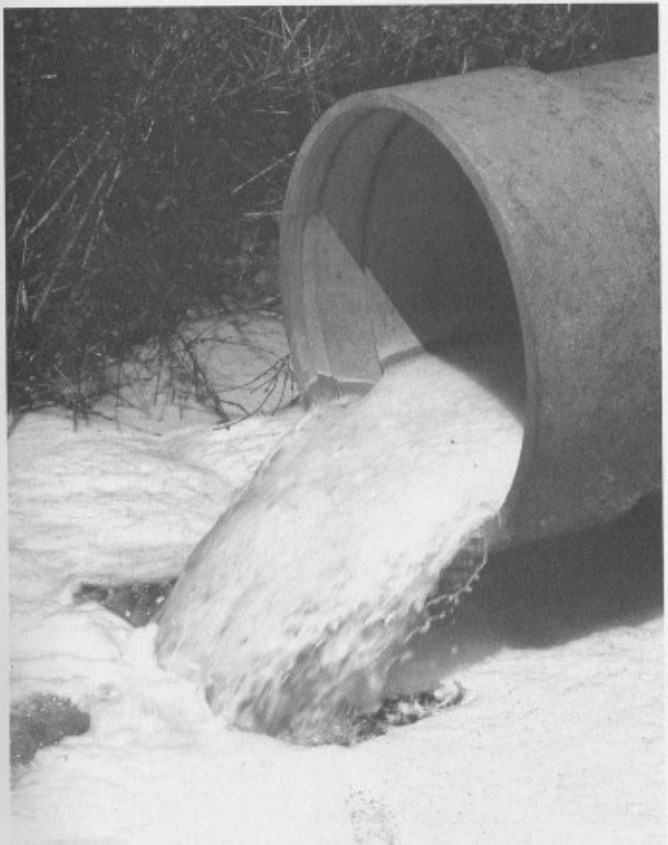
The EPA points out that "each of us can contribute to the problem without even realizing it." But each of us can, and must, help combat it, too. Federal, state, and local agencies must work with individuals to prevent or minimize this kind of pollution. (Source: *http://epa.gov/owow/nps/qa.html*)

Similarly, when overgrazing is allowed, the amount and speed of runoff increase and erosion occurs much more readily than when grazing is managed so that grass and other plants remain healthy. Fire also can remove plant cover from the land and expose bare soil to beating rains; then, muddy runoff flows down slopes and fills streams and lakes with sediment. The damage to a city's water supply can be devastating.

Plant cover is important in controlling runoff, but in many instances it is not possible to keep plants growing on the land. Sometimes the surface of the land needs to be shaped to guide and control runoff. Small dams and other types of water-retarding structures often must be built to control runoff so that the land and the water are not damaged.

Erosion in Urban Areas

We often think of erosion problems as most important on farms and ranches, yet the greatest erosion problems occur when land in or near cities is being shifted to use for homes, shopping centers, and other urban purposes. Pay attention to signs of conservation problems in your area—mud in nearby street gutters, on sidewalks, or in a corner of your yard; bare spots in lawns, on the schoolyard, or on sloping banks; a muddy creek or river. Learning more about soil and water conservation will help you become aware of some of the conservation problems your community might face.



Conservation on the Land

People are constantly changing the uses of land. There might now be a building under construction on the vacant lot where you played last year. Perhaps a roadway that cuts through hills and fills in low places has been constructed. Changes in land use probably are being made at your Scout camp each year. Farmers, of course, rotate crops each year and, as they do so, they can make great changes on the face of the landscape.

As areas become more populated and new houses, stores, factories, and schools are needed, and as people change their minds about what they want from the land, there will be more and more shifts in land use. During changes in land use, the soil often can be left unprotected and subject to damage by water and wind, as you've read. Improper care of land can result in costly and serious damage to soil and water resources.

You can now recognize many of the familiar signs of trouble that can be traced to poor use of land and lack of proper conservation measures:

- Mud and silt on sidewalks and driveways after a rain
- Exposed tree roots where the soil has been washed away
- Roadside ditches filled with sediment
- Muddy water in a stream or river
- Caved-in stream banks
- Rills and channels on exposed road banks
- Bare soil where there once was grass on your campsite
- Small and large gullies scarring the face of the land

However, much land is wisely used, and conservation is practiced on millions of acres in the countryside as well as in cities and suburbs.

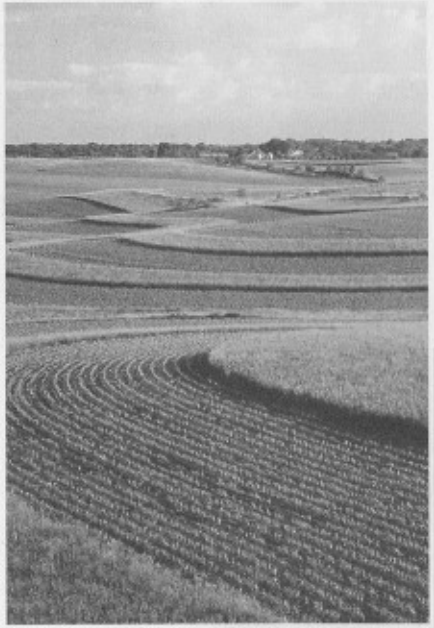
Good conservation practices are properly designed, carefully implemented, and tested.

Conservation Practices

A *conservation practice* is any specific action or process to care for natural resources so they are protected from damage and improved for certain uses. In some instances, a good conservation practice might be complete elimination of someone's use of a piece of land, leaving it just for scenery and wildlife. Many conservation practices help to furnish the things that all wildlife must have—food, shelter, and water. Even in cities, an amazing variety of wildlife could appear if these needs are provided for in small areas.

Sure signs of conservation at work are the large, graceful, curving strips of crops you can see on many farms. These winding ribbons include the dark green of grasses, gold of ripening grains, and different hues of soil exposed between crop rows.

Professional conservationists have solved many conservation problems. Some practices may be suitable only for application on croplands, rangelands, or forestlands. Because plants are the great protectors of land surfaces, most practices involve the use and management of plants so that they can hold soil in place. When we want to use land for such things as buildings, campsites, or crops, we often have to use engineering to properly change the shape of the land surface to use and control water. Vegetation and engineering conservation practices often must be used together to be effective.



Grassed contour buffer strips cover an entire field in Iowa.

Conservation buffers help prevent blowing soil in windy areas, reduce flooding, and provide wildlife habitat.

Conservation Buffers

Grassed waterways and windbreaks are two kinds of *conservation buffers* (or buffer strips), a special practice encouraged by the U.S. Department of Agriculture. Conservation buffers are small areas or strips of land kept in permanent vegetation. These areas then help control soil erosion and pollution by breaking up and slowing the movement of runoff, sediment, and other pollutants within fields and from field to field.

The USDA launched the National Conservation Buffer Initiative in 1997. Through this initiative, public and private agencies are working together to help landowners create 2 million miles of conservation buffers in the United States. (Source: Natural Resources Conservation Service.)

Working With Vegetation

Applying a thin layer of organic material on the land surface to hold surface soil in place while grass or other newly seeded plants become established is called *mulching*. Often, mulching is used on road banks, new lawns, the backside of earth dams, and croplands where wind or water might erode soil.

Contour planting is when crops, fruit trees, and garden plants are grown on sloping land, across the slope on the level (where all places along a contour line are of equal elevation)—rather than uphill and downhill. Contour planting reduces erosion and is most effective with crops grown in rows. It is used widely on farms and should be used in gardens or wherever plants are cultivated on sloping land.

Strip-cropping is the growing of crops in broad or narrow bands or strips across the general slope of a field or large garden. Crops are arranged so that a strip of grass or other close-growing crop is alternated with a strip of clean-tilled crop where some of the soil surface is exposed. The close-growing crop slows runoff from the clean-tilled strip. Strip cropping often is done on the contour. Where soil blowing causes problems, the strips are at angles to the direction of prevailing winds to help prevent wind erosion.

Growing temporary crops of plants that cover the soil between seasons or between rows of a main crop to protect the soil from erosion is called *cover cropping*. It can be used in gardens, on farms, and on construction sites where soil might be exposed for a season before permanent vegetation can be established.

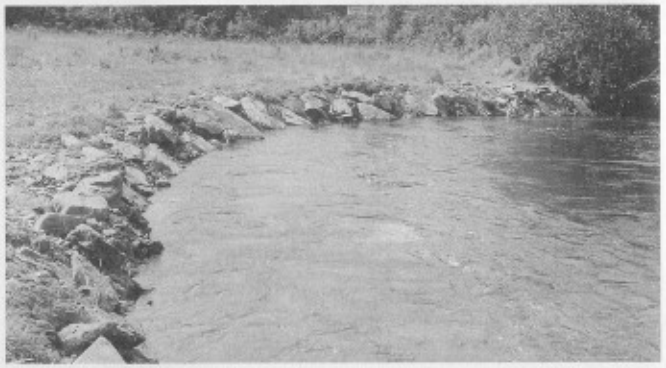
Stream banks can be protected against erosion and water-scouring by using plants, rocks, or structural measures. Specific methods include establishing certain types of grass

Contour strip-cropping combines the benefits of both contour planting and strip-cropping.

Cover crop in a pear orchard

Screens of trees, shrubs, or vines can be planted to block views of unsightly things such as garbage cans, junkyards, and dumps; to shield homes and people from traffic and other noises; and otherwise to beautify an area.

after sloping the banks, planting such trees as willows and alder below the tops of the banks, or placing a thick layer of rocks or combination of wood, rock, and plants along the banks.

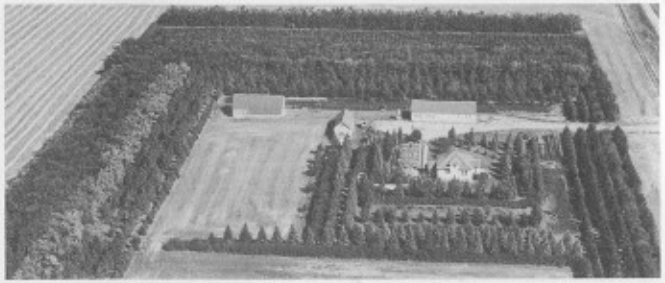


Stream bank protection with rocks

Planting, thinning, pruning, and properly harvesting woodlands can provide enough growing space for good trees, eliminate poor trees, establish stands of species best suited to the soil and climate, maintain natural beauty, improve conditions for wildlife, and maintain cover for erosion control. These techniques also make it possible to obtain wood products without damaging soil and water resources.

Working With Wind and Water

Trees and/or shrubs can be used as *windbreaks* to reduce the effects of damaging winds. Windbreaks help control soil blowing in fields; protect homes, other buildings, and delicate plants



Tree and shrub windbreaks

from cold winter winds; reduce evaporation from soil; and trap snow (necessary along farm fields, especially in the Great Plains). They also add comfort and beauty to suburban homes and provide food and homes for many kinds of wildlife.

Terracing is needed on sloping soils in gardens, around homes and buildings, and on cropped lands.

Terracing

Terracing, or constructing ridges of earth, controls water runoff in wet areas and conserves moisture in dry areas. The ridges can be as low as a few inches or as high as 2 feet or more. The distance between terraces must be designed so that the runoff can flow to each terrace without overtopping it.

A *grassed waterway* is a natural or artificial drainage to which runoff flows after a storm. Excess water can be channeled from a field, garden, or other area to this permanent cover of

To be effective, a grassed waterway must be designed to carry the volume of water it will receive.

drop spillway. A concrete, metal, or wood structure used to slow the velocity of water and control gullying and drop water to a lower level.

grass. The grass protects the channel from erosion and helps keep sediment out of the water.

A constructed pool or basin formed by placing a dam or barrier across a waterway at a suitable location to trap and hold sediment is called a *sediment basin.* To guide runoff into basins, *contour diversions,* or shallow ditches that follow the contour on slopes, are sometimes used.

A sediment basin temporarily holds sediment on property where construction is underway and in other places to keep sediment and debris out of reservoirs, lakes, and streams.

A *pond,* a reservoir of water made by building a dam or embankment, could be as small as a few feet or as large as several acres wide. Among its many useful purposes—fish production, water for livestock and wildlife, recreation, fire protection—it enhances the appearance of camps, homes, and farms.

Floodwater-retarding structures are dams, embankments, or other devices built to provide temporary storage and controlled release of floodwater.

Working With Wildlife

Wildlife habitat development is an important part of conservation and includes planting shrubs, trees, and many other kinds of vegetation to furnish food, cover, and shelter for wildlife; creating water supplies; making openings in dense woods;

Wetland developments can be used wherever enough water and land are available.

limiting the use of an area; and many other projects to attract and provide for the needs of wildlife. Often these practices are a part of other conservation work on farms, ranches, and around homes, in parks, on school grounds, and in other open areas in cities.

Wildlife wetland developments improve or create habitats by ditching, diking, or other means of providing appropriate amounts of water, and by establishing plants to provide food, cover, and shelter. This includes limiting other uses of the wetland and maintaining the measures installed.

Conservation in Watersheds

As rain falls on the land and makes its way back to the oceans, it gathers in streams and rivers. The area of land from which water runs off—your own backyard, a vacant lot, or just about anywhere—and travels to a specific stream or outlet is called a *watershed.* Wherever you live, you are in a watershed.

Watersheds come in all sizes, from those not much bigger than a football field to those that contain millions of acres of land and include several states, such as the Mississippi River watershed.

This watershed dam is surrounded by houses.

Hundreds of small watersheds with their little streams are part of, and lie within, large watersheds that are drained by rivers. A watershed boundary may not be obvious where the land is nearly level, but in many places, the boundary might be plainly marked by high ridges. Water that flows one way from the ridge goes into one watershed, while water flowing off the other side of the ridge goes into another watershed.

One way to determine the boundaries of a watershed is to look at a *topographic,* or *contour,* map. On such a map contour lines represent a single elevation; all points along a contour line are equal in elevation. If you actually walked along such a line on the land, you would always be walking on the level, never going uphill or downhill. Since water always runs downhill, you can locate on the topographic map the areas of high ground from which water drains in some kind of pattern to a lower elevation.

See the *Orienteering* merit badge pamphlet for more on topographic maps.

Your merit badge counselor can help you find a topographic or contour map for your area. You might be able to look at a map at the local office of most government agencies that deal with areas of land—the city or county engineer, planning commission, Natural Resources Conservation Service, Forest Service, National Park Service, Bureau of Land Management, or your state geological survey office. Also check your Scout camp's library for a topographic map of the camp property.

You may be able to obtain topographic maps from a local sporting goods store or bookstore. You also can find local dealers in your state at the U.S. Geological Survey Web site, *http://www.usgs.gov,* or by sending a postcard for information to the U.S. Geological Survey National Center, 12201 Sunrise Valley Drive, Reston, VA 20192.

The Watershed Community

Geologist John Wesley Powell, emphasizing the web of nature, defined a watershed as "that area of land . . . within which all living things are inextricably linked by their common water course." These linked living things are the *watershed community* —the animals, birds, plants, fish, and people who live in a watershed.

Runoff doesn't stop at artificial boundaries such as county lines, city limits, or the fence around your yard. All the people, plants, and animals are affected by what happens to the water and the land in the watershed; they depend on the watershed and they influence what happens there. When runoff from hundreds of small streams enters a larger stream, flooding often occurs. In addition to slowing down runoff from individual

Because land, water, and other resources are so closely tied together in a watershed, the most natural way for people to solve conservation problems is by working together.

When poorly or improperly treated waste is released into streams from sewer systems or industry, or allowed to run off carrying sediment and harmful materials into streams, the polluted water is a problem for the entire watershed community.

fields, yards, gardens, and parks, watershed residents working together can build flood-prevention dams. They also could advise people not to build homes, offices, and factories on floodplains.

Wildlife is part of the watershed community.

City and regional planners also explore ways to make living safer and more comfortable for people while protecting soil and water resources. They try to persuade local governments to set aside floodplains for recreational areas, for open space, and for other uses that cannot be greatly damaged by flooding.

Proper Use and Care of Land

Remember, the care and use of land in your watershed is important to you. Careless logging, overgrazing, and construction work that leaves large areas of land bare will increase erosion, runoff, sedimentation, and possibly flooding along the streams in the watershed. Fires that have swept through watersheds in the western United States and have been followed by heavy and prolonged rains have washed huge amounts of soil down hillsides. In some places, mudslides have carried houses and other buildings with it. Water supplies became polluted. Great amounts of money and effort were spent to repair this damage and to establish plants on the eroded slopes.

Because development and good use of a watershed benefits many people, including those who live far outside the watershed, the federal and state governments share with local people the cost of doing land and water conservation work. This program of cooperative work on watershed projects is carried out under the Watershed Protection and Flood Prevention Act of 1954. In 1972, major amendments emphasized wider environmental concerns, including conservation, use, development, and disposal of water; and conservation and use of land.

Soil conservation practices can help reduce the damaging effects of fire and erosion, but local people must work together to protect their watersheds and the resources in them. Local, state, and federal governments offer much help with organizing people to plan and work together to control water and soil erosion. They also help individuals plan and carry out conservation plans on their property.

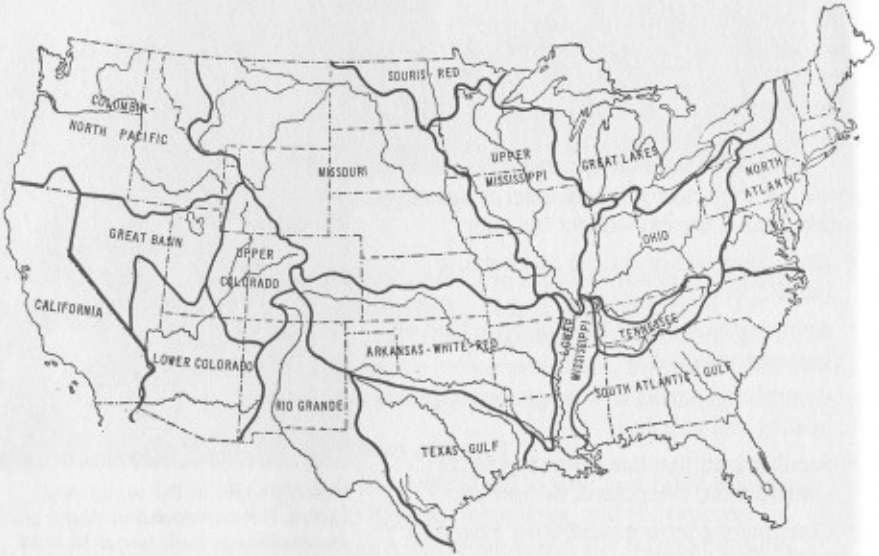
In watershed projects, conservation measures to protect soil and water resources—called *land treatment*—might include:

- Better methods of cutting and hauling out timber
- Applying mulch after seeding bare land on highway road banks
- Controlling grazing to keep grass and plants healthy and growing
- Seeding land that has been cleared for construction, overgrazed, or burned
- Constructing terraces and other means of controlling water
- Growing and cultivating crops on contours
- Planting trees to break the force of the wind

When people in the watershed desire, flood-prevention dams and reservoirs are built larger to hold water for recreation, industry, cities and towns, fish and wildlife, and irrigation, which is what was done with this watershed project in Iowa.

Watershed dams like this one in Iowa help control runoff from streams and hold and store sediment.

In most watershed projects, one or more small dams are needed to hold back runoff temporarily. These dams usually are designed to hold and store sediment as well as water. In some cases it is necessary to build sediment traps. Other conservation practices are applied in connection with many of these reservoirs to improve wildlife and recreation values. Such watershed projects are called *multipurpose projects.*



The continental United States has 18 major river basins; in each basin are combinations of rural areas, industrial sites, and cities, and all depend on the water in that basin because very little water moves between river basins.

River Basins

The more than 1 million square miles that is drained by the Mississippi River is a large watershed. But this area is also called a *river basin,* an area of land drained by a river and all its large and small tributaries. All river basins are large watersheds, but not all watersheds can be called river basins—some watersheds are very small and their runoff is collected by a small stream. Today, attention is being focused on river basins as areas for large-scale planning, development, and conservation of natural resources.

Most rivers cross several political boundaries and many types of terrain as they flow through different states on the way to the ocean. The way that land and water are used and managed in the small watersheds in the upper part of the river basin affects the quality and quantity of water people in cities downstream will have. So in dealing with the complex problems of natural resource use and population growth, attention must be given to the needs of all the people in the river basin because the river links them together.

In planning improvements for a watershed community, many factors must be considered: flood control, hydroelectric power, water supplies, sewage disposal, air and water pollution, locations for homes and industry, open space and recreation areas, fish and wildlife resources, land for crops and forests. Though each state has its own problems, states must work cooperatively to find intelligent solutions to water resource problems. Several states now are working together on river-basin commissions. With the federal government's help, they are surveying the community's needs and making broad plans for water and land resources in the entire basin.

The way people in cities along a river use water and the kinds of wastes they put into the river will affect industries, businesses, and cities farther downstream.

Desalination

Scientists and technicians are working hard to solve the problem of water supply in areas of acute water shortage near the ocean by making freshwater out of salty and brackish (slightly salty) water. The process of removing salts from seawater is known as *desalinization, desalination,* or *desalting.*

When water evaporates, salt and other substances are left behind. If we catch and condense the water vapor from dirty or salty water, we then have freshwater. This process, called

Large seawater distillation plants operate in Kuwait, Saudi Arabia, the Virgin Islands, Guantanamo Bay in Cuba, Hong Kong, and Tijuana, Mexico.

distillation, has long been used to obtain small amounts of freshwater from seawater. But producing freshwater in large quantities by evaporating seawater and catching and condensing the vapor is expensive, even if the source of heat to cause evaporation—such as from the sun—is free. Heating seawater by using fuel oil or a nuclear reactor speeds up evaporation but adds to the cost of producing freshwater.

Freezing is another method for purifying seawater. When salty water freezes, the ice crystals formed are pure. However, when freezing is accelerated in machines, the crystals of ice formed are coated with a thin film of salt water, which must be washed from the crystals before they are melted. Thus, it is difficult (and expensive) to get large amounts of freshwater by this means.

Another membrane process is *electrodialysis*, used mostly for brackish waters. In this process electric current is used instead of pressure. The current causes the salt ions to move through the membranes, leaving freshwater behind.

Other desalination processes use membranes. One of these, *reverse osmosis*, is used to treat brackish and slightly salty water. Osmosis occurs when a diluted solution passes through a membrane into a more concentrated solution, much as water from the soil moves into plant roots through cell walls. This process can be reversed if sufficient pressure is applied on the concentrated or salty water side and freshwater will flow through the membrane out of the salty water—hence the name reverse osmosis.

The number of desalination plants is increasing steadily, but the water is costly. However, cheaper and more efficient processes for desalination are constantly being developed. This is an exciting field for study and experimentation.

Water Pollution

In general, polluted water is water that contains anything that makes it unfit for a specific purpose. Except for small quantities used in science laboratories, all water contains dissolved substances and suspended materials. Even the safe, clean water most people drink is not absolutely pure. In studying water pollution, we must learn how the quality of water can be damaged by people (or in other ways) and how to avoid or remedy this damage.

Water is considered *polluted* when it contains anything—such as bacteria, insecticides, oil, salt, toxic chemicals, decaying vegetation, or litter—that makes it unfit for a specific purpose.

Water is not considered polluted until the kind or quantity of material or energy added to it makes use of the water less healthful, useful, or enjoyable.

Water might look sparkling clean, but if it contains any bacteria that cause disease, it is considered unfit for human consumption. Yet, such water could be safely used for navigation. Water that is far too dirty for swimming might be perfectly suitable for irrigating crops. Water that is so polluted by heat that fish cannot live in it could well be safe for birds to drink. We see, then, that part of the overall problem with water pollution is deciding how safe water must be or, in effect, how much pollution we will tolerate in water to be used for different purposes.

The problems of water use and pollution control are a major focus of river-basin planning. Progress is being made in developing water-quality standards that apply to waters flowing across state lines, but pollution control generally is still a matter for action through local governments, for they make many of the laws that govern water use and sources of pollution.

Careful Planning Is Needed

If we are to have water of suitable quality for various uses, we must plan carefully, learn to use water resources intelligently while controlling pollution, and spend sizable sums of money to clean up the damage already done to many of our water sources.

Broadscale planning for use of water resources and pollution control is difficult because the rain that falls on a watershed might travel in streams and rivers or underground through several states and be used many times for different purposes. Each city, each community, and each individual water user must take responsibility for returning water to the rivers in good condition and keeping pollutants out of it, so that the people farther down the river will not have to clean up the water for their use. In some cases, cleanup might not be possible, and, of course, plants and wildlife suffer from dirty water.

Watershed Success Story

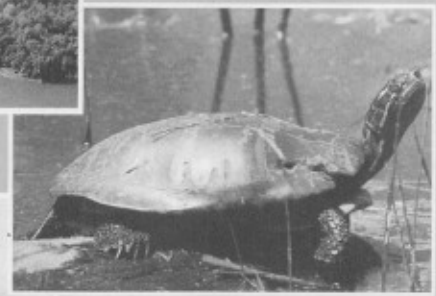
One of the great success stories of people working together to make and keep our water clean and wildlife habitats healthy is that of the Chesapeake Bay. The bay's watershed covers about 64,000 square miles and includes 150 rivers through parts of six states and the District of Columbia. It is the nation's largest estuary.

In the mid-1900s, people started noticing that the water was becoming more and more polluted. After Congress passed the Clean Air Act and the Clean Water Act in the 1970s, governmental support was in place for citizens' groups to start working to save the bay. In 1983 the first Chesapeake Bay Agreement was signed, forming the Chesapeake Bay Program. This is a partnership among Maryland, Pennsylvania, Virginia, the District of Columbia, the U.S. Environmental Protection Agency, and the Chesapeake Bay Commission. This agreement has been renewed and amended several times, most recently in 2000.

The agreement has the goal of restoring and maintaining the bay through

- Restoring and protecting its living resources, recognizing that "the entire natural system must be healthy and productive"
- Reducing and controlling water pollution
- Planning for and managing the environmental effects of population growth and development
- Promoting understanding through education and participation
- Promoting public access and appreciation

This joint effort shows how many groups of people have worked together to help make our habitat healthy and accessible for recreational



and commercial use. You can learn more about the Chesapeake Bay story at *http://www.chesapeakebay.net.*

The Federal Water Pollution Control Act amendments of 1972 established national goals for clean water. Section 208 of the act generated two major objectives: determining limitations to waste material needed to meet water-quality standards, and developing statewide and areawide management plans for reducing pollution.

There are two basic sources of pollution—point and nonpoint. *Point source pollution* has an identifiable location from which the pollutants are coming, such as an industrial or sewage-treatment plant. *Nonpoint source pollution* has no single identifiable source and is caused by runoff moving over, through, and into the ground, picking up pollutants on the way. It usually is associated with changes in land usage.

Major Pollutants

Scientists have specified eight general categories of water pollutants: sediment, plant nutrients, infectious agents, organic chemicals, sewage and organic wastes, salts and mineral substances, radioactive substances, and thermal (or heat) pollution.

Each kind of water pollutant is related to the use people make of water resources, and in many cases, the use they make of soil resources, too. The links between water and soil and the web of nature make the problems of water pollution and its control very complicated. Understanding the problems of water use and some of the processes of water treatment is important, for unless people understand the vital need for water-pollution control, they will not be willing to pay for it.

Sediment is the principal pollutant of surface waters.

Sediment

As we have seen, soil washed from its source and deposited where it is not wanted is called sediment. It is estimated that about half of the soil that erodes each year in the United States reaches our rivers, streams, and lakes. About 1 billion tons of soil is delivered to the oceans by rivers. The Mississippi River alone dumps more than 500 million tons of sediment into the Gulf of Mexico during an average year; reservoirs trap another 1.3 billion tons.

Much of the sediment in surface waters comes from erosion on poorly managed rural lands, but a good deal comes from unprotected areas in or near cities, such as urban construction sites. Yields from undisturbed urban lands are much lower, most of which come from stream-channel erosion.

Control of erosion requires good soil and water conservation practices—from the first tiny trickle of water at the head of a stream to the river's end at the ocean. You can help solve the problem of sediment pollution of water by applying conservation practices so that your own yard, school grounds, Scout camp, and other places do not erode and add to the silt load of streams.

The masses of algae that sometimes grow in a body of water are known as *algal blooms*.

Plant Nutrients

The main plant nutrients that cause pollution problems (because relatively large amounts of the nutrients get into surface waters) are nitrogen, phosphorus, and potassium. At present, probably the most damaging to water resources is phosphorus, which comes from city sewage, detergents in wastewater, runoff from land where much phosphorus fertilizer has been applied, and natural sources.

Whatever the source, phosphorus often causes a great increase in the growth rate and the quantity of algae in ponds, lakes, and rivers. Like all plants, algae must have certain nutrients. In most waters, the main factor that limits their growth is a lack of phosphorus, so when additional amounts of it become available, the blooms grow rapidly.

The growth of these plants in enormous quantities crowds out other aquatic life. As decomposing organisms go to work on dead algae, so much oxygen is used from the water that little else can live, and the pond, reservoir, or river becomes a mass of rotting algae.

The solution to plant-nutrient pollution of water is effective treatment of sewage—which contains much phosphorus from detergents—and the proper use of soil conservation practices to reduce runoff and delivery of sediment to streams from fertilized fields, livestock feeding operations, and yards and recreation areas.

The water in your city swimming pool is treated with chlorine to kill disease-causing organisms.

Another way pathogens in water can be killed is by heat. Generally, boil water 20 minutes to kill all pathogens effectively.

Infectious Agents

Microorganisms and bacteria known as *pathogens* are especially significant pollutants of water because they cause disease. Before scientists learned how diseases were carried from place to place, many people and animals got sick as a result of swimming in or drinking water polluted by disease-causing organisms. Among the serious diseases people might get from drinking polluted water are cholera, typhoid, dysentery, hepatitis, leptospirosis, and amebiasis. Several of these also affect animals.

Human and animal wastes, including those from birds and other wild creatures, are the source of pathogens that enter the water. Runoff can carry pathogens as it flows over the land to a stream. Some disease-causing organisms can remain alive in the soil for a long time and can move through the soil to underground supplies for shallow wells. Periodic tests should be made of all water for human use to make sure it is free of pathogens.

The *effluent*, or waste material, from sewage-treatment plants may be treated with chlorine to kill pathogens. Most cities treat their water supplies with chlorine before piping it to homes and businesses.

Organic Chemicals

Many materials that pollute water are organic chemicals, such as pesticides and herbicides, insecticides, fungicides, and petroleum derivatives. These and other chemicals enter the water by being washed off the land. They usually move with soil particles carried by runoff—another important reason for controlling erosion and runoff.

We must do everything possible to keep organic chemical pollutants out of streams, rivers, and lakes. We should use the proper chemicals for a specific purpose very carefully and devise ways of preventing "accidents" through which the chemicals get into water. These pollutants have led to many experiments with wastewater treatment to find means of removal. Some industrial plants are setting up new waste-disposal and waste-treatment facilities to remove all chemical pollutants from wastewater.

Because some chemical pollutants such as certain pesticides are stored in animal fat, they can undergo what is called *biological magnification*. This means that the lowest link in a food chain, such as an insect, might contain only a minute amount of the pesticide, but each successive link will contain higher concentrations as fish, birds, animals, or people eat the things that contain these chemicals.

Sewage and Organic Wastes

Sewage and organic wastes are highly significant pollutants because of their large volume in the environment and the close connection between them and other categories of pollutants. In addition to the wastes that are carried by water from homes, great quantities of organic wastes result from food-processing and some industrial operations. Such wastes contain pathogens and large amounts of plant nutrients. Untreated or inadequately treated sewage and organic wastes often cause a body of water to smell bad, and they can upset the natural biological balance of a river or lake.

In a river or lake, aquatic plants, fish, insects, and billions of different kinds of microorganisms work in harmony to maintain a cycle of life that helps keep the water clean. The green plants add to the oxygen in the water and a certain amount of oxygen is picked up by the water from the air. Oxygen is vital to most life in water. Fish need it to live, and great amounts of it are required in the decomposition of the natural wastes of the river such as sewage, dead plants, fish, and other organic matter.

Because *decomposition organisms* (that also require oxygen to break down organic matter) multiply rapidly when there are large amounts of material for them to live on, a stream can quickly become overloaded with wastes and short on oxygen.

We call the amount of oxygen required to decompose the organic matter present in water *biochemical oxygen demand*, or BOD. Sewage and organic matter added to water reduce its quality largely through their high BOD. A body of water can handle a small amount of these pollutants; natural processes break them down over time and the water remains clean.

Accidents or careless discharges of some materials have resulted in oil or deadly poisons getting into water and greatly damaging fish and wildlife along seashores, on inland lakes, and in streams and rivers.

A turbulent stream will pick up more oxygen from the air than a smooth-flowing, quiet one.

Depending on temperature and other factors, fish and other forms of aquatic life will have enough oxygen when the water contains 10 to 12 parts per million of dissolved oxygen. When the dissolved oxygen content drops below 3 to 5 parts per million for a long period, fish suffocate and the whole association of plants and animals in the river or lake usually changes.

As cities became more populated and more people used water for industries, the volume of waste dumped into rivers and lakes increased far more than what could be processed naturally. The pollutants upset the natural biological balance to such a degree that some streams became little more than open sewers. The fish could no longer survive, and people downstream had difficulty treating the water for use. Today, some communities continue to dump untreated sewage into streams and lakes, and a number of coastal cities pump raw sewage out into the ocean.

Salts and Mineral Substances

Salts and mineral substances are troublesome pollutants in many places in the United States. As water moves through the soil and over the land, especially in dry parts of the country, it picks up natural salts and minerals. Salt is a major irrigation problem in the Southwest. Improved management of water used for irrigation can help ease this problem.

Drainage from irrigated lands can contain 25 tons of salt per acre-foot of water.

Drainage from acid-mine waste is another example of this type of pollutant, and it has severely damaged some streams and rivers. Coal and other minerals are frequently mined by using huge machines to strip away layers of soil and rock so that the minerals can be scooped up and hauled away. This is called *strip mining*. The waste materials from this type of mining contain chemicals such as sulfur, which, when combined with water from rain or snow, form strong acids. If enough of this acid water gets into a creek or river, no aquatic plants or animals can survive.

The Surface Mining Control and Reclamation Act of 1977 regulates strip mining and provides for the control of erosion and drainage from acid-mine wastes. It takes a little more time and money to use improved methods of strip mining, but with these methods the mined land can be made useful for other purposes, and pollution of streams by minerals and acid can be controlled.

Radioactive Substances

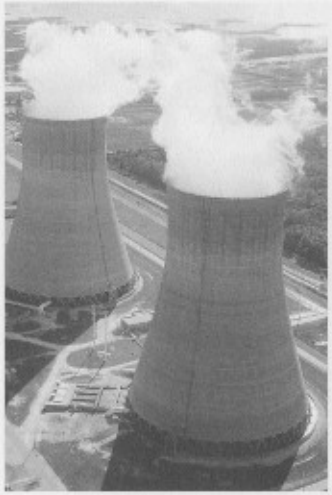
Radioactive substances are among the newest of water pollutants. Even though the radiation from these substances decreases (decays) with time, these pollutants are still dangerous to humans and other forms of life. However, since we can't speed up the rate of decay, holding or putting radioactive wastes in a safe place until they are no longer dangerous is the only waste-treatment method. As the number of industrial plants producing power from nuclear energy increases and as the need for radioactive materials grows, disposal of these toxic, radioactive wastes will become an even greater problem.

Liquid nuclear wastes range from low to high levels of radioactivity. Treatment of radioactive wastes can involve evaporating the water from them and fixing the solid wastes in clay, ceramics, or cement, which then can be buried deep in the earth or possibly the ocean.

Thermal Pollution

Thermal pollution, or raising the water temperature so that it is less useful, is a growing problem. Many aquatic plants and animals cannot survive for long in lakes and streams where the water temperature is much higher than normal. When large amounts of water are used for cooling purposes in industrial processes, air conditioning, electric power production, and other ways, the stream's temperature can be raised to the point where even plants cannot live.

Raising the water temperature only a few degrees can make a big difference in the types of plants and animals that can grow in a stream, river, or lake.



People became especially concerned about thermal pollution during the 1970s when nuclear power plants were being developed and built. These plants use water to cool the reactors, thereby heating the water. The easily recognizable 400- to 500-foot cooling towers at some nuclear plants help remove heat from the water so that it can be discharged back into the river or reused at the plant.

To help reduce thermal pollution in surface waters, some industries are using methods such as cooling towers. Many new industrial plants now have systems for recirculating water, enabling them to use the water several times for different purposes. By installing facilities for cleaning up and reusing water, one chemical plant cut its daily water requirements from 130 million to 4 million gallons *and* reduced its costs for water.

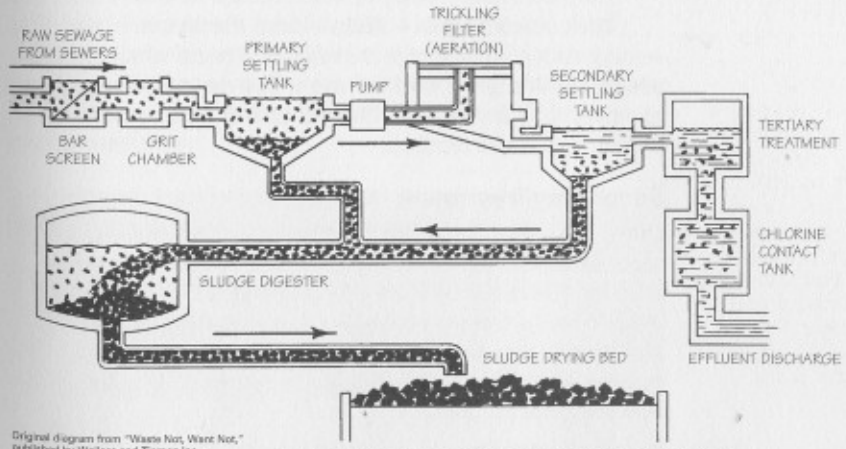
Sewage Treatment

Because we want to continue to use water to move sewage and organic wastes and still have relatively clean streams, rivers, and lakes, we must do something to our huge quantities of sewage and wastes so they will not pollute our water sources. This is the purpose of sewage-treatment plants. Cities and towns usually build and operate their own central sewage-treatment plants. In addition to receiving the sewage from homes, hospitals, garages, hotels, and other businesses, the plants often also serve some industries. However, numerous industrial plants maintain their own facilities for treating sewage before letting the water they've used get back into the environment.

Thousands of years ago when the ancient Romans built storm-water sewers, mostly to help improve drainage in their cities, they still dumped household waste on the street. It wasn't until the 1800s when people realized that disposing of household waste in storm sewers and gutters, where it was removed rapidly, could improve community health—especially if those sewers were underground. Sanitary sewage systems were expensive to build, but by 1910, there were about 25,000 miles of underground sewer lines in the United States.

Cities and towns generally are not building or expanding sewage treatment plants fast enough to keep up with their growing populations. Many cities and towns use sewage treatment plants that were designed and built years ago, and these are becoming overloaded. In many places, storm drains built to handle the runoff from city streets flow into the sewer system. After heavy rains, the sewage treatment plant cannot handle the great amount of runoff. Some of this runoff flows directly into rivers or lakes, carrying raw sewage along with it.

After sewage is collected in public sewers and brought to a central point, it might receive *primary treatment* or primary and *secondary treatment*. In a few instances, it might also receive *tertiary treatment*. Each type of treatment calls for different methods. The type of treatment used depends largely on the strength and quantity of the sewage in relation to the nature and volume of the water (river, stream, lake, reservoir) into which the treated wastewater is discharged.



Original diagram from "Waste Not, Want Not," published by Wallace and Tiernan Inc., 25 Main St., Belleville, NJ 07109.

A basic method of treating municipal sewage

Primary Treatment

Primary treatment of sewage mainly involves removing the solids from wastewater. It is the only kind many towns use, but there are different methods of accomplishing it. The first step in primary treatment usually is some type of screen to trap sticks, rags, and other large objects. The sewage might

pass through a grinder that chops these large objects into smaller pieces. Then, the sewage moves slowly through a *grit chamber* where stones, sand, and other heavy inorganic materials sink to the bottom and are removed from the chamber. Next, the wastewater goes to a *settling tank* where organic matter and fine particles of other material settle and are collected, and scum and grease float to the surface to be skimmed off. Certain chemicals can be added to the settling tank to cause the fine particles to cling together and settle faster.

In primary treatment, the water left from the settling tank is discharged into a river or stream or allowed to soak into the land. Sometimes, as this fluid, called *effluent,* flows out of the settling tank, it is treated with chlorine to kill harmful bacteria.

The collected solids—*sludge*—from the bottom of the settling tank go to a *sludge chamber* or *digester* where decomposing bacteria go to work on them. The digested sludge then moves on to a drying bed, after which it can be burned, buried, or used as fertilizer.

Secondary Treatment

Often, the effluent resulting from primary treatment requires secondary treatment. The wastewater repeats all the steps of primary treatment and then one of two processes for further organic waste decomposition. Both processes depend on biological action and both require oxygen. The oxygen is supplied through *aeration*, that is, by spraying the effluent into the air or by pumping air into it.

In one process, the effluent goes from the primary settling tank to a *trickling filter.* There, it passes slowly over stones or other material where biological growths decompose the waste left in the effluent. The stones and other material in the trickling filter provide as much surface area as possible with oxygen so that the biological growths can live and do their work. In the other basic secondary process, effluent from the primary settling tank goes into a sludge tank where *activated sludge*—material that has various biological growths in it—completes the process of decomposing organic materials. While the effluent remains in the sludge tank, it is continuously aerated.

The effluent from either the trickling filter or the activated sludge tank then goes to a secondary settling tank to allow more waste materials to settle out. These materials go with the sludge from the primary settling tank to the sludge chamber or digester. As it flows from the secondary settling tank, the effluent is treated with chlorine before being released into a stream, river, or lake or being allowed to soak into the ground.

Tertiary Treatment

Even secondary treatment doesn't get wastewater clean enough in some situations. Tertiary treatment is used after the wastewater goes through primary and secondary treatments. Tertiary treatment gets the wastewater clean enough to be run through a city's water-treatment process for household use.

Properly treated wastewater is no longer water wasted. It is good water and can be used again. Sewage treatment is similar to nature's endless chemical and physical water-purifying processes. But nature's methods take a long time and simply cannot process the huge amounts of waste people generate each day. Primary, secondary, and tertiary wastewater treatment does the same thing nature does, only faster and under controlled conditions.

Very little wastewater now receives tertiary treatment, and there is no typical tertiary treatment plant. The process used depends on the specific need for further treatment of the effluent after it has received secondary treatment. Tertiary treatment consists of slow or rapid filtering of the effluent through sand to remove dissolved solids. This treatment could be aeration to foam out detergents. It could be the use of *chemical precipitation* to settle the solids. Or it could be *superchlorination* followed by *dechlorination* to kill harmful bacteria and pathogens.

Conservation tillage leaves residue from the past year's crop on the soil surface for protection from erosion.

Conservation and Agriculture

Soil and water conservation practices help agriculturists maximize their production while paying responsible attention to the web of nature. This calls for attention to energy-consumption needs.

Conservation tillage uses crop residues to improve soil structure, maintain organic matter, and provide good working conditions for soil bacteria.

Agribusiness is the country's largest consumer of petroleum products. In 1994, it took 1.4 billion gallons of gasoline, 3.5 billion gallons of diesel, and 0.9 billion gallons of propane to produce all the crops grown in the United States. Liquid fuel is used for tilling, harvesting, and other farming operations, including the production and feeding of livestock. Crop drying uses liquefied petroleum gas (LPG), natural gas, and fuel oil. Petroleum energy also is used for irrigation, frost protection, and greenhouse culture. Furthermore, the manufacture of agricultural supplies such as fertilizers, herbicides, insecticides, and other chemicals uses great amounts of energy. Other segments of the agribusiness industry, including transportation, processing, manufacturing, and packaging, consume vast amounts of energy.

One potential for reducing fuel requirements in agriculture is the use of *conservation tillage,* also called minimum tillage. *Tillage,* such as plowing, prepares the soil for growing crops. Conservation tillage limits the use of the plow because farmers leave the residue of previous crops, such as stalks and leaves, on the ground rather than plowing it under. Besides reducing the number of trips across the field with large machinery, thereby cutting fuel costs, conservation tillage also provides excellent protection of the soil because the crop residue helps control erosion of and conserve moisture in the soil.

Another potential for energy savings—and water conservation—in agriculture (and your own garden) lies in improved irrigation. This can be done through *drip irrigation,* or watering plants slowly and directly at their bases. The system uses a series of main and lateral lines that run parallel to rows of crops. These lines pipe water from a central source to drip at a rate of 1 to 4 gallons per hour directly to the roots of individual plants. It is not for every crop or every farmer, but drip irrigation can provide great savings in energy and water. An estimated annual savings of 231.2 million gallons of fuel and 55.8 million acre-feet of water could be achieved by using this method of irrigation.

Other conservation practices that could reduce agriculture's consumption of energy include increasing the use of animal waste as fertilizers, building and planting parallel terraces, and planting windbreaks. A carefully planned and researched *pasture management program* usually helps reduce energy costs and keeps pasturelands healthy and productive. To effectively manage their lands, farmers and ranchers had to allow grazing at the right time of year; avoid overgrazing or undergrazing pastures; be attentive to and correct soil acidity when necessary; fertilize responsibly; control undesirable plants; manage animal waste; and rotate crops.

Agriculture research has expanded its alternative energy sources. Work is underway on the use of *biomass* (*bio*logical *mass*), or organic materials produced by plants and animals—such as wood chips, peanut shells, grass clippings, and manure—to produce energy. Biomass energy has actually been around for a long time. Even today, in some less-developed countries, wood, crop residues, and dung remain major sources of energy. Biomass is renewable, and the residues of biomass benefit the land when returned to it. There are pros and cons to the use of biomass, but many believe that it could make a major contribution to energy savings in the future.

Agriculture researchers also pay attention to solar and wind energy. Power derived from the sun offers prospects of significantly reducing the amount of fossil fuel needed by agriculture for many tasks, including processing food, drying grains and crops, heating livestock shelters, and heating and cooling greenhouses. Other applications for both solar and wind energy include operating irrigation pumps, supplying energy for rural homes, and providing power for pumping water.

The development of alternative sources of energy will continue to increase. As new uses for these energy sources are found, costs for manufacturing and installing energy systems and collecting, storing, and delivering the energy will be reduced, making the use of alternative energy sources more attractive to farmers.

How You Can Help

As you take a "conservation look" at your neighborhood, town, or community, you will see many opportunities for conservation projects and practices that will protect and improve soil and water resources and at the same time add to the attractiveness of areas.

If you need help in getting started on a project, don't hesitate to ask experts—soil conservationists, foresters, fish and game managers, soil conservation district supervisors, teachers, park commissioners, county agricultural agents, city and regional planners, highway supervisors, or anyone else who works with natural resources.

The conservation task you choose doesn't need to be a big one. Select a project that will give you a chance to apply some of the basic conservation ideas you have learned in working for your Soil and Water Conservation merit badge.

Plan First

Plan before the work actually begins; it will help you organize your thinking. Include the following in your planning:

- A description and map of the project area
- A definition and description of the problem that needs attention
- An outline of steps to be taken to accomplish the task
- A list of the necessary tools and materials needed
- Notes on any follow-up or maintenance requirements

Be realistic about what you can and cannot do. It is better to choose a small project that you can complete successfully than to get involved in a large one that overwhelms you.

Ask yourself the following questions:

- What factors of slope, climate, and soils need to be dealt with?
- What will be the appropriate grasses, shrubs, trees, or vines to plant for the purposes you have in mind?
- Will the project harmonize with the soil and water needs of the surrounding area?
- When is the best time to do the work?
- What care will be needed to keep the project in useful condition after it's done?

You also will want to be sure your plan includes normal safety precautions for using tools, handling plant materials, and conducting yourself on hazardous terrain or near ponds and streams.

Before you carry out your plan, share it with your merit badge counselor and discuss it together for more ideas. This is a good way to get the kinks out of your plan—and gain confidence, too. Your counselor also can help you get the tools and materials you will need.

Ideas for Projects

Now for some specific project ideas. In most cases, you will need to adapt these suggestions to your situation. Analyze conservation tasks you can do around your home, at your Scout camp, or within your neighborhood or community, and make practical plans for carrying them out.

Plant Grasses and Other Ground Cover

Aim: Keep soil covered and hold it in place to control water and wind erosion, reduce flooding and siltation, and beautify an area.

You will find many places where you can practice conservation by establishing a cover of grass, vines, or other plantings. Check out schoolyards, wildlife areas, parks, roadside rest areas, your place of worship, camping areas, and the grounds around hospitals or other public buildings.

Most grasses can be planted using the same basic procedure: First, learn something about the soils on the site, and find out which grasses, combinations of grasses, or other plants will grow best there. In some locations, you may need to add lime to the soil as well as use fertilizers or organic material.

Spade or work the soil into a good seedbed, adding lime and fertilizer if needed. Smooth and roll to a firm base and then distribute the seeds. Rake the surface lightly, barely covering the seeds. Sprinkle carefully with water to avoid disturbing soil particles and washing away seeds. In some cases, you might need to water the area periodically.

Especially useful on steep slopes are vining plants that form excellent ground cover to help protect the soil. Many of these will grow in shady areas where grass does not grow well. Determine the kind of soil you have to work with and the kinds of vining plants best suited to the location. Plant them from the top of the slope downward. This way, you will help check erosion at the top of the slope first and will avoid trampling on plants as you add to the plantings farther down the slope. Prepare the soil as for any planting by spading or loosening it to the depth of a few inches. Work in lime or fertilizer if needed. Most vining plants are started from small plants rather than from seed.

Protect a Stream Bank

Aim: Repair and protect embankments subject to flooding and erosion to reduce sedimentation and improve conditions for fish and stream-side wildlife.

Choose an area that needs attention along a small brook or creek. Leave the protection of rivers banks to engineers and other professionals. If the bank is steep and undercut, use hand tools to reslope it to a uniform, gentler grade. Find out what plants, grasses, and seeds would be suitable for bank stabilization. Use several different kinds.

Sometimes a stream bank needs more protection than planting; if the current is swift or the bank is eroding too fast for plants to get started, place a layer of stones or broken rock at the foot of the bank—extending a few feet above the expected waterline.

You can also use the basic principles of protecting a stream bank along the shores of ponds and lakes.

Plant Trees and Shrubs

Aim: Help hold the soil in place, provide shade, produce timber, provide shelter and food for wildlife, and beautify an area.

You need to consider many factors before planting trees or shrubs, including the kind of soil, how long the tree or shrub will likely live, the size and shape of the tree when fully grown, the kind to use for a specific purpose, and the care it can and will be given as it grows.

When you get the tree and shrub seedlings you will plant, be sure to keep their roots completely in water, or in moist organic material such as peat moss, until you actually plant them in the ground. Dig planting holes spaced according to local laws and recommendations for the kind of trees or shrubs you are planting; usually these holes should be about 2 feet apart in rows about 2 feet apart. It is important that the holes you dig are large enough to hold all the roots without crowding them. Be sure the soil at the bottom of the hole is not packed so hard it will interfere with root growth. If the soil is dry, you might need to put a little water in the hole. Press the soil carefully and extra firmly about the roots as you fill the hole, because air pockets in the root zone could kill the seedling.

Prevent weeds, grass, and other plants from growing up around small seedlings. Of course, you may have to water the seedlings regularly if there is little rain. Should the seedlings need protection, pile a layer of brush over the planted area. Drive stakes and use wire to tie down the matting of brush.

For large-scale tree-planting projects, you will need the help and direction of experts who know about the best trees to use for different purposes and the kinds of soils in which the trees can be expected to grow.

Control Trail Erosion

Aim: Protect footpaths in camp areas, hiking and nature trails, and primitive roads from damage caused by erosion and from earth slides caused by heavy rains ahd melting snow.

In laying out new trails or dirt roads, avoid trouble by locating them as nearly as possible on the contour. Other precautions in the layout and construction stages include making lanes no wider than absolutely necessary and taking care not to remove the natural cover of vegetation near the side of the trail.

Where trails go downhill and runoff could flow rapidly and cut into the trail surface, you can use a conservation device known as a water bar. This is made by cutting a shallow channel across the trail at an angle to the slope. A small log or stones can then be placed in the channel. When water flows down the trail, this bar serves as a small dam to divert water off the trail and onto an area of grass where it can soak into the soil and provide moisture for plants.

To ensure against erosion and make the trail less muddy in wet weather and less dusty in dry weather, put a layer of organic material—such as wood chips, sawdust, pine needles, or leaves—on the trail surface.

Be sure to get the advice of a conservation specialist before trying to control erosion. If you don't design and carry out erosion control practices properly, you could end up creating more problems.

Mulch Your Soil

Aim: Hold surface soil in place until newly seeded plants become established, and shelter otherwise bare soil from water-erosion damage.

Mulches check erosion by protecting the surface soil from the action of water and wind. They help keep the soil surface from drying out and protect the plant's root zone from extreme cold or heat. A heavy layer of mulch around growing plants retards the growth of weeds. When using mulches, nitrogen usually must be added with them over and above the usual amount recommended for the soil.

Use a fork or spade to apply a mulch wherever soils or young plants need protection. To keep light materials such as leaves or straw from blowing away, push the edge of a shovel or spade through the mulch into the surface at close intervals to anchor the materials in the soil.

Build a Grass Waterway

Aim: Dispose of excess runoff safely, prevent soil loss and other water damage, and help keep sediment out of water.

Grass waterways are needed on the sloping soils of gardens, lawns, camps, playing fields, croplands, pastures, wildlife areas, and many other places.

Note where water runs toward a lower area after a storm and find a place where it can be disposed of safely. This could be a street gutter, a stream, a patch of woods, or a small pond. Starting from the lower end of the waterway, move soil to create a wide, shallow channel where you want the water to flow. Prepare a good seedbed in the shaped channel and then seed recommended kinds of grass.

For quick cover during a rainy season, you might want to seed some annual grasses or some quick-growing oats, rye,

or barley. Keep the waterway mowed and free of weeds and brush; you also might have to treat it occasionally with lime and fertilizer to keep the turf dense and tough. The liming and fertilization rates should be a part of the property's overall soil and water conservation plan.

Educate Others

Aim: Help other people in your town or community to understand the importance of conservation and the need for the intelligent use and management of natural resources.

You can give talks and demonstrations on conservation practices to your fellow Scouts and other groups. Describe a planting project or stream-bank erosion control project, or talk about how to make a compost pile. You could demonstrate, with little equipment, how water runs off bare soil, soil with a grass cover, and soil with a mulch on it.

Organize your talk around a central theme. Define a conservation problem and then give specific examples of conservation practices that have been or should be used to deal with it. Tell briefly and clearly how we depend on soil, water, plants, and animals for our survival, and explain how you are helping in the important work of conservation—and how your listeners can help, too.

You can make exhibits for science fairs or for display in the windows of banks and stores, at county fairs, at airports, in your school auditorium, at flower shows, at your Scout headquarters, or at the local library. Exhibits tell a story about local conservation problems and how they are being solved.

Do a Conservation Inventory

Aim: Uncover and explore conservation needs in a selected area within your community and direct the attention of people to them so conservation practices can be applied.

Choose an area—perhaps a number of blocks in your neighborhood, your Scout camp, or the entire town—and look at its conservation needs. Here are some questions to ask yourself as you make your conservation inventory and pinpoint on a map the conservation problems you discover:

- Are the banks of rivers or smaller streams eroding?
- Can you see evidence of flooding? When did the last flood occur?
- What flood-control measures or devices does your community have?
- Where does your community or town get its water?
- How does your community treat its sewage?
- Are there little ditches along the sidewalks where grass once grew?
- What is the condition of slopes along highways?
- Do you see any litter baskets or barrels in your community? Are they being used?
- Does your community have any shade trees? Are they healthy? Who takes care of them?
- How many different kinds of birds and other wildlife live at various locations in your neighborhood? Why do they live there?
- What is happening to vacant lots?
- Are there any junkyards in your community?
- Does your school have a conservation project?