Forest Roads and Trails

It's All About Water!

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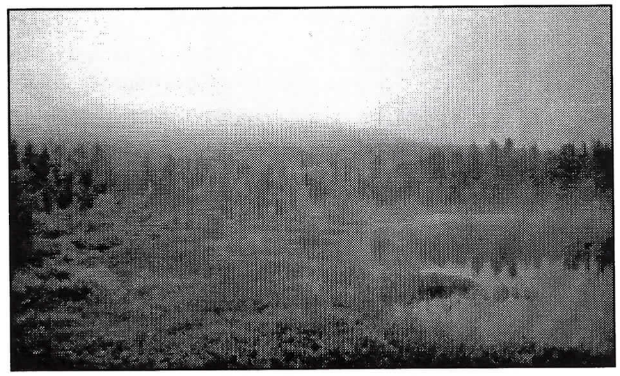

Forest access systems are essential for a variety of forest uses, including recreation, fire control, and timber removal. Moreover, perhaps more than any other forestry-related activity, forest roads represent avenues of public exposure – for hikers, skiers, hunters, motorists, and forestland owners. The impacts of forest roads, landings, and skid trails on forest values—including water quality, aesthetics, and recreation—therefore, come under close, continual scrutiny.

The transport of logs from the woods to the mill looked very different decades ago. In the past, there was heavy reliance on manpower, horsepower, and water power. During this period, when logs were moved from the stump to a mill, the effects of log transport on water quality were virtually ignored.

Today, the movement of logs from the stump to a landing is generally accomplished by mechanized equipment, such as skidders and forwarders, over woods trails. Secondary transport, from the woods to a mill, for example, is generally by trucks over woods and highway roads.

The transition in the ways in which logs were moved required a system of woods trails and roads that demands consideration of transportation network cost and efficiency, and the reduction of environmental impacts, especially to water quality. Although the impacts of nonpoint source pollution from logging are minimal relative to other land use practices, decreasing the potential impacts of harvesting on all forest values, especially water quality, has become an issue receiving increasing attention. If poorly planned, constructed, maintained, or retired, forest roads can have a major impact on the forest environment.

This publication accompanies the video/DVD "Forest Access Systems for Better Water Quality" Its purpose is to help create a better awareness among foresters, loggers, and landowners of the principles associated with forest road and trail building, as well as to illustrate some methods for constructing forest roads and skid trails to minimize impacts to water quality. It should be noted, however, that neither this publication nor the video is intended to replace Best Management Practices (BMP) guidelines or forest practices regulations published in various states. When planning roads, foresters, loggers, and landowners should be aware of all applicable federal, state, and local guidelines and restrictions.

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Concepts and Principles

Much of what is discussed in this guide is based on several fundamental concepts. Understanding these concepts may provide a background for decision making when planning, constructing, or retiring forest roads and skid trails.

Issues challenging forest road construction, rated from 1 (unimportant) to 5 (very important) by a panel of forest engineers.

Issue	Average rating
water management	**4.9**
lack of planning	4.3
slope/topography	4.1
access	4.1
environmental issues, including endangered species and wetlands	4.0
landowner rights	4.0
maintenance and reclamation	3.9
usage	3.4
cost	3.4
aesthetics and public opinion	3.1
politics and federal and state regulations	3.0

Forest roads are essentially horizontal features on a landscape characterized by vertical, gravity-driven processes. These processes include the erosive forces of rainfall, snowmelt, and runoff, as well as soil movement and deposition. If poorly planned, constructed, or retired, forest roads can have a major impact on the forest environment.

Bare soil exposed during forest road construction is the major source of sediment due to logging. Precipitation events and spring snowmelt and runoff that would normally travel downhill as shallow subsurface flow may be intercepted by compacted roads and road ditches and become surface flow. In addition, road cuts often take shallow subsurface water and convert it to surface flow, causing increased potential for erosion of the exposed soil surfaces that characterize most forest roads.

Haul and skid road planning, construction, maintenance, and retirement are particularly important practices in mitigating these effects. Forest road experts agree that the most significant challenges facing forest road construction are adequate planning, water management, and dealing with difficult topography, from steep slopes—where the momentum of runoff increases—to flat areas with high water tables.

Momentum is calculated by multiplying mass by velocity. Any practices that reduce either the mass or velocity (or both) of water will decrease its momentum, thereby decreasing its erosive force. For example, practices may include shedding water from surfaces by constructing broad based dips on haul roads or water bars on skid trails. These practices reduce the mass of volume on the road or trail. Reducing the grade of roads and trails, for example, will help to reduce the velocity of water on those surfaces. The greater the momentum of water on forest roads, the greater the potential for dislodgement and transportation of soil particulate matter – resulting in soil erosion and the possibility of nonpoint source pollution. Not surprisingly, most forestry BMPs are designed to reduce the momentum of surface water on forest roads by decreasing either its mass or velocity, thereby reducing its erosive potential. Water bars, for example, reduce the mass of surface flow on the trail surface by directing it to adjacent undisturbed forest. Avoiding steep grades reduces water velocity on road and trail surfaces.

Ignoring road and trail drainage will reduce logging efficiency.

Therefore, when planning, constructing, and retiring forest roads it is often useful to consider the following variables for preventing soil loss:

- The amount and type of precipitation and runoff. This will change by geographic location.
- The erodibility of the soil, which is defined primarily by the texture of the soil.

- The length and steepness of the road or trail.
- The vegetative cover on the road or trail.
- Practices that could be used to decrease the momentum of rainfall and runoff, such as the implementation of best management practices.

Most of these variables can be manipulated in some way during the road building process. For example, soil erodibility is related to soil texture, which can be affected by adding aggregate to the road surface or by building roads on coarser soils when possible. Road and trail length and grade can be controlled by working with, instead of against, contours and by using switchbacks to gain elevation. The road's vegetative cover can be influenced by seeding road surfaces, cut and fill banks, and landings with the appropriate seed mixture when necessary. And BMPs, such as road ditching and broad based dips can be implemented to deal with water that enters the forest access system through precipitation or snow melt.

All phases of forest road and skid trail construction, maintenance, and retirement involve planning. Road planning is critical, since it has been shown that most damage to water quality occurs during and immediately after logging. Planning considerations include:

- Deciding on forest management and road use objectives.
- Communication among the landowner, logger, forester and others involved in the road building process.
- Reconnaissance of the area being roaded.
- Identification of positive and negative controls.
- Working the road out on paper first, if necessary.
- Hiring road construction crews who have experience building forest roads.

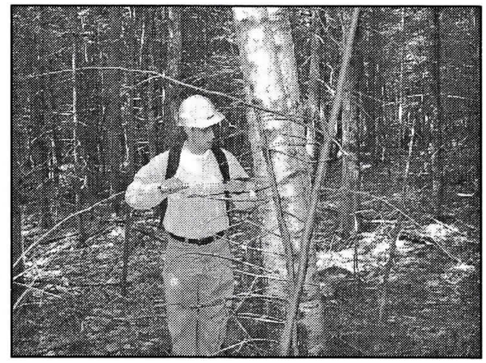
Positive and negative control points should be identified from topographic maps, aerial photography, soil surveys, BMP guidelines, and field reconnaissance.

- Positive control points are places on the landscape that the road should go through or be near. These include points of ingress and egress for log trucks, the location of timber to be harvested, landings, stream crossings, and gravel banks.
- Negative controls are places on the landscape that the road should avoid, such as wetlands, seeps, streamside management zones, and ledges.

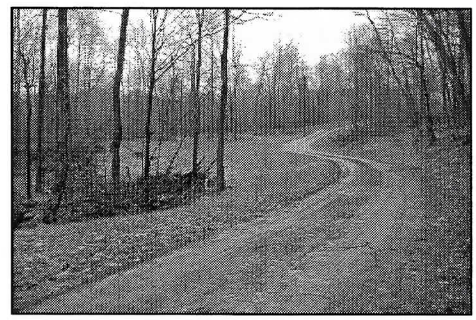
The gradeline is run on the ground using a clinometer or abney and the gradeline is flagged. For most lower standard forest roads, the gradeline then becomes the center line for the finished road and little or no road adjustments or surveying are needed prior to road construction. Higher standard roads often require adjustments after the gradeline has been identified and before the road is built.

Streamside management zones must be accounted for before roads are constructed. SMZs are undisturbed or carefully logged areas between roads and skid trails that behave as a filter for particulate matter that may otherwise move from the road surface to surface water.

After positive and negative control points are identified and the gradeline is



Research has shown that involving a forester in the planning and construction of forest roads has increased compliance with best management practices.

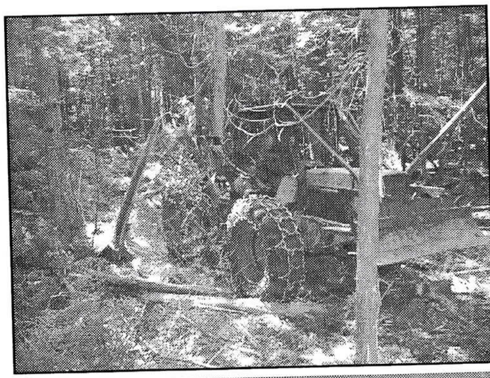


A study comparing forester planned with unplanned skid roads in West Virginia found that planned road areas were smaller and their slopes were gentler.

Negative controls can include wetlands and rock ledges.

established on minimum standard roads, construction can begin. Once determined, positive and negative controls form the basis for the location of the road.

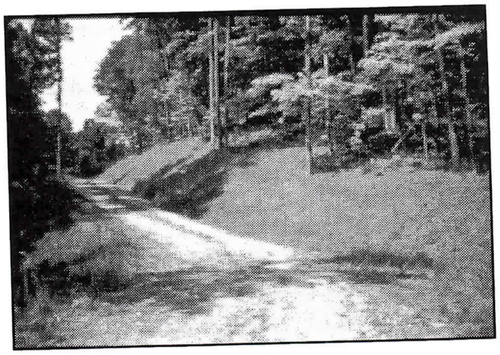
Pre-harvest skid trail designation often results in an overall reduction of the amount of the timber sale area dedicated to skid trails. It may also decrease the likelihood of damaging areas of greater sensitivity (e.g., advance regeneration, poor soils for skidding, stone walls) that the landowner may wish to preserve. Deciding on skid trail location from the cab of a skidder/feller-buncher does not generally afford the operator the type of stand-level appreciation for the logging chance as does doing it on foot with a roll of flagging and a clinometer, if necessary.



Planning skid trails from the cab of a skidder is rarely a good idea.

Haul Roads

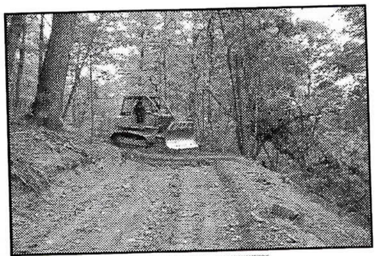
Traditional logging road construction techniques that scrape a road surface into the forest floor have often resulted in roads that are banked on each side. This results in roads that become both undesirable interceptors of and conduits for surface flow. In addition, shedding water from these roads is difficult because the road surface is generally below ground level. Methods that use an excavator to build logging roads, for example, allow the road surface to be elevated above the surrounding ground surface, making the drainage and diversion of surface flow much more efficient. However, roads built with an excavator are generally expensive, and may not be appropriate in all situations or for all landowner objectives.



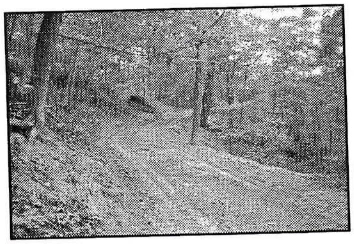
Ditching, insloping, and seeding help to prevent soil erosion and nonpoint source pollution.

When deciding on the standards to which a logging road is built, landowners should consider the potential cost of the road relative to the benefits the landowner expects to derive from it. Road building costs depend on an array of factors, including design vehicle, soil type, road length, number and type of water crossings, slope, and the amount of cut and fill required. However, accounting for how water and runoff will be handled is critical regardless of the standard to which the road is built.

All-season roads are built for potential use at any time of year. Using an excavator, forest roads are built at or above the level of surrounding topography to avoid drainage problems and to maintain a dry and firm subgrade and running surface. The road is surfaced with coarse material that can often be found on site. In this case the soil profile on the edge of the road is often inverted on the road surface, with the coarse ledge material becoming the road's running surface. Roadside borrow pits are then filled with vegetation and soil. The resulting road surface is above the level of the surrounding ground and is blended with the topography.



Removing berms ...



... and outsloping will help to drain water from haul roads.

Insloping, outsloping, and crowning of the road surface will help to move water in small amounts from the road's surface to undisturbed forest where it loses its erosive force. Although ditching may be necessary in some situations, roadside ditches concentrate water that then must be moved to undisturbed forest floor without eroding the ditch or the cross-drainage outlet. In addition, some roadside ditches can hold puddled water due to lack of grade in the ditch or obstructed ditches or cross drainage culverts. This water can permeate and weaken the road's subgrade. Reducing the amount of roadside ditching reduces the potential for ditch erosion and ditch maintenance, and allows for the efficient and safe passage of woods equipment between the road and the woods. Ditches may also impede or provide dangerous "traps" for woods traffic, such as skidders.

Forest road grades should generally have a minimum grade of 3 percent so that water does not puddle and weaken the road. Road grades should be kept under 10 percent, and up to15 percent for short distances. Sustained haul road grades greater than 10 to 15 percent are sometimes difficult for trucks to navigate, especially under poor road conditions. They also increase the velocity of water that they intercept, thereby increasing its erosive force.

Roads should generally have a minimum grade of 3 percent, with a maximum grade of 15 percent only for short distances.

Gaining elevation by using properly constructed switchbacks, for example, can help to alleviate this problem. However, as in the application of any forest road building technique, switchbacks require both planning and knowledge of elementary soil and water engineering and road construction principles. Switchbacks involve cutting on the uphill side of the switchback and filling on the downhill side so that the slope of the road in the middle of the switchback curve is not the same as the slope of the side hill on which the road is being built.

On steep ground, where roads are cut into the side of the slope, berms should be removed to allow water to be shed from the road surface, especially if the road is outsloped or crowned. Roads are often insloped to an inside ditch; ditch relief culverts are used to move water under the road, from the ditch to undisturbed forest floor.

Switchbacks can be an effective way of gaining elevation.

In some situations, 3-inch gravel has been used in the construction of forest roads because it reduces the amount of exposed surface soil, provides a firmer road surface that resists rutting, and reduces the velocity of water on the road surface, thereby reducing its erosive force.

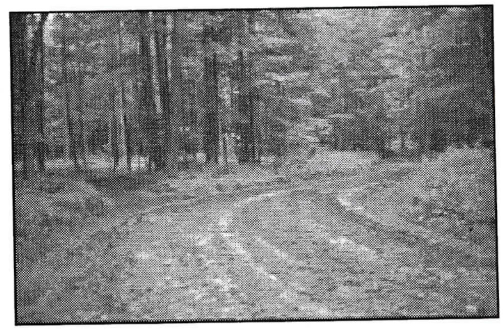
The problem of fitting BMPs to already poorly located and constructed road surfaces is all too common, reducing the effectiveness of the BMPs that may be implemented upon logging road and skid trail retirement. Methods that use an excavator to build logging roads, for example, allow the road surface to be elevated above the surrounding ground surface, making the drainage and diversion of surface flow much more efficient.

Winter roads. In the northern US, winter roads are a less expensive alternative to all-season roads. They are often built to access timbered areas that are either limited in size or that do not have timber valuable enough to justify a more expensive all-season road. In addition, winter roads are often built to access seasonally wet areas that freeze in the winter. Winter roads are generally built by removing vegetation and stumps from the roadway, and then backdragging the road surface. Road drainage is not as important as it is for all season roads, since winter roads are used during periods of frozen ground. Trucks and other vehicles travel on a frozen surface smoothed by both the filling in of rough spots by snow and backdragging.

Logging slash barriers may help to decrease soil movement on slopes.

As with any road, winter roads must be maintained to prevent water quality problems and maintain their effectiveness. Plowing, for example, helps to keep winter roads clear, and allows roads to freeze more deeply, increasing their utility. Road scarification helps to increase traction on winter roads, and reduces the need for sand and salt. Salt, in particular, can be costly to store and apply, and may have potential negative effects on water quality.

Rebuilding old roads. One of the major challenges to forest road building is rebuilding old forest roads. In the past, many forest roads were built by scraping the soil surface with a bulldozer, sidecasting the surface material to the edge of the road. This created a road with a weak running surface that was located below the level of the surrounding ground, and banked on one or both sides with sidecast material. As a result, water from precipitation and snowmelt remained on the road, weakening its structure and rendering it unusable. More recent road building techniques using excavators blend the road surface with the surrounding topography by building the road up rather than scraping the road surface. This improves water drainage and the utility of the road.



Wing (diversion) ditches help to move water from a road surface to undisturbed forest floor.

One of the first steps in rebuilding an old road is to widen the old road, then pull the previously sidecast material back onto the road surface. This necessitates first removing the layer of vegetation that has grown on the sidecast banks since the road was initially scraped out. As with new forest roads, the road is then surfaced with coarse material that can often be found on site.

Maintenance. Roads require periodic maintenance. However, if done incorrectly some road maintenance methods, particularly grading, may cause uprooting of grass, movement of gravel to the edge of the road, and reduction of gravel depth. In some cases maintenance of forest roads can disturb already stabilized roads and can contribute to soil losses and possible deposition in surface water.

Old roads that were scraped with a bulldozer often must be built up with an excavator to achieve better drainage.

In some situations, road inslopes and outslopes and reverse grade sections can be created or maintained when the road surface is regraded. Planting grass on cut and fill slopes of new roads and the beds of intermittent-use roads is recommended. Planting grass on ungravelled roadways can significantly reduce soil loss under light traffic conditions. Natural berms may develop on roads as they are used, trapping runoff on the road. This may be a result of improper road grading or gradual entrenchment of the road below the level of the surrounding terrain. During maintenance, berms may either be removed, or channels may be cut into them at appropriate places to relieve runoff volume. Orphan roads -- roads that have been abandoned and are not being maintained by the landowner -- should be permanently closed. Gates are an effective way of limiting traffic on woods roads and trails, especially from all-terrain vehicles.

Water diversion from haul roads. On haul roads, *cross drainage and ditch relief culverts* are used to move water from one side of the road to the other in order to relieve water accumulation that may flood or weaken the road. Ditch relief culverts move water from an inside ditch on the uphill side of the road to undisturbed forest ground on the downhill side of the road. This relieves the ditch of accumulated water, preventing ditch erosion, and allows for dealing with water in small amounts -- that is, decreasing its mass -- and reducing the potential for ditch erosion.

A cross drainage culvert.

Broad based dips or rolling ditches are gradual and subtle reverse grades on haul roads that divert water from the road while allowing for the passage of log trucks and other traffic. They collect and shed water from the road surface that otherwise might gain momentum, causing soil erosion and possible delivering sediment to streams.

Open top box culverts may also be used on haul roads to intercept water on the road surface and shed it from the road in small amounts. The same effect may also be accomplished by using belting, such as conveyor belt or mine belt. Both methods are installed to allow for the passage of traffic on the road. Diversion ditches, or wing ditches, also help to divert water from a roads surface and shed it onto undisturbed ground.

Broad-based dips are an effective way of draining water from haul roads.

Skid Roads, Trails, and Landings

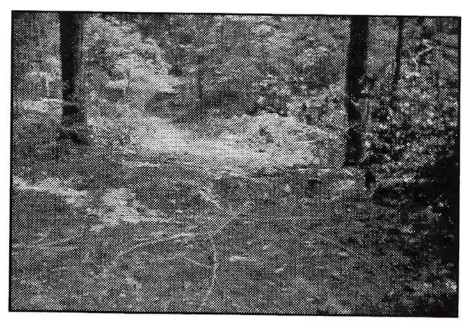
Skid roads and trails. Trails for timber harvesting operations are designed to carry off-road harvesting equipment such as tractors, skidders, forwarders, feller-bunchers, and processors. In some parts of the northeast, a distinction is made between skid roads and skid trails. The primary difference between skid roads and trails is the degree of preparation and use. Main skid roads are flagged and often cleared and graded before logging. Skid trails may require little or no grading and clearing. In steep sections of the Appalachian Mountains, for example, many skidding systems are built by a bulldozer along a series of switchbacks. In other, less steep, areas of the region, skid ways may be nothing more than trails cut through the woods over which logs are skidded, with little or no earth moving required.

Woods traffic from horses to forwarders use forest trails.

The following points should be considered when locating skidding systems:

- Locate landings in relation to the main haul road, then lay out skid roads on a low grade to the landing.
- Locate skid roads across, rather than perpendicular to, contours as much as possible.
- Avoid streambeds, rock outcrops, and steep grades.
- Cross streams at close to right angles.
- Minimize damage to residual stands or sensitive areas, e.g., wetlands. Identify bumper trees on inside curves of roads and trails to protect interior trees and stands.
- Where possible, maintain grades under 15%, up to 20% for short distances.
- For steep grades, "working" water bars and turn-outs may be installed to maintain the integrity of the trail and minimize erosion.
- Locate skid roads for quick turnaround, if necessary, especially if more than one machine is skidding to the landing.

As with haul roads, skid trails should be protected from excessive water volume and velocity after they are constructed. Water bars help to divert water from skid trails so that water on the trail can be dealt with in small amounts and not build up momentum that may lead to erosion. More water bars are needed the steeper the grade of the trail, since these soils are often more vulnerable to erosion. In general, water bars should be placed at a 30 degree angle across the trail, with the inlet and outlet ends extending beyond the trail surface in order to adequately intercept water on the trail and divert it to undisturbed forest floor. Logs are sometimes used to help form an earthen water bar.

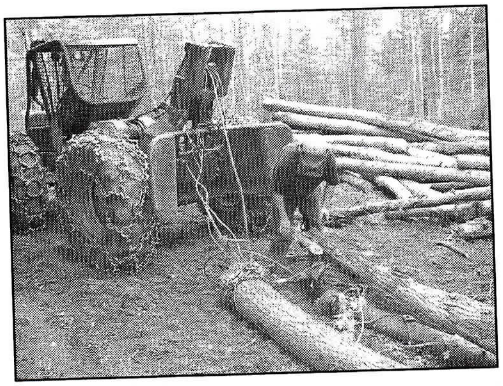


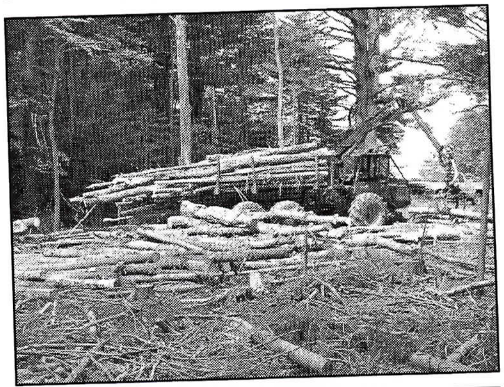
Water bars on skid trails reduce the mass of water and maintain the integrity and utility of the trail.

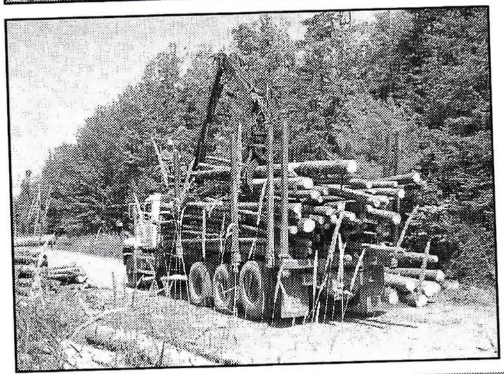
Landings. Also referred to as decks, brows, and headers, landings are staging areas where logs are sorted and decked to be trucked later. It is important to remember that landings are places where woods equipment (e.g., skidders and forwarders) meet highway equipment (e.g., log trucks and service vehicles). Therefore, different from haul roads and skidding networks, landings should be constructed to accommodate many different kinds of traffic and equipment.

General guidelines for the location of log landings, include:

- Allow for filter strips between the landing and streams.
- Use a diversion ditch or earth berm above a landing when necessary or locate the landing on a slight upslope.
- Slope the landing gradually to encourage water to run off (landings tend to become compacted by traffic, reducing infiltration).
- Locate landings away from low or wet areas. Look for well drained conditions.
- When possible, locate landings out of view of public roads.
- "Drag" rutted landings in winter at the end of each day to prevent frozen ridges in the soil that may impede traffic.
- Account for log truck ingress to and egress from the landing, considering impacts on the highway (e.g., use of gravel), view of traffic (location related to bends in road or obstructed in other ways), turn-arounds and/or backing into landing.
- Disturb only the area needed for operations. This area will depend on several factors:
  - number of log sorts
  - number and type of equipment on landing, including skidders, forwarders, loaders, delimbers, chippers and chip vans, and trucks and support vehicles
  - method of decking and/or sorting logs
  - length of wood skidded, e.g., log length, tree length, or whole tree
  - physiographic constraints





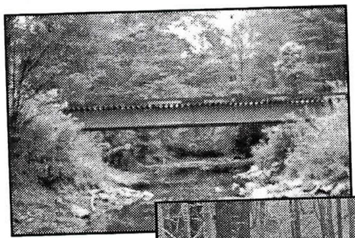


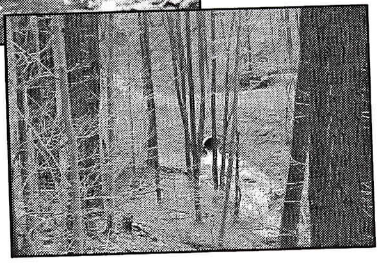
Landings must be planned and constructed to accommodate woods and highway equipment.

Crossing Streams and Wet Areas

During logging, it is often necessary to cross small streams and seasonally wet areas without damaging water and soil quality. Culverts are often installed on haul roads to cross streams. Care should be taken to maintain water quality while installing culverts. Culverts are often sized by measuring the cross-section of the stream channel at its normal high water mark and multiplying that cross-section by 2.5. For example, a channel that is four feet wide and 1 foot deep has a cross section of 4 square feet. This would require a culvert with an opening of 10 square feet to adequately handle water flow through the culvert. As with any culvert, whether it be for cross drainage or for a stream crossing, it should be cleaned regularly to allow for unobstructed water flow.

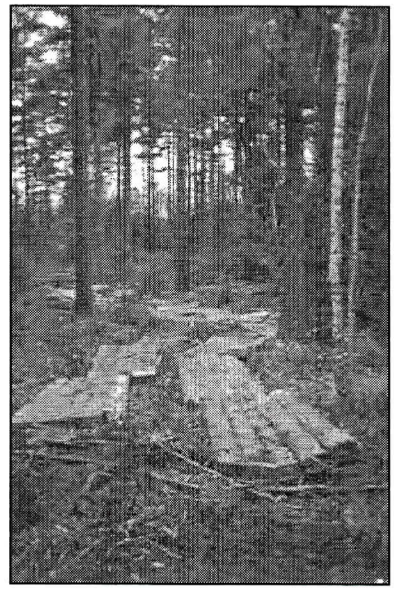
Portable wooden skidder bridges have become increasing popular for crossing small streams with woods equipment, as have wooden swamp mats for operating in seasonally wet areas without excessive rutting and churning of the soil.





For many loggers, the only equipment available to install portable bridges and swamp mats is a rubber-tired skidder. As with any project, it's important to plan what will be done before installing these structures. This may help to avoid having to shift or move the structure prematurely because they were not properly aligned or positioned when first installed. In addition, adequate planning may allow for the installation of these weather or wood quotas, thereby avoiding cutting into time when loggers could be producing logs.

Using swamp mats and portable skidder bridges not only protect water and soil quality, but may also help to keep active some logging jobs that may otherwise be temporarily abandoned because of ground conditions that are too wet. In some cases, the costs associated with purchasing or fabricating your own mats and bridges, taking the time to plan how they may best be used, and then installing them may make more sense than abandoning a job until ground conditions are just right.



Swamp (crane) mats

Cross-drainage culvert spacing guidelines:

Slope (percent)	Spacing (ft)
0-2	300-500
3-5	180-250
6-10	140-165
11-15	130-135
16-20	120-125
21-25	65-100
≥26	50

Water bar spacing:

Slope (percent)	Spacing (ft)
0-2	250-400
3-5	135-200
6-10	80-100
11-15	60-80
16-20	40-45
21-25	40-45
26-30	35-40
≥30	30

References and Suggested Reading

Blinn, C.R., R. Dahlman, L. Hislop, and M.A. Thompson. 2000. Temporary stream and wetland crossing options for forest management. USDA Forest Service North Central Research Station Gen. Tech. Rep. NC-202

Corbett, E.S., J.A. Lynch, and W.E. Sopper. 1978. Timber harvesting practices and water quality in the eastern United States. *Journal of Forestry.* 8(80):484-488.

Egan, A., A. Jenkins, and J. Rowe. 1997. Forest roads in West Virginia, USA: Identifying issues and challenges. *Journal of Forest Engineering.* 33-40.

Egan, A. 1999a. Reducing forest road erosion: Do foresters and logging contracts matter? *Journal of Forestry.* 97(8):36-39.

Egan, A. 1999b. Forest roads – Where soil and water don't mix. *Journal of Forestry.* 97(8):18-21.

Hornbeck, J.W. and K.G. Reinhart. 1964. Water quality and soil erosion as affected by logging in steep terrain. *Journal of Soil and Water Conservation.* Jan.-Feb. 1964:23-27.

Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalachians. USDA For. Serv. NE For. Exp. Stn. Res. Pap. NE-158.

Kochenderfer, J.N. 1977. Area in skidroads, truck roads, and landings in the central Appalachians. *Journal of Forestry.* 8(79):507-508.

Kochenderfer, J.N., G.W. Wendel, and H.C. Smith. 1984. Cost of and soil loss on "minimum-standard" forest truck roads constructed in the central Appalachians. USDA For. Serv. NE For. Exp. Stn. Res. Pap. NE-544.

Kochendefer, J.N. and J.D.Helvey. 1987. Using gravel to reduce soil losses from minimum-standard forest roads. *Journal of Soil and Water Conservation.* Jan.-Feb. 1987:46-50.

Layton, D.A., C.B. LeDoux, and C.C. Hassler. 1992. Cost estimators for construction of forest roads in central Appalachians. USDA For. Serv. NE For. Exp. Stn. Res. Pap. NE-665.

Mitchell, W.C. and G.R. Trimble. 1959. How much land is needed for the logging transport system? *Journal of Forestry*. 1(61):10-12.

Olson, E.D. and J.C.W. Seifert. 1984. Machine performance and site disturbance in skidding on designated trails. *Journal of Forestry*. 6(86):366-369.

Patric, J.H. 1976. Soil erosion in the eastern forest. *Journal of Forestry*. 10(78):671-677.

Swift, L.W. 1984. Gravel and grass surfacing reduces soil loss from mountain roads. *Forest Science*. 30:657-670.

Swift. L.W. 1986. Filter strip widths for forest roads in the southern Appalachians. *Southern Journal of Applied Forestry*. 10:27-34.

Swift, L.W. and R.G. Burns. 1999. The three Rs of roads: Redesign, reconstruction, and restoration. *Journal of Forestry*. 97(8):40-44.

Taylor, S., R. Rummer, K. Yoo, R. Welch, and J. Thompson. 1999. What we know -- and don't know -- about water quality at stream crossings. *Journal of Forestry*. 97(8):12-17.

Walbridge, T.A. 1991. Field tables for direct location of forest roads.

Wiest, R.L.1998. A landowner's guide to building forest access roads. USDA Forest Service, Pub. # NA-TP-06-98.

Culvert diameters and end areas:

Diameter (in.)	End area (sq.ft.)
15	1.23
18	1.80
24	3.10
30	4.90
36	7.10
42	9.60
48	12.60
54	15.90
60	19.60
66	23.80
72	28.30

Spacing of broad-based dips:

Grade (percent)	Spacing (ft)
2-4	200-300
5-7	170-180
8-10	140-150

Photo credits

Mike Eckley, West Virginia Division of Forestry, Andy Egan, Sarah Folsom

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