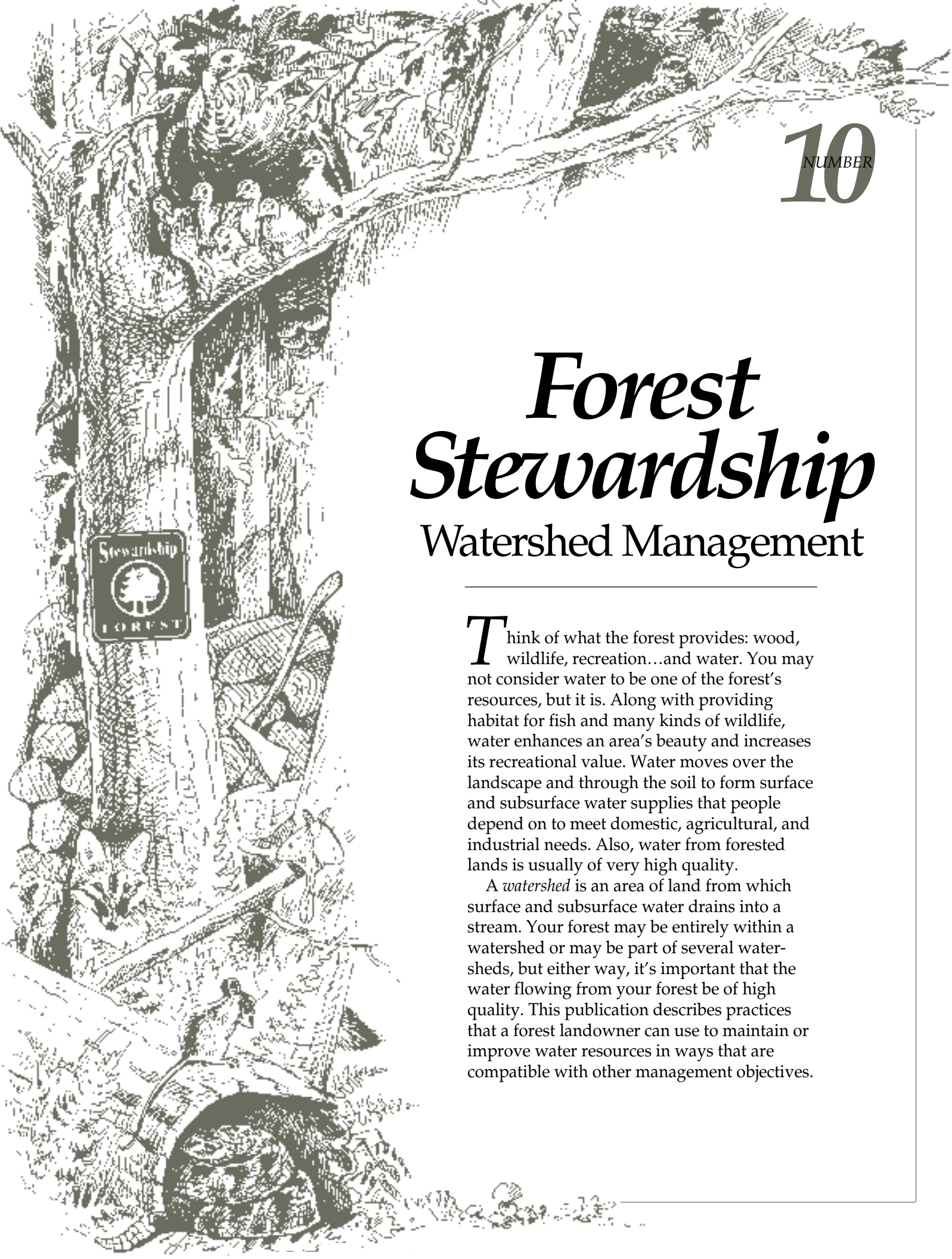

NUMBER 10

Forest Stewardship

Watershed Management

Think of what the forest provides: wood, wildlife, recreation…and water. You may not consider water to be one of the forest's resources, but it is. Along with providing habitat for fish and many kinds of wildlife, water enhances an area's beauty and increases its recreational value. Water moves over the landscape and through the soil to form surface and subsurface water supplies that people depend on to meet domestic, agricultural, and industrial needs. Also, water from forested lands is usually of very high quality.

A *watershed* is an area of land from which surface and subsurface water drains into a stream. Your forest may be entirely within a watershed or may be part of several watersheds, but either way, it's important that the water flowing from your forest be of high quality. This publication describes practices that a forest landowner can use to maintain or improve water resources in ways that are compatible with other management objectives.

Forested Watersheds

Forests make excellent watersheds chiefly because their soils usually have a high infiltration capacity—they are capable of quickly absorbing large amounts of water. Therefore, rainstorms or melting snow in woodlands produce relatively little surface runoff with the associated problems of *erosion* (detachment and movement of soil) and *sedimentation* (the deposition of soil). *Turbidity* is the term applied to water that has reduced clarity due to suspended sediments. Turbid water looks cloudy. Generally, the water flowing through streams in stable forests has very low turbidity.

Trees contribute to the high infiltration capacity of forest soils. When tree roots remove water from soil pores, space is created for additional water to be stored. Forest soils also have a great deal of pore space. The abundance of organic matter from decaying plant parts creates a well-structured soil in which the individual soil particles tend to form *aggregates* (small clumps of soil stuck together). This clumping of soil particles produces large, interconnected pores between the aggregates. Water poured on the surface of such soils quickly disappears into the pores. Microorganisms, insects, small animals, and growing tree roots also contribute to soil aggregation (and consequently more pore space) by moving and mixing soil. These actions put soil particles in contact with each other, increasing the likelihood that soil particles will clump together, resulting in large pores through which water can easily drain. The *litter layer*, which consists of leaves and bits of wood in various stages of decay on the forest floor, helps maintain healthy populations of soil organisms. By shielding the soil from the elements, the litter layer provides soil organisms with a less-hostile, more-stable environment.

Even in the winter, when forest soils may be frozen, they can maintain a high infiltration capacity. *Concrete frost*, a solid impermeable layer of soil and ice, rarely forms in forest soils. The litter layer insulates soil from extreme cold. Also, because the loose forest soils have high amounts of organic matter and large pores, the frost penetrating such soils is of a more porous, granular, or honeycomb nature, permitting water to percolate through.

The forest vegetation also protects the soil's infiltration capacity. Raindrops falling on exposed soil may have enough energy to break up soil aggregates. Individual soil particles are then easily eroded and washed into soil pores, clogging them and preventing rainwater absorption. When such conditions occur, water tends to flow over the soil surface, increasing the chance of erosion. But in a forest, rain is intercepted by the forest canopy, by the leaves of shrubs or small trees in the understory, and by the organic litter layer covering the forest floor, reducing the force with which rain falls on the soil. Soil pores remain unclogged, allowing infiltration.

Effects of Timber Harvesting

Cutting timber affects both water quantity and quality. Clearcutting (harvesting all trees) allows more water to flow to streams, because there are no leaves to intercept rain and snow (some of which would later evaporate) and roots no longer take water from the soil. Areas being considered for clearcutting should have a substantial ground layer of organic material to help minimize these effects. Much of the water taken into trees by their roots passes through the leaves into the atmosphere in a process called *transpiration*. Trees and other plants return water to the atmosphere through *evapotranspiration*—a combination of evaporation and transpiration. Evapotranspiration is an important process—during the growing season in a Pennsylvania hardwood forest, as much as sixty percent of the rainfall is returned to the atmosphere through evapotranspiration.

In the humid Northeast, the greatest increase in streamflow occurs during the first growing season after the clearcut. But in following years, as the area begins to revegetate, the increased flow lessens. Five to ten years after the cut, streamflow may return to precut levels. This effect on quantity is most important to managers of water-supply watersheds.

Of greater concern to woodland owners is the effect of timber harvesting on water quality. Because of the possibility of accelerating erosion, logging can contribute to sedimentation—the most damaging and widespread water pollutant from forested watersheds. Sediment harms water resources by destroying fish habitat, reducing the storage capacity of reservoirs, and increasing treatment costs for municipal water supplies. The greatest problems do not occur as a result of the actual cutting of trees, but from moving them out of the forest, which requires the use of heavy equipment on a system of trails and roads. If the transportation system is not carefully designed and maintained, erosion on the watershed can be greatly increased, because roads account for the vast majority of sediment associated with timber harvesting. In Pennsylvania, any activity, including timber harvesting, that disturbs more than 25 acres of earth requires a permit from the Department of Environmental Protection (DEP). Most timber harvests disturb less than 10 percent of the harvested area, so a permit is seldom required for logging fewer than 250 acres. Even if you are cutting less acreage, you must develop an erosion and sedimentation control plan and have it on site throughout the operation. Contact your local conservation district office for permit application procedures and guidelines for developing an erosion and sedimentation plan.

WHY SAY NO TO SEDIMENT?

Effects on aquatic life

- Sedimentation of gravel-stream bottoms buries and suffocates fish eggs, and covers *benthic* (bottom-dwelling) organisms that provide food for fish.
- High concentrations of suspended sediment irritate fish gills and may cause death. Suspended sediment can destroy the protective mucus covering the eyes and scales of fish, making them susceptible to infection and disease.
- Sediment particles absorb warmth from the sun and thus increase water temperature and deplete oxygen supply, causing stress to cold-water fish such as trout.
- Aquatic plants need light to grow, but water that is cloudy with suspended sediment produces a shading effect that harms plant health.
- Suspended sediment limits the ability of sight-feeding fish to find food.
- Because sediment often carries phosphorus, a plant nutrient, sediment promotes *eutrophication*—a process whereby water becomes enriched with nutrients, leading to excessive algae growth. When algae die, their decomposition removes oxygen from the water, making the water less habitable for fish and other organisms.

Effects on other water uses

- Sedimentation reduces the capacity of streams to carry water and reservoirs to hold water. This decreased flow and storage can increase flooding and decrease the water available for water supplies.
- Suspended sediment harms irrigation equipment, erodes bridge footings and increases treatment costs for public water supplies.
- Turbid water is unsightly, unsuitable for swimming, and undesirable for boating.

Source: adapted from *Water—The Transporter*. 1992. Environmental Citizenship, Freshwater Series, A-8. Ottawa, Ontario: Environment Canada. P. 2; and *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.* 1993. 840-B-92-002. Washington DC, U. S. Environmental Protection Agency, Office of Water. P. 3–4.

Protecting the Watershed

SKID TRAILS

Skidding is the process of dragging logs (usually with a rubber-tired tractor called a skidder) from the stumps to a central location, called a *log landing*, where they are loaded onto trucks and transported to the mill. The process can be very damaging to the soil surface. The weight of the skidder compacts the soil, reducing its infiltration capacity. Dragged logs scour the soil surface, plowing away the protective litter layer and the upper inches of soil. These gouges become channels through which water can flow at erosive velocities, carrying sediment to the streams.

The following practices can help you minimize the damage from skidding.

- Keep well away from streams and never use streambeds, even dry ones, as skid trails.
- If streams (even seasonally dry ones) must be crossed, cross them at a right angle with temporary bridges or culverts. Check with the Department of Environmental Protection or the county conservation district office to see if such action requires a permit. (General Permit number 8—temporary road crossings—usually applies to these situations.)
- Avoid rocky areas, seeps, springs, and steep grades. (Grades of 10 percent or less are best but not always possible.)
- Do not skid straight up and down slopes; rather, bend and turn skid trails, and have them break grade or change grades to eliminate long stretches on the same slope.
- When logging is completed, lime, fertilize, and seed grasses to revegetate steep sections of skid trails and scatter logging debris (tree tops and branches) on other sections. Consult the *Penn State Agronomy Guide* for specifics on selecting grass species and mixtures and for proper fertilization and seeding rates.
- Remove cross-drain culverts from stream crossings unless trails are to be used again. You will need a Department of Environmental Protection permit (General Permit number 7—minor stream crossings) if the culverts will be in place for more than six months.

LOG LANDINGS

If not properly located, log landings have the potential to get very muddy or allow large amounts of soil to wash away. Log landings create large areas of unprotected, exposed soil. Because of the skidders and trucks working there, the soil can also become extremely compacted. Therefore, it is crucial that water be kept from flowing through, or collecting in, the landing area.

Some methods of protecting soil at log landings include the following:

- Locate the landings on gently sloping, well-drained portions of the upper or middle part of the slope.
- Never build landings at the base of long slopes or immediately below steep slopes.
- Avoid depressions.
- Divert water from the skid roads leading to the landing, and do not let water run into the landing area.

As a final precaution, leave a filter strip (an area of undisturbed forest) of at least 50 feet between the landing and any streams. (Filter strips of 100 to 200 feet are suggested for cold-water streams.) This buffer zone will slow water flowing from the landing and allow sediment to settle out before reaching the stream. Larger filter strips will be more effective than smaller ones. At a minimum, size the buffer using the widths given in Table 1. As with skid trails, when a landing is retired, the soil can be protected by scattering logging debris and revegetating the area.

ROADS

Most erosion and sedimentation problems are caused by the haul roads constructed for logging trucks to carry harvested trees from the forest. Problems can occur both during road construction and after the transportation system is in place.

Road construction greatly disturbs forest soil. The protective litter layer is removed, the mineral soil below is compacted, and steep, potentially unstable cut-and-fill slopes are often created. Roadbeds increase surface runoff (by reducing infiltration) and also concentrate the runoff, creating favorable conditions for accelerated erosion. Natural drainage patterns may be altered—water that once flowed below the surface may be intercepted by road cuts. This formerly subsurface water now seeps from road banks, adding to the surface flow. A rapid, dramatic type of erosion, *mass movement*, may be encouraged. Mass movement occurs when an unstable section of soil (such as a road fill) suddenly slips down slope. Severe sedimentation of nearby streams can result. Road-stream crossings are an especially sensitive area. The presence of flowing water in a stream channel means any disturbance of the streambanks or bottom immediately sends sediment into the stream.

To lessen these problems, properly plan and design the haul road system. The shorter the better. Besides doing less environmental damage, you will have less financial investment—building and maintaining roads is expensive. However, sometimes tradeoffs are necessary. For example, avoiding a steep or poorly drained area may require you to design a route that is longer than one that did not work around these problem areas.

To minimize road length, plan a road system that covers your entire forest, even if you currently intend to harvest only one section. You do not have to actually build the whole system. Build what you need. Although the initial construction cost may be more (since you may not always be taking the shortest route), when the entire system is complete it will be shorter and more efficient than if you had planned each section separately. Road systems through steep slopes and erosion-prone soils will need to be more extensive to reduce the distance of skidding logs to the road.

For the initial layout, use the Soil Survey, topographic maps, and aerial photographs (all normally available at the local conservation district office or service forester's office). Position roads on the sides of hills for good cross drainage and as far from streams as possible. If roads must be near a stream, leave a filter strip. Avoid swampy areas and steep slopes; the poorly-drained soils make poor road bases and the cuts and fills needed on steep slopes are expensive.

Roads should be designed with grades of 2 to 10 percent. Some grade is needed to prevent water from collecting, but grades of more than 10 percent are hard on equipment and promote erosion. Steep grades may sometimes be needed to reduce road length, or to avoid unstable soils or cuts and fills. Keep these sections as short as possible.

During construction try to do two things: (1) keep the area of exposed soil to a minimum and (2) keep water off the roadway. Do not let the bulldozer operator go overboard. Make roads as narrow as possible. A 16-foot width (including ditches) is usually adequate. Also, because most erosion takes place during road construction and use, do not build or use the roads during wet weather.

Remember that the most important factor in controlling erosion and sedimentation is proper drainage. Construct roads so that water will not settle on or run down them. The following engineering practices should prevent this problem.

- Crowned roads have centers that rise 3/8 of an inch for every foot of width. Use crowned roads with cross-drain culverts to provide cross drainage.
- Outsloped and insloped roads may be used where the erosion hazard is slight. The surface is pitched 3 percent either toward or away from the bank:

Table 1. Widths of filter strips between log landings or roads and streams

Slope of land between log landings or roads and streams (%)	Minimum width of filter strip (feet)
0	25[a]
10	45[a]
20	65
30	85
40	105
50	125
60	145
70	165

[a]Widths of less than 50 feet require a permit or written waiver from the Bureau of Dams, Waterways, and Wetlands.

Source: Adapted from *Controlling Erosion and Sediment Pollution from Timber Harvesting Operations*. 1992. Bureau of Land and Water Conservation, Department of Environmental Resources, Commonwealth of Pennsylvania; Cambria County Conservation District and Cooperative Extension, College of Agriculture, The Pennsylvania State University. p. 8

—Outsloped roads are appropriate for the upper parts of long slopes, but icy or otherwise slippery outsloped roads may be dangerous for trucks.

—Use insloped roads on steep turns for safety reasons. Insloped roads usually require diversion ditches and cross-drain culverts (see Figure 1).

- Diversion ditches intercept water from cut banks and carry water away from crowned roads.
- Cross-drain culverts move water collected in ditches from seeps and insloped roads across roads for nonerosive discharge down slopes. Sloping culverts at least 2 percent higher than the ditch and angling culverts 30-degrees to the road will make them less likely to plug with sediment and will make conditions safer for trucks to cross. Put rocks or logs at the culvert outlet to disperse the water and dissipate its energy; spacing depends on the road grade.
- There are two types of cross-drain culverts:

  —Open-top box culverts, generally a temporary measure, are wooden channels set in the road. They will need to be cleaned of soil and leaves periodically (see Figure 2).

  —Pipe culverts are more expensive than open-top box culverts, but they are the best choice for permanent roads (see Figure 3).
- Broad-based dips handle cross drainage and drainage from the road surface and are a less expensive alternative to culverts. Dips slope outward to divert water down slopes. As with cross-drain culverts, spacing depends on the road grade (see Figure 4).

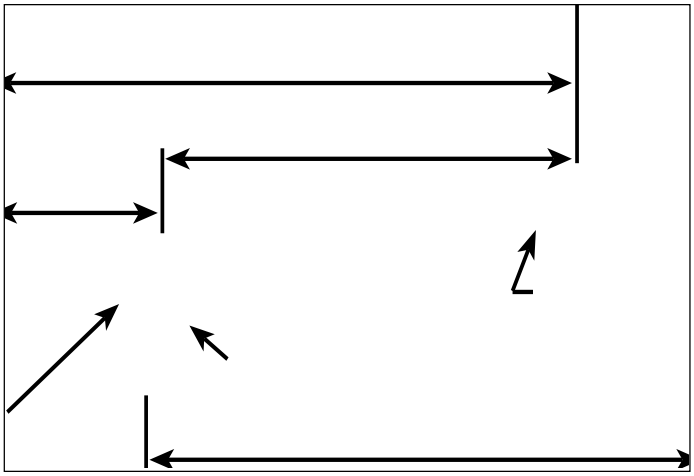

Figure 1. An insloped road with a surface that slopes away from the stream and toward the higher elevation provides an extra measure of safety in steep terrain. In this illustration, surface water drains to the left-hand side of the road.

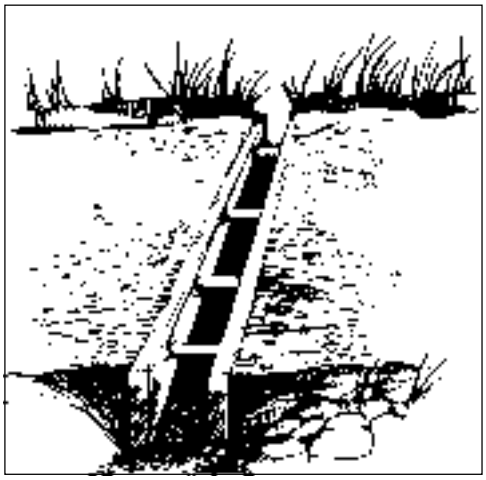

Figure 2. An open-top box culvert is relatively easy and inexpensive to build and install, but it requires regular maintenance to keep it free of debris. This type of cross-drain culvert is best suited for use on temporary roads.

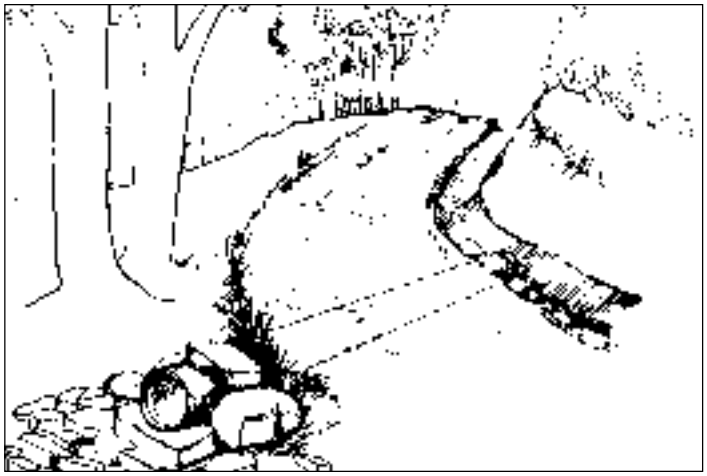

Figure 3. Although more expensive than box culverts, pipe culverts require far less maintenance and are the best choice to install on permanent roads.

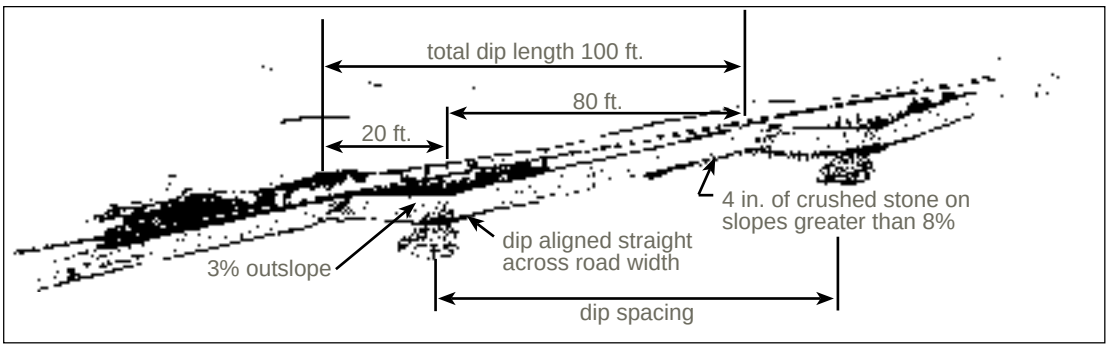

Figure 4. Broad-based dips are sometimes used in place of cross-drain culverts. The illustration shows the dimensions commonly used in the construction of this type of cross-drain structure.

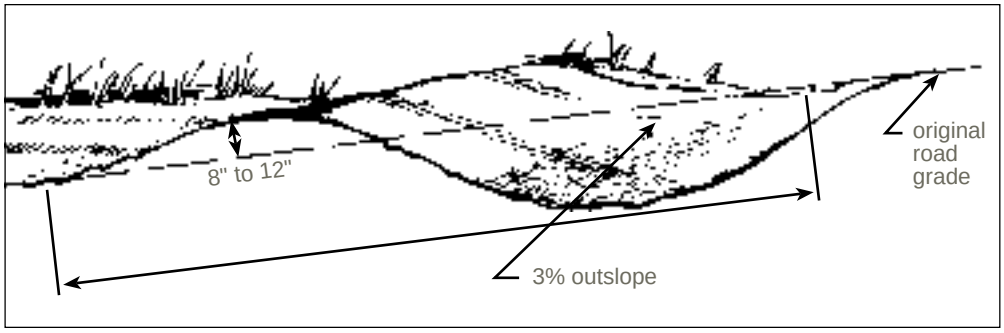

Figure 5. If a road is retired (taken out of use), replace cross-drain culverts with water bars, which require less maintenance than culverts.

For more precise specifications on construction and spacing of these measures, consult the technical publications listed on the last page.

Roads need simple maintenance to ensure proper drainage. Clean ditches and culverts when they fill with sediment or debris. Grade roads annually to prevent ruts or as soon as rills (small channels carved by water) are 1 inch deep. Once roads begin washing out they deteriorate rapidly.

After the timber is harvested, roads should be retired if no further use is intended. Replace cross-drain culverts with water bars (see Figure 5), which require less maintenance. Revegetate the road by breaking up the surface, liming, fertilizing, and seeding grasses. Vegetation stabilizes the area and improves wildlife habitat.

Some other methods of minimizing the roads' impact on the watershed include the following.

- "Daylighting" roads by cutting overhanging branches increases the exposure of the roads to sun and wind, so that they dry out faster.
- Mulch or seed cut-and-fill banks. Seed has a much better chance of becoming established if it is sown immediately following the cut-and-fill operation.
- Allow roads to settle for two or three months before they are used. Divide the timber sale into sections; recondition one section as much as is possible before moving on to the next.
- Suspend logging operations during extremely wet periods.
- Have a professional supervise all aspects of the design, construction, operation, and retirement of the transportation system. Many timber harvesters are trained in proper road design and installation. In addition, your forester, county conservation district office, or cooperative extension office can provide you with further information or technical assistance.

Other Issues to Consider

Logging may affect water quality in ways other than sedimentation. One example is thermal pollution. Clearcutting right up to a stream can result in thermal pollution—excess sunlight can increase a stream's temperature and upset the aquatic ecosystem. Slowly flowing, wide streams warm rapidly because they absorb more of the sun's rays than swift-running, narrow streams.

For a number of reasons, a warmer stream may be an unsuitable habitat for cold-water fish such as trout. Warm water holds less dissolved oxygen than cold water, and trout have high oxygen requirements. All fish thrive only within a narrow range of temperatures. Temperatures outside these ranges can harm or kill fish.

Cutting streamside trees can cause other problems too. Logging debris may end up in the stream, forming what are called debris dams and channel splits. The stream may then try to carve a new channel around the dam or split, eroding the treeless banks. Also, a pool may form behind a debris dam, slowing the flow and spreading water over a large area. This pond water is more susceptible to a temperature increase. During storms the dams also may not be able to hold back the swollen streams. A ruptured dam can release a large volume of water and sediment with a great deal of energy, possibly causing severe channel erosion downstream.

Some well-placed, in-stream, woody debris provides essential cover for aquatic wildlife, but, as noted above, excessive or poorly placed debris can be detrimental. Large amounts of logging debris in a stream can also cause water quality problems. Chemicals leached from this debris discolor water. But more important, when organic matter decays, fish are robbed of oxygen. The biological and chemical processes that break down organic matter use oxygen. The more oxygen that these processes use, the less that is available for fish. Biochemical oxygen demand is a measure of the oxygen that will be used when organic matter decays. The higher the biochemical oxygen demand, the poorer the conditions for fish.

To protect the water quality of a stream running through a clearcut, leave a buffer strip of at least 100 feet, or one and one-half times the average tree height, whichever is greater, on each side of the stream. Leave a buffer along both *perennial streams* (those that flow year round) and *intermittent streams* (ones that have water only during wet periods.) In this buffer strip, often referred to as a streamside management zone, you can still selectively harvest timber. The key is to treat this area very gently, disrupting the natural system as little as possible.

HOW FOREST VEGETATION SUPPORTS HEALTHY STREAMS

Vegetation	*Benefits*
Tree and shrub canopy overhanging the channel	• Stable water temperature improves conditions for desirable game fish • Source of large and fine plant debris • Source of terrestrial insects that fish eat
Leaves, branches, and other vegetative debris in stream channel (in proper amounts)	• Help create pools, riffles, and cover • Provide food source and stable base for many stream channel aquatic organisms
Roots in the streambank	• Increase bank stability • Create overhanging bank cover
Stems and low-growing vegetation in the floodplain	• Retard movement of water, sediment, and floating debris in flood water

Source: Adapted from Craven, S.; Jackson, G.; Swenson, W.; and Webendorfer, B. 1987. The Benefits of Well-managed Stream Corridors (G-3404). Department of Agricultural Journalism, University of Wisconsin-Madison.

Beyond Logging

In addition to timber harvesting, water quality can be harmed by the following activities:

RECREATION

A forest that is used for recreation often requires roads and sewage facilities. Both of these are potentially harmful to water resources. Install and maintain access roads at least as well as you would logging roads. Ideally, even more care is needed because the road will be used continually, and will not be retired after a timber sale. Make sure sewage facilities are located away from water. Such facilities must be properly designed, installed, and maintained. In addition, restrict recreational vehicles to existing roads and trails that avoid sensitive areas such as wetlands and shallow streams.

PESTICIDE APPLICATION

When applying pesticides, follow the label directions and take precautions to prevent spray from landing directly on water. Avoid areas with streams by designating "no-spray" buffer zones, and select materials, equipment, and weather conditions that will minimize spray drift.

MINERAL EXTRACTION

Coal mining (strip mines and deep mines) and oil and gas development can degrade water quality dramatically. Mining often contaminates water by producing sediment and acidic drainage that has a high iron and sulfur content. Acid mine drainage causes the formation of "yellowboy" (ferric hydroxide), a yellowish slime that coats stream bottoms. In addition to sediment from access roads, pipeline rights-of-way, and well sites, the use of oil and gas wells makes it difficult to dispose of the brine pumped up with the deposits. In either case, protection of surface water and groundwater is difficult.

CHOOSING STEWARDSHIP

Water resources are intimately connected to land use. The quality of our water resources is affected by the manner in which we use land. Some land use practices protect water, others degrade it. Forests protect people as well as wildlife. They are natural guardians, consistently providing us with high-quality water for drinking, fishing, swimming, boating, or simply enjoying the intrinsic natural beauty of a clear stream, lake, or pond. Forests have a great influence on water. Be aware of this connection when using the various resources of your forests and you will profit by enjoying the many benefits of clean water.

Technical Information Specific to Pennsylvania

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PENNSTATE

College of Agricultural Sciences
Cooperative Extension

Penn State College of Agricultural Sciences research, extension, and resident education programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

This publication is available from the Publications Distribution Center, The Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802. For information telephone (814) 865-6713.

Issued in furtherance of Cooperative Extension Work, Acts of Congress May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture and the Pennsylvania Legislature. T. R. Alter, Director of Cooperative Extension, The Pennsylvania State University.

This publication is available in alternative media on request.

Pennsylvania Forest Stewardship Program

Forests for Life

The Forest Stewardship Program is administered nationally by the USDA Forest Service and is directed in Pennsylvania by the DCNR Bureau of Forestry with assistance from a statewide steering committee. The Forest Stewardship Program assists forest landowners in better managing their forestlands by providing information, education, and technical assistance. For more information about program services and publications contact: The Pennsylvania Forest Stewardship Program, DCNR Bureau of Forestry, P.O. Box 8552, Harrisburg, PA 17105-8552. Phone: (800) 235-WISE, or (717) 787-2105.

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Cover illustration by Doug Pifer. Illustrations on pages 5 and 6 by Phyllis Kipp.

Printed on recycled paper. R5M1198ps