3D: Road Management

Management Measure for Road Management

(1) Avoid using roads where possible for timber hauling or heavy traffic during wet or thaw periods on roads not designed and constructed for these conditions.

(2) Evaluate the future need for a road and close roads that will not be needed. Leave closed roads and drainage channels in a stable condition to withstand storms.

(3) Remove drainage crossings and culverts if there is a reasonable risk of plugging or failure from lack of maintenance.

(4) Following completion of harvesting, close and stabilize temporary spur roads and seasonal roads to control and direct water away from the roadway. Remove all temporary stream crossings.

(5) Inspect roads to determine the need for structural maintenance. Conduct maintenance practices, when conditions warrant, including cleaning and replacement of deteriorated structures and erosion controls, grading or seeding of road surfaces, and, in extreme cases, slope stabilization or removal of road fills where necessary to maintain structural integrity.

(6) Conduct maintenance activities, such as dust abatement, so that chemical contaminants or pollutants are not introduced into surface waters to the extent practicable.

(7) Properly maintain permanent stream crossings and associated fills and approaches to reduce the likelihood (a) that stream overflow will divert onto roads and (b) that fill erosion will occur if the drainage structures become obstructed.

Management Measure Description

The objective of this management measure is to ensure the management of existing roads to maintain their stability and utility; to minimize erosion, polluted runoff from roads and road structures, and sedimentation in water bodies; and to ensure that roads no longer needed are properly closed and decommissioned so they pose minimal risk to water quality.

Roads that are actively maintained reduce the potential for erosion to occur. Road drainage structures, road fills in stream channels, and road fills on steep slopes are of greatest concern with respect to water quality protection in road management. Roads actively used for timber hauling usually need the most maintenance, and mainline roads typically need more maintenance than spur roads. Regular road use by heavy trucks, especially at stream crossings, creates a chronic source of sediment runoff to streams (Murphy and Miller, 1997). It is important to inspect and repair roads prior to heavy use, especially during wet or thawing ground conditions (Weaver and Hagans, 1984). Use of roads during wet or thaw periods can result in excessive sediment loading to water bodies when road surfaces become deeply rutted and drainage becomes impaired. The first rule of maintaining a stable road surface is to minimize hauling and grading during wet weather conditions, especially if the road is unsurfaced (Weaver and Hagans, 1984).

Sound planning, design, and construction measures often reduce road maintenance needs after construction. Roads constructed with a minimum width in stable terrain, and with frequent grade reversals or dips, need minimum maintenance. Unfortunately, older roads remain one of the greatest sources of sediment from managed forestlands. After harvesting is complete, roads are often forgotten, and erosion problems might go unnoticed until after severe resource damage has occurred.

Routine maintenance of road dips and road surfaces and quick response to drainage problems can significantly reduce road deterioration and prevent the creation of ruts that could channelize runoff (Ontario Ministry of Natural Resources, 1988; Oregon Department of Forestry 1981). Roads and drainage structures on all roads, including decommissioned roads for as long as water quality effects might result from them, should be inspected annually, at a minimum, prior to the beginning of the rainy season (Weaver and Hagans, 1984). Also inspect and perform emergency maintenance during and following peak storms.

In some locations, problems associated with altered surface drainage and diversion of water from natural channels results in serious gully erosion or landslides. In western Oregon, 41 out of the 104 landslides reported on private and state forestlands during the winter of 1989-90 were associated with older (built before 1984) forest roads. These landslides were related to both road drainage and original construction problems. Smaller erosion features, such as gullies and deep ruts, are far more common than landslides and very often are related to poor road drainage.

Sedimentation from roads can be reduced significantly if drainage structures are maintained to function properly. Culverts and ditches that are kept free of debris are less likely to restrict water flow and fish passage. Routinely cleaning these structures can minimize clogging and prevent flooding, gullying, and washout (Kochenderfer, 1970). Fish passage was discussed in the last management measure as an issue of proper sizing and installation of culverts and other stream crossings, and it is equally important to inspect culverts, fords, and bridges on a regular basis to ensure that debris and sediment do not accumulate and prevent fish migration. Undercutting of culvert entrances or exits can create vertical barriers to fish passage, and debris buildup at the entrances of culverts or at trash racks can prevent fish migration. If roads are no longer in use or won't be needed in the foreseeable future, removing drainage crossings and culverts where there is a risk of plugging or failure from lack of maintenance is a precautionary measure. Where a road will be used in the future, it is usually more economical to periodically maintain crossing and drainage structures than not to do so and to have to make extensive repairs after failure.

Road Reconstruction

Road reconstruction provides the opportunity to upgrade and improve substandard and old roads that are no longer used. After an on-site inspection of the entire route and consideration of the economic and environmental costs of the reconstruction, a decision about reopening a road can be made. Reconstruction might be economically feasible for a particular road but could entail unacceptable environmental costs. Roads where stream crossings have been washed out or short, steep sections of road have been entirely lost to progressive erosion or landsliding are examples of roads where the environmental costs of reconstruction might be too high (Weaver, 1994). In such cases, it might be possible to lessen the environmental damage incurred in reconstruction by rerouting the road around problem areas with a section of new road. Factor overall project costs into the economic and environmental costs of any rerouting to determine its feasibility, and do all road reconstruction in a manner consistent with the Management Measure for Road Construction.

Washed-out stream crossings are the most common obstacle to effective road reconstruction. Initial improper sizing of drainage structures or their not being installed or maintained properly results in erosion at stream crossings. When reconstructing stream crossings, it is important to follow the same design and installation procedures as are used for new crossings.

Road Decommissioning

Proper closure, decommissioning, and obliteration are essential to preventing erosion and sedimentation on roads and skid trails that are no longer needed or that have been abandoned (Swift and Burns, 1999). Road closure involves preventing access by placing gates or other obstructions (such as mounds or earth) at road access points while maintaining the road for future use. Roads that will no longer be used or that have remained unused for many years may be decommissioned and obliterated. Decommissioning typically involves stabilizing fills, removing stream crossings and culverts, recontouring slopes, reestablishing original drainage patterns, and revegetating disturbed areas (Harr and Nichols, 1993; Kochenderfer, 1970; Rothwell, 1978). Revegetating disturbed areas protects the soil from rainfall and binds the soil, thereby reducing erosion and sedimentation and the potential for mass wasting in the future. Because closed roads and trails are rarely inspected, it is important to leave them in as stable a condition as possible to prevent erosion that could become a large problem before any damage is noticed (Rothwell, 1978).

Road decommissioning can significantly reduce water quality effects from unused roads, and road closure and decommissioning can help realize many objectives and purposes (Harr and Nichols, 1993; Moll, 1996):

- Eliminate or discourage access to roads to reduce maintenance expenditures.
- Eliminate the potential for drainage structure failure and stream diversion.
- Reduce soil loss, embankment washout, mass wasting, failures, slides, slumps, sedimentation, turbidity, and damage to fish habitat.
- Provide cover and organic matter to soil, and improve the quality of wildlife and fish habitat.
- Enhance the visual qualities of road corridors and disturbed areas.
- Attempt to restore the natural pre-road hydrology to the site.

Benefits of Road Management

Proper road maintenance has definite economic benefits. In one comparison of road maintenance costs over time, maintenance costs on a road where BMPs were not installed initially were 44 percent higher than costs on a road where BMPs were installed initially (Dissmeyer and Frandsen, 1988) (Table 3-20).

Table 3-20. Comparison of Road Repair Costs for a 20-Year Period With and Without BMPs[a] (Dissmeyer and Frandsen, 1988)

Maintenance Costs Without BMPs		Costs of BMP Installation	
Equipment	$365	Labor to construct terraces and water diversions	$780
Materials (gravel)	122	Materials to revegetate	120
Work supervision	0	Cost of technical assistance	300
Repair cost per 3 years	527		
Total cost over 20 years[b]	$2,137	Total cost over 20 years	$1,200

IRR: 11.2%
PNV: $937
B/C ratio: 1.78 to 1.00 for road BMP installation versus reconstruction/repair.

[a] BMPs include construction of terraces and water diversions, and seeding.
[b] Discounted at 4%.

In another economic study, the costs of various revegetation treatments and associated technical services (e.g., planning and reviewing the project in the field) were compared to the benefits over time of the initial planning and BMP installation (Dissmeyer and Foster, 1987) (Table 3-21). Savings resulted from avoiding problem soils, wet areas, and unstable slopes, and the analysis demonstrated that including soil and water resource management (i.e., revegetating and technical services) in road planning and construction is more economical over the long term.

As part of the Fisher Creek Watershed Improvement Project, Rygh (1990) examined the costs of ripping and scarification using different techniques and specifically compared the relative advantages of using track hoes for ripping and scarification versus using large tractor-mounted rippers. Track hoes were found to be preferable to tractor-mounted rippers for a variety of reasons, including the following:

Table 3-21. Analysis of Costs and Benefits of Watershed Treatments Associated with Roads (SE United States) (Dissmeyer and Foster, 1987)

	Treatment[a]		
	Seed Without Mulch	Seed With Mulch	Hydroseed With Mulch
Costs			
Cost per kilometer ($)	511	816	1,006
Cost per kilometer for soil and water technical services ($)	89	89	89
Total cost of watershed treatment ($)	600	905	1,095
Benefits[b]			
Savings in construction costs ($/km)	446	446	446
Savings in annual maintenance costs ($/km)	267	267	267
Benefit/cost (10-year period)	4.4:1	2.9:1	2.4:1

Note: All costs updated to 1998 dollars.
[a] Treatments included fertilization and liming where needed.
[b] Cost savings were associated with soil and water resource management in the location and construction of forest roads by avoiding problem soils, wet areas, and unstable slopes. Maintenance cost savings were derived from revegetating cut and fill slopes, which reduced erosion, prolonging the time taken to fill ditch lines with sediment and reducing the frequency of ditch line reconstruction.
Source: Adapted by Dissmeyer and Foster from West, S., and B.R. Thomas, 1982. Effects of Skid Roads on Diameter, Height, and Volume Growth in Douglas-Fir. *Soil Sci. Soc. Am. J.*, 45:629–632.

- A reduction in furrows and resulting concentrated runoff caused by tractors
- Improved control over the extent of scarification
- Increased versatility and maneuverability of track hoes
- Cost savings

The study concluded that the cost of ripping with track hoes ranged from $406 to $506 per mile compared to $686 per mile for ripping with D7 or D8 tractors (1998 dollars) (Table 3-22).

Road decommissioning, however, can be expensive. The estimated cost for small roads with gentle terrain and few stream crossings is approximately $22,500; for larger roads with greater slope and larger and more stream crossings, the cost can equal or exceed $282,000 (1998 dollars) (Glasgow, 1993).

Table 3-22. Comparative Costs of Reclamation of Roads and Removal of Stream Crossing Structures (ID) (Rygh, 1990)

Method	Cost (dollars/mile)
Ripping/scarification	
Ripping with D7 or D8 tractor	$686
Scarifying with D8-mounted brush blade	$1,053
Scarification to 6-inch depth and installation of water bars with track hoe	$2,086
Ripping and slash scattering with track hoe	$549–$823
Ripping, slash scattering, and water bar installation with track hoe	$1,013
Ripping with track hoe	$406–$506

Best Management Practices

Road Maintenance Practices

◆ *Blade and reshape the road to conserve existing surface material; to retain the original, crowned, self-draining cross section; and to prevent or remove berms (except those designed for slope protection) and other irregularities that retard normal surface runoff.*

Ruts and potholes can weaken road subgrade materials by channeling runoff and allowing standing water to persist. Erosion from forest roads is a process associated with their location, construction, and use, and erosion begins with the development of ruts and the erosion of fine material from the road surface (Johnson and Bronsdon, 1995). Severe rutting on a road can cause drivers to seek routes around the ruts and lead to traffic's moving closer to riparian areas and stream channels, essentially widening a road and magnifying the problem (Phillips, 1997). Natural berms can develop on regularly used roads at undesirable locations and can trap runoff on the road instead of allowing it to drain off at design locations. Natural berms can also develop from improper road grading or gradual entrenchment of the road below the surrounding terrain (Swift and Burns, 1999). If serious road degradation due to rutting or other causes has occurred, the road can be regraded, and periodic regrading of roads is usually necessary to fill in wheel ruts and reshape roads. Regrading a road removes ruts, but it exposes more fine sediment that continues to erode for some months after grading until a protective, coarser layer on the road surface is developed. Serious rutting can indicate the need for a more durable surface.

◆ *Maintain road surfaces by mowing, patching, or resurfacing as necessary.*

Annual roadbed mowing and periodic trimming of encroaching vegetation is usually sufficient for grassed roadbeds carrying fewer than 20 to 30 vehicle trips per month.

◆ *Clear road inlet and outlet ditches, catch basins, culverts, and road-crossing structures of obstructions as necessary.*

Avoid undercutting back slopes when cleaning silt and debris from roadside ditches. Minimize machine cleaning of ditches during wet weather. Do not disturb vegetation when removing debris or slide blockage from ditches. The outlet edges of broad-based dips need to be cleaned of trapped sediment to eliminate mud holes and prevent the bypass of storm water. The frequency of cleaning depends on traffic load.

Clear stream-crossing structures and their inlets of debris, slides, rocks, and other materials before and after any heavy runoff period. Surveys by Copstead and Johansen (1998) of the roads in the Detroit Ranger District after storm damage showed that plugged culverts accounted for a greater percentage of damage to the roads than any other cause (Figure 3-30). Culverts were plugged by stream bedload and woody debris. Many times a small branch caught in the culvert inlet caused stream bedload to accumulate, eventually burying the inlet. Undersized culverts accounted for 81 percent of the plugged culverts.

Although regular cleaning of road ditches and culvert inlets and outlets is important, there are circumstances under which leaving accumulated debris in ditches is sometimes called for to help prevent erosion. Some debris might be left in ditches simply to interrupt the free flow of runoff down the ditch, thus reducing the velocity of the runoff and erosion as well.

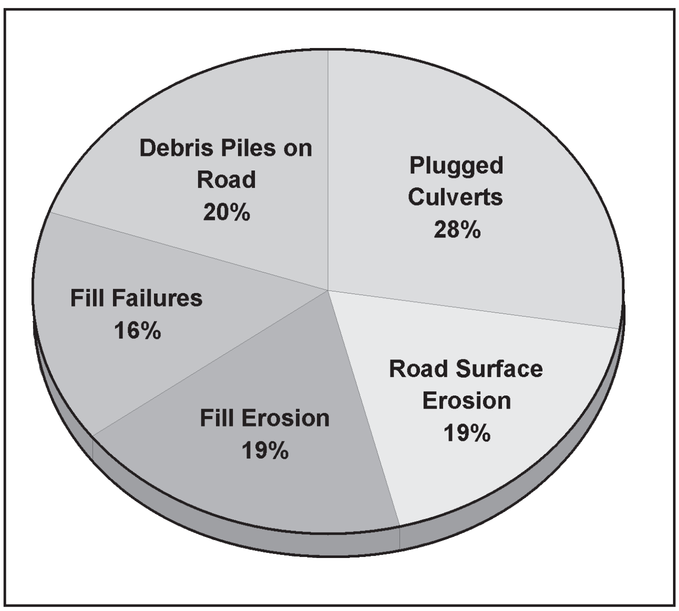

Figure 3-30. Road-related storm damage by type in the Detroit Ranger District (Copstead and Johansen, 1998).

During road construction, the cut slope is often undercut to provide the design flow capacity in roadside ditches or to provide room for culvert inlets, and undercut slopes are usually unstable. Especially above culvert inlets, soil erosion on the cut slope can lead to high maintenance costs. If, based on experience gained after the road is constructed, the flow in the ditch is less than it was designed for, leaving the accumulated debris in the ditch can help stabilize the cut slope above it. If debris has to be cleared out of a portion of ditch that repeatedly fills with sediment to provide sufficient volume for runoff flow, an option is to build a permanent or temporary passage under the accumulated debris and leave the debris to help stabilize the slope above the ditch. A temporary underpass can be constructed of two logs placed parallel with a gap between them and a third log on top. A permanent underpass can be constructed much like a culvert (Firth, 1992).

◆ *Remove any debris that enters surface waters from a winter road or skid trail located over surface waters before a thaw.*

◆ *Return the spring following a harvest and build erosion barriers on any skid trails that are steep enough to erode.*

◆ *Abate dust problems during dry summer periods.*

Excessive road dust during the summer is a condition that can threaten water quality. Dust can deliver large quantities of fine sediment to nearby stream channels. This fine material can be especially damaging to fish and fish habitat. Seasonal summer roads need almost the same amount of maintenance as permanent roads.

Dust control methods such as applying dust oil and watering during dry summer conditions are almost always necessary during an intensive dry season to prevent excessive loss of surface materials.

Wet and Winter Road Practices

◆ *Before winter, inspect and prepare all permanent, seasonal, and temporary roads for the winter months.*

Winterizing consists of maintenance and erosion control work needed to drain the road surface (Weaver, 1994). Clean trash barriers, culvert inlet basins, and pipe inlets of floatable debris and sediment accumulations. Clean ditches that are partially or entirely plugged with soil and debris, and trim and remove heavy concentrations of vegetation that impede flow. Gate and close seasonal and temporary roads to nonessential traffic.

Surface runoff problems caused by winter use of a bermed, unsurfaced road can cause rutting. The ruts collect runoff and cause additional erosion of the road. Lack of waterbars or rolling dips, together with the graded berm along the outside edge of the road, keep surface runoff on the roadbed. Annual grading can produce an outside berm of soil and rock that can be graded back onto the road surface.

Winter is a popular time to harvest wetlands or areas that are not accessible during wet periods, and road structures that will have to be maintained during the winter can be marked prior to snowfall. Snow accumulation could otherwise hide the BMPs.

◆ *On woodland roads "daylight" or remove trees to a width that permits full sunlight to reach the ground.*

The objective of road "daylighting" is to have sunlight dry the road so that it is less susceptible to erosion and damage from vehicle traffic. Daylighting also promotes the establishment of protective vegetative cover on road fillslopes and cutslopes and vegetation for wildlife. Vegetation clearing to promote daylighting needs to be managed so that slope integrity is not compromised. Daylighting should also be coordinated with wildlife specialists so that openings that might be detrimental to certain wildlife species, such as neotropical migratory birds, are not created.

Stream Crossing and Drainage Structure Practices

◆ *When temporary stream crossings are no longer needed, and as soon as possible upon completion of operations, remove culverts and log crossings to maintain adequate streamflow. Restore channels to pre-project size and shape by removing all fill materials used in the temporary crossing.*

Failure or plugging of abandoned temporary crossing structures can result in greatly increased sedimentation and turbidity in the stream, as well as channel blowout.

◆ *Replace open-top culverts with cross drains (water bars, dips, or ditches) to control and divert runoff from road surfaces.*

Open-top culverts are for temporary drainage of ongoing operations. It is important to replace them with more permanent drainage structures to ensure adequate drainage and reduce erosion potential prior to establishment of vegetation on the roadbed. It is recommended that open-top culverts be used for ongoing operations only and that they be removed upon completion of activities (Wiest, 1998).

◆ *During and after logging activities, ensure that all culverts and ditches are open and functional.*

Culvert plugging is common in woodland streams (Flanagan and Furniss, 1997). The risk of culvert plugging is greatest where small culverts have been installed on wide streams. Channel width controls the size of debris that can be transported in a stream, and culverts with a diameter that is less than the width of the stream are prone to block and accumulate woody debris. Another configuration that leads to debris trapping is increasing channel width toward a culvert inlet. Woody debris, transported in a lengthwise position down a stream, can rotate to a position perpendicular to the channel where the channel widens and block the culvert inlet. Hand, shovel, and chainsaw work can remedy almost all culvert maintenance needs (Weaver and Hagans, 1984). Heavy machinery and equipment is usually unnecessary to keep culverts clean.

Where culvert and ditch plugging is a problem, assess the cause of the problem and develop a strategy to correct it (see Roads Analysis in the Management Measure for Preharvest Planning, subsection 3A). Corrective measures might include installation of a new culvert, trimming dead wood from overhanging vegetation, or performing regularly scheduled maintenance.

Road Decommissioning, Obliteration, and Closure Practices

◆ *Decommission or obliterate roads that are no longer needed (see Road Decommissioning in this section).*

When a road is not needed for harvesting, forest management activities, or recreation, it can be decommissioned. Effective decommissioning reduces actual and potential erosion from the road and saves maintenance costs. Typically, a road is decommissioned by removing temporary stream crossings, installing water bars to minimize erosive surface runoff flows, and planting stream crossings and the road surface with vegetation to retail soil. If decommissioning is properly done, an area previously occupied by a forest road blends into the surrounding landscape naturally, erodes no more than an undisturbed site, and provides wildlife habitat. Decommissioned roads are generally left in a state such that they can be opened and used again in the future should the need arise.

More than 120 miles of roads have been decommissioned in the Targhee National Forest in Idaho (USDA-FS, 1997). Roads in riparian areas were particularly targeted for decommissioning. Decommissioning the roads involved seeding with grasses and adding water bars to prevent erosion. In the Lake Tahoe Basin, existing road surfaces are ripped to a depth of 12 to 18 inches, the surface is seeded, and pine needle mulch is spread on top to prevent erosion and encourage good establishment of vegetation. The road prism and drainage features are left in place to prevent erosion and soil runoff while the vegetation establishes itself. Roads decommissioned by the U.S. Forest Service in Region 8 are similarly seeded to create linear wildlife open areas that provide forage and edge vegetation. The U.S. Forest Service in Region 4, where the Targhee National Forest is located, found that public acceptance of the road decommissioning was enhanced by adding turnarounds and parking areas at the closure gates.

Road obliteration goes further than road decommissioning by returning a forest road to its natural drainage characteristics and topography to the extent possible. It is a suitable goal for roads that will not be used in the future. Road obliteration aims to eliminate alterations in drainage patterns created by a road system and the potential for drainage structure failure and stream diversion, and to reestablish drainage connectivity that might have been interrupted by the presence of the road (Moll, 1996).

Stabilizing areas disturbed by road construction and use is another major goal of road obliteration. Disturbed slopes, road cuts and fills, and areas to which drainage will be directed after the obliteration is terminated are areas that need to be stabilized. In some cases, artificial means to stabilize slopes might be necessary until vegetation has become established.

Road obliteration can lead to improvements in fisheries habitat where sediment runoff from old forest roads enters streams. The practice was used in a watershed in northwest Washington as part of watershed rehabilitation to improve fisheries habitats and water quality and to reduce flood hazards. On unused, 30- to 40-year-old, largely impassable roads and landings, fills were stabilized, stream crossings were removed, slopes were recontoured, and drainage patterns were reestablished at an average cost of $3,950 per kilometer (with a range of $1,500 to $7,500 per kilometer) (1998 dollars). Costs were lowest where little earthmoving was involved, more where a lot of brush had to be cleared away and sidecast material had to be pulled upslope, and highest where fills were removed at stream crossings and landings. Afterward, however, the obliterated roads and landings sustained much less damage from storms than unused roads that were not obliterated (Harr and Nichols, 1993).

Road obliteration in the Redwood National Park demonstrated that the following measures are effective for restoring hydrology and habitat (Belous, 1984, cited in NCASI, 2000): stream crossing removal, road outsloping, straw mulch placement, tree planting on road alignments and stream crossings, and waterbars. Soil decompaction and terrain recontouring wee found to be important first steps in successful road obliteration. Topsoil replacement significantly aided vegetation establishment.

◆ *Wherever possible, completely close roads to travel and restrict access by unauthorized persons by using gates or other barriers (Figure 3-31).*

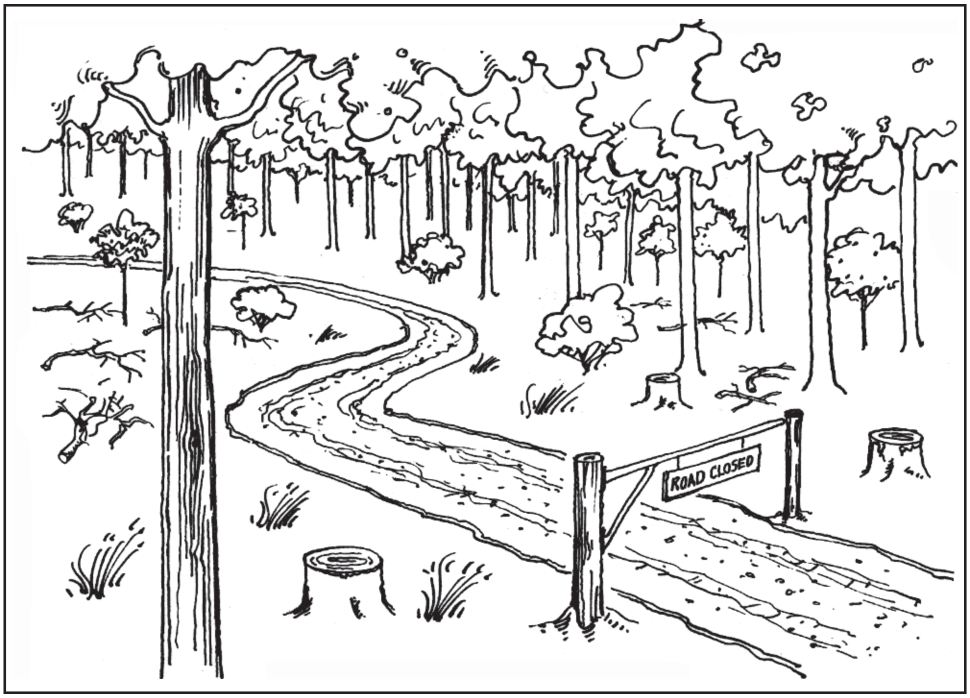

Figure 3-31. Install visible traffic barriers where appropriate to prevent off-road vehicle and other undesired disturbance to recently stabilized roads (Indiana DNR, 1998).

Closing a road that is not needed in the immediate future for harvesting or other forestry purposes can minimize use that could create erosive conditions and the need for continual maintenance. Closed roads should be decommissioned or maintained regularly. Access to roads at entry points can be restricted using rocks, logs, slash piles, or other on-site materials; planted trees; fences, gates; guardrails; or concrete barriers. Complete obliteration of a road access point can be accomplished by recontouring and removing all drainage structures, bridges, and other road features. Traffic entry should be regulated where restricting access with such barriers is not feasible.

◆ *Convert closed forest access roads into recreation trails.*

An unused forest access road can be converted to recreational use for off-road vehicles, horseback riding, mountain biking, and hiking. All of these activities, however, create the potential for road or trail damage, and regular maintenance of stream crossings, waterbars, and other drainage structures is necessary to ensure that sediment runoff from the road does not threaten water quality. The frequency and type of maintenance depends on the type and intensity of recreational use allowed on the road. Trails need the same kinds of runoff control measures as roads, and regular trail maintenance is as important as regular road maintenance (Figure 3-32).

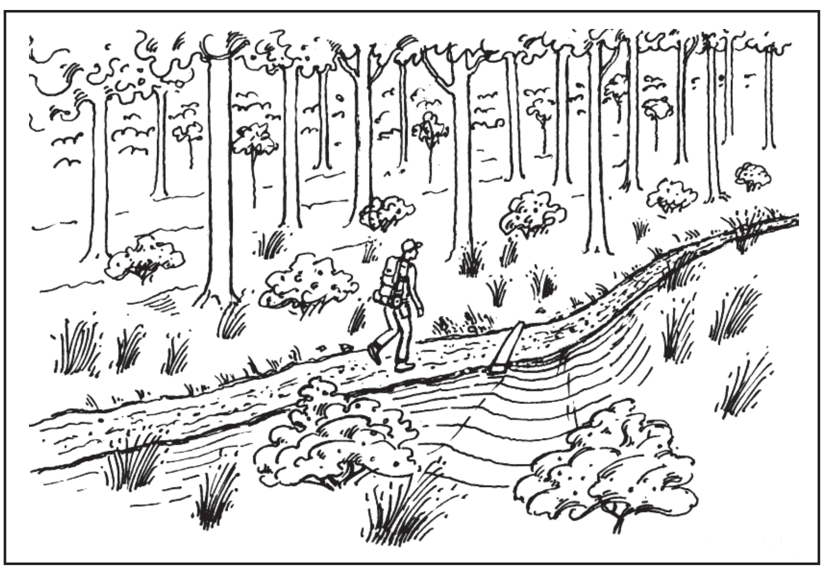

Figure 3-32. Construct trails using the same drainage structures as closed forest roads (Indiana DNR, 1998).

◆ *Install or regrade water bars on roads that will be closed to vehicle traffic and that lack an adequate system of broad-based dips (Figure 3-33).*

Water bars help to minimize the volume of water flowing over exposed areas and remove water to areas where it will not cause erosion. Water bar spacing depends on soil type and slope. Table 3-23 presents the Oregon Department of Forestry's suggested guidelines for water bar spacing. In other states with different climates, topographies, and soil types, recommended spacing might differ from these guidelines; contact the state forestry department for assistance. Divert water flow off the water bar onto rocks, slash, vegetation, duff, or other less erodible material and avoid diverting it directly to streams or bare areas. Outslope closed road surfaces to disperse runoff and prevent closed roads from routing water to streams.

◆ *Revegetate disturbed surfaces to provide erosion control and stabilize the road surface and banks.*

Refer to the Management Measure for Revegetation of Disturbed Areas for a more detailed discussion of this practice.

◆ *Periodically inspect closed roads to ensure that vegetational stabilization measures are operating as planned and that drainage structures are operational. Conduct reseeding and drainage structure maintenance as needed.*

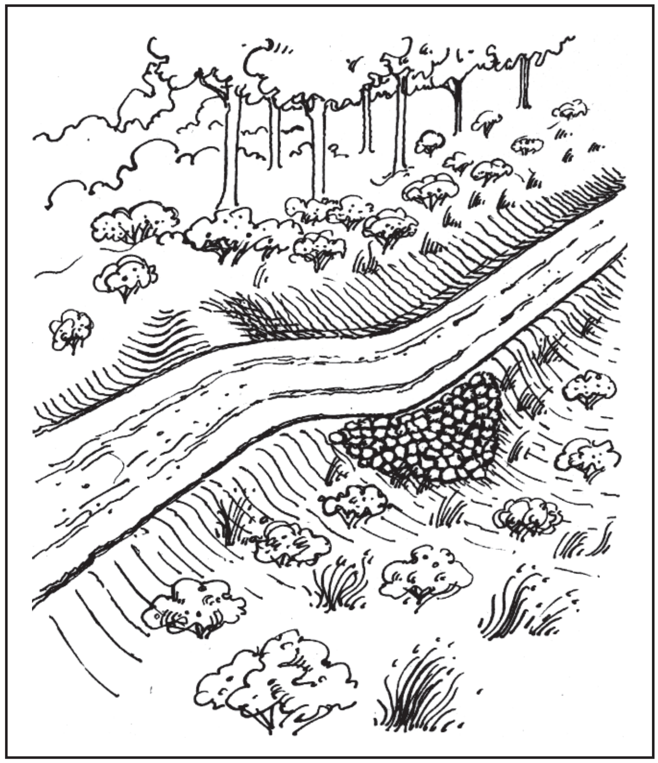

Figure 3-33. Broad-based dips reduce the potential for erosion (Indiana DNR, 1998).

Table 3-23. Example of Recommended Water Bar Spacing by Soil Type and Slope (Oregon Department of Forestry, 1979a)

Road Grade (percent)	Soil Type		
	Granitic or Sandy	Shale or Gravel	Clay
2	900	1,000	1,000
4	600	1,000	800
6	500	1,000	600
8	400	900	500
10	300	800	400
12	200	700	400
15	150	500	300
20	150	300	200
25+	100	200	150

Note: Distances (in feet) are approximate and are varied to take advantage of natural features.
Recommendations of spacing will vary with soil type, climate, and topography. Consult your state forester.