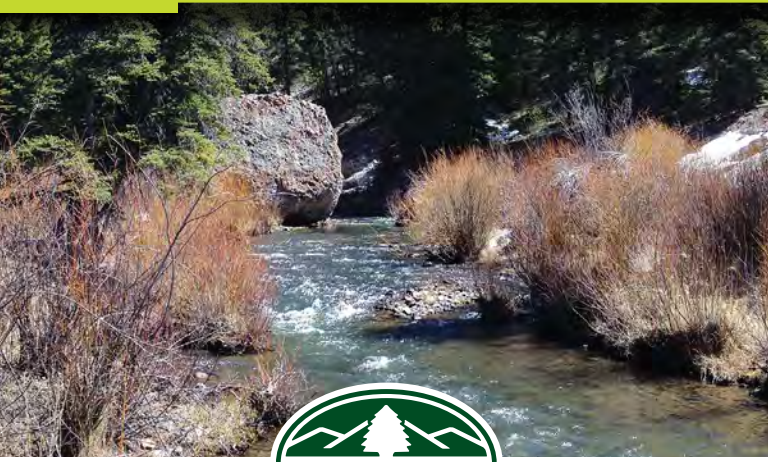
2023 FORESTRY BEST MANAGEMENT PRACTICES

TO PROTECT WATER QUALITY IN COLORADO



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- **Colorado State Forest Service**
- **Colorado Timber Industry Association**
- **Intermountain Forest Association**
- **Jefferson County Open Space**
- **U.S. Environmental Protection Agency**
- **USDA Forest Service**

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INTRODUCTION

Colorado's forestlands provide aesthetic value, clean water, abundant wildlife, minerals, recreation, renewable resources such as forage and timber, and forest-related jobs. This publication is dedicated to the stewardship of those resources – specifically clean water.

This guide outlines **Best Management Practices** (BMPs) for the protection of natural resources. Best management practices are defined as structural or non-structural methods, measures or practices implemented to prevent, reduce or mitigate adverse water quality impacts resulting from a forestry project. BMPs are tools and techniques to control or eliminate nonpoint source pollutants. These BMPs apply to all forest management activities, including product harvests, fuels mitigation projects and forest health treatments.

Photo: CSFS

BMPs include

- Practice and personal judgment
- Voluntary compliance
- Structural and nonstructural controls
- Operations
- Maintenance procedures
- Application before, during and after activities
- Practices to reduce or eliminate nonpoint source pollution
- A strict focus on water quality
- Application on private and state land ownerships in Colorado

BMPs do not

- Replace or supercede Section 404 of the Clean Water Act
- Address wildlife, archaeological or recreation BMPs
- Address wildfire operations
- Replace or supercede BMPs on federal lands

Using this field guide

Key points are listed at the beginning of each section and are the primary take-home message for reducing nonpoint source pollution.

Symbol

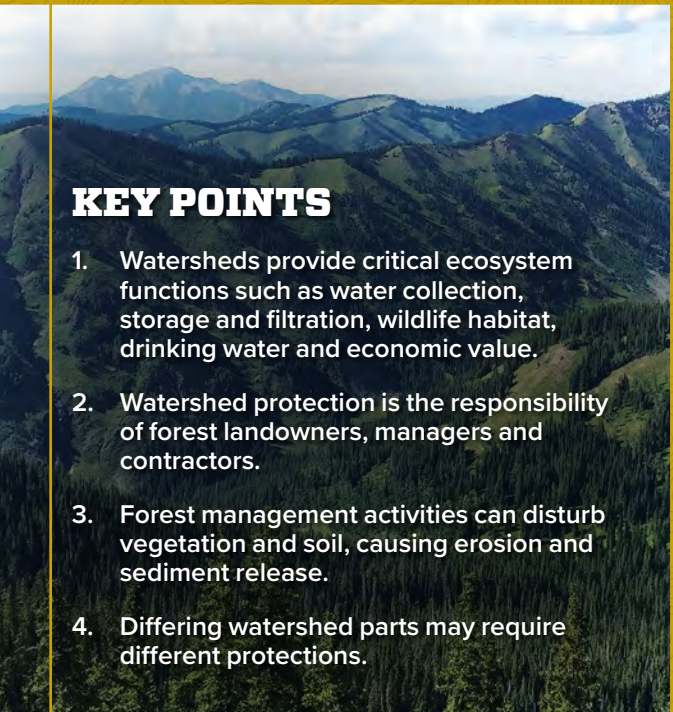
Applicable BMPs are listed early in each section. These are the criteria by which the forestry operations of land managers and contractors are measured during Colorado State Forest Service monitoring activities, and they can be used as a quick reference while using this field guide.

 = Applicable BMP

WATERSHEDS

A watershed is an area of sloping land surrounded by ridges and drained by a watercourse. Watersheds collect rainfall and snowmelt and deliver the water to a single outlet. They range in size from a few acres to thousands of square miles. Understanding watershed functions is critical to informing proper forest management implementation and use of BMPs.

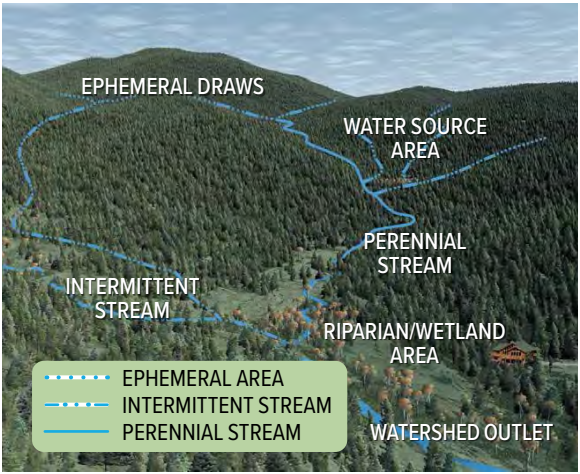
Photo: CSFS



KEY POINTS

1. Watersheds provide critical ecosystem functions such as water collection, storage and filtration, wildlife habitat, drinking water and economic value.
2. Watershed protection is the responsibility of forest landowners, managers and contractors.
3. Forest management activities can disturb vegetation and soil, causing erosion and sediment release.
4. Differing watershed parts may require different protections.

A watershed and its parts



A watershed and its parts. Illustration: Montana Department of Natural Resources & Conservation-Forestry Division

Parts of a watershed

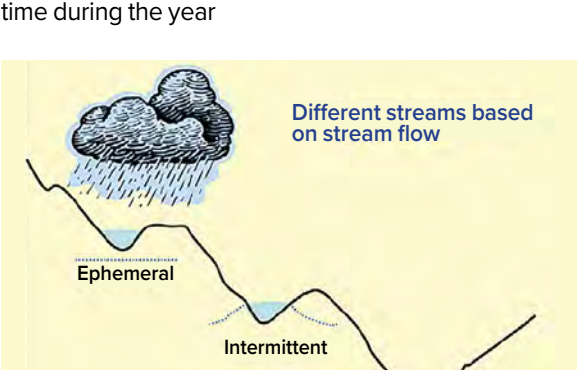
Perennial stream: Streams that hold water throughout the year

Intermittent stream: Streams that hold water during wet portions of the year

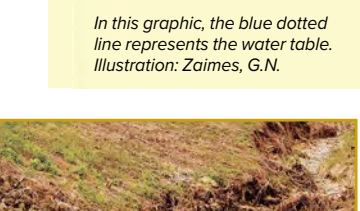
Ephemeral stream: A channel flowing with water during or immediately after precipitation events as indicated by an absence of forest litter and/or exposure of mineral soil

Riparian area: Interface between land and a river or stream

Wetlands: Areas, including springs, where water covers the soil or is present either at or near the surface of the soil all year or for varying periods of time during the year



In this graphic, the blue dotted line represents the water table. Illustration: Zaimes, G.N.



ABOVE: *Zaimes, G. & Emanuel, R. (2006). Stream Processes Part 1: Basics. Watershed Stewards, University of Arizona.*

LEFT: *Wittenberg, A. (2019). Where EPA saw no data, Trout Unlimited crunched the numbers. E&E News: Greenwire. Retrieved from https://www.eenews.net/articles/where-epa-saw-no-data-trout-unlimited-crunched-the-numbers/*

Identifying sensitive areas

Specific understory, shrubs and trees can serve as indicators of wetlands and saturated soils that may require special precautions during treatment. Wetland or riparian area indicator species in Colorado are available from the Colorado Natural Heritage Program at https://cnhp.colostate.edu/cwic/library/field-guides/.

How can forest management affect watersheds?

Colorado's forested watersheds deliver clean water to residents of 19 states and Mexico, and they provide the biological diversity needed for a future that is balanced both socially and ecologically. Current and expected future conditions, including persistent droughts and uncharacteristic wildfires, have and will continue to negatively affect forest health and the source water and habitat these forests provide. Water is an increasingly limited resource in Western states. Therefore, practicing forest management to improve forest health is critical to protecting and enhancing this precious resource.

Properly implemented BMPs decrease the chance of degrading water quality or impairing watershed conditions during forest operations.

When BMPs are not applied, forest management may have unintended negative consequences to watersheds:

- Runoff of sediment and associated nutrients into stream courses

- Improperly planned, located or constructed roads, skid trails and landings that can act as human-made stream channels carrying sediment
- Undesirable loading of masticated/mulched material causing changes to water/soil chemistry
- Slash/material broadcast into stream channels altering stream flows and courses

When BMPs are applied, forest management can have a multitude of positive impacts to watersheds:

- Protecting communities, critical infrastructure and the watershed itself from severe wildfire
- Restoring ecosystem functions
- Wildlife habitat improvement

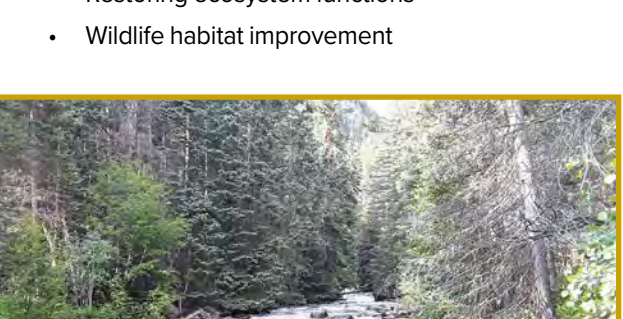
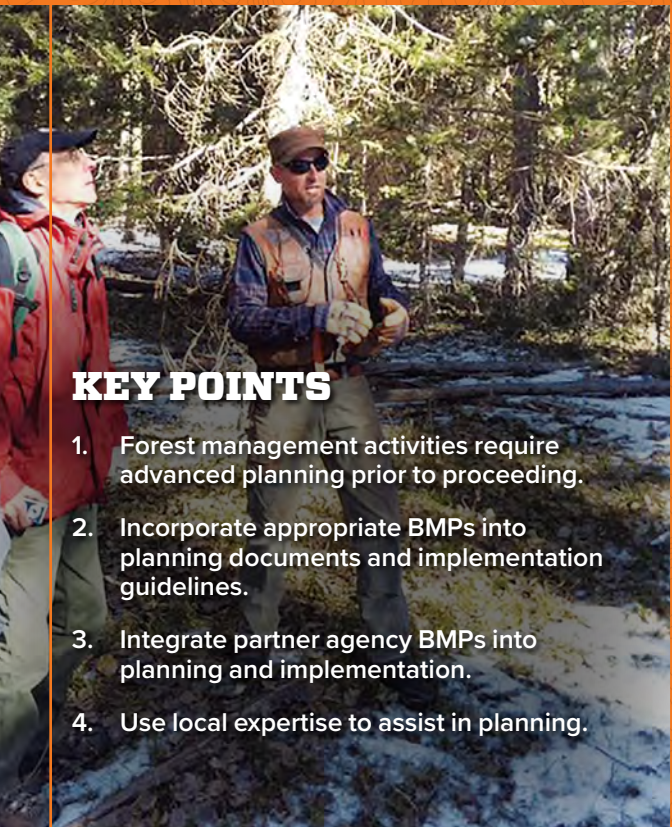


Photo: CSFS

PLANNING

Comprehensive planning conducted prior to treatment operations is critical to achieving forest management goals and objectives.

Photo: CSFS



KEY POINTS

1. Forest management activities require advanced planning prior to proceeding.
2. Incorporate appropriate BMPs into planning documents and implementation guidelines.
3. Integrate partner agency BMPs into planning and implementation.
4. Use local expertise to assist in planning.

Use these information sources during site review and project planning.

In the office

- *Colorado Forest Action Plan* and partner priority plans
- Topographic maps
- Aerial photos
- Natural Resources Conservation Service soils/ wetland maps
- Colorado Natural Heritage Program maps
- Watershed maps
- Forest management plans
- Silvicultural guides

In the field

- Landowner knowledge
- Access points
- Existing roads, landings and skid trails
- Soil conditions
- Steep slopes and poorly drained soils
- Streams, lakes and wetlands
- Stream and wetland crossings
- Wildlife habitat
- Presence of invasive species

The CSFS recommends using the *Colorado Forest Action Plan* as a critical tool for watershed level planning: https://csfs.colostate.edu/forest-action-plan/.

After site-specific analysis, conduct a Watershed Analysis to determine the following:

- Other management activities in the watershed and how treatment may affect them
- Potential treatment effects on water yield and sedimentation
- Treatment effects on water quality/quantity and on-site snow storage (Consider residual canopy cover, potential for snow scouring, dust on snow, etc.)
- Soil erosion hazard and soil characteristics (Check with local conservation districts/NRCS for assistance with soil mapping and characteristics.)
- Precipitation: Seasonal pattern and amount (e.g., operations on highly erodible soils may require installation of some BMPs prior to monsoon season to prevent sedimentation.)
- Topography: Where are slopes, drainages, streams and other physical features located? Are there critical areas that require special attention?

Plan for a new forest

Consider what kind of forest will grow after the harvest and how quickly the site may be reforested. Will your treatment result in natural regeneration of trees or will supplemental planting be required? Leave trees for future harvest that are acceptable species and of sufficient vigor to ensure continuous growth and harvesting. Protect these remaining trees from damage to enhance their survival and growth. Consult with your local forestry expert for silvicultural prescriptions appropriate for your site. Further, develop a schedule for maintenance activities after the project is completed.

Other planning considerations

Although the focus of this guide is on forest management implications to water quality, there are many additional considerations when planning a forest treatment including, but not limited to, the following:

- Wildlife habitat
- Archaeological/historical sites
- Recreation
- Aesthetics
- Economics
- Timber production
- Agro-forestry

- Wildfire
- Critical infrastructure
- Carbon storage
- Climate resilience
- Native biodiversity

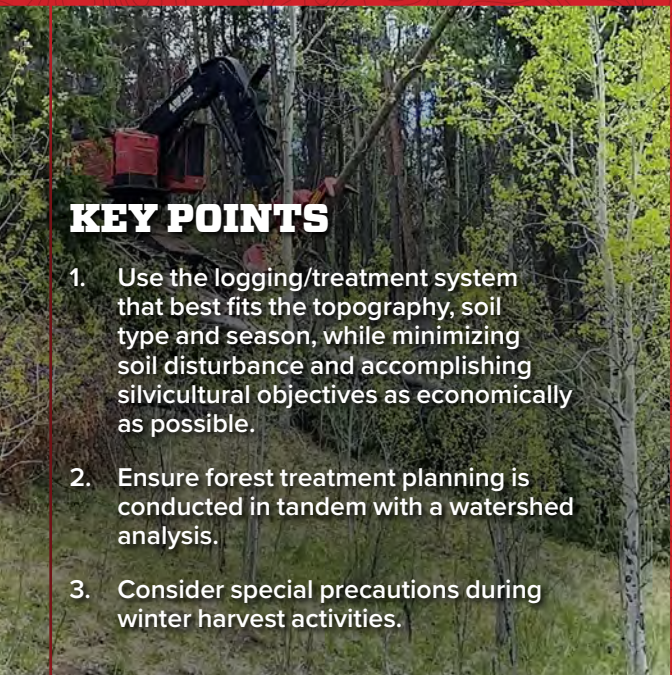
It's recommended that practitioners consult their local experts in the above areas to ensure that these other, important considerations are taken into account during planning and implementation of forest treatments.

Develop a treatment plan and harvest design that incorporates and addresses concerns identified in reconnaissance and watershed analysis.

FOREST TREATMENT & REVEGETATION

Forest treatment planning involves more than deciding how to cut trees. The treatment design must consider the long-term effects of management activities on important resources.

Photo: CSFS



KEY POINTS

1. Use the logging/treatment system that best fits the topography, soil type and season, while minimizing soil disturbance and accomplishing silvicultural objectives as economically as possible.
2. Ensure forest treatment planning is conducted in tandem with a watershed analysis.
3. Consider special precautions during winter harvest activities.

Applicable BMPs

Treatment design

- Use a suitable logging system for topography, soil type and season of operation
- Design and locate skid trails/primary transport network to minimize soil disturbance and avoid wet soils and sensitive areas
- Use suitable location, size and number of landings

Treatment activities

- Minimize soil compaction and displacement during skidding operations
- Avoid tractor skidding on unstable, wet or easily compacted soils and on slopes that exceed 40 percent unless not causing excessive erosion
- Provide adequate drainage for landings
- Provide adequate drainage for skid trails

Slash treatment and site preparation

- Scarify only to the extent necessary to meet resource management objectives
- Treat slash to limit soil disturbance, displacement or compaction of the surface
- Retain adequate material to slow runoff, return soil nutrients and provide shade for seedlings
- Limit activities to frozen or dry conditions to minimize soil compaction and displacement
- Limit scarification on steep slopes to minimize erosion

Reforestation/revegetation

- Ensure adequate revegetation in disturbed areas, if required

Treatment design considerations

- Location, number and size of temporary roads, skid trails and landings
- Equipment limitations and operating slopes
- Slash management and location
- Stream crossing locations

Characteristics of the harvest site (terrain, in particular) influence the choice of a logging system.

Ground-based harvesting

On gentle terrain, tractors and skidders, or even horses, are a logical choice. In Colorado forests, ground-based skidding equipment is most common.

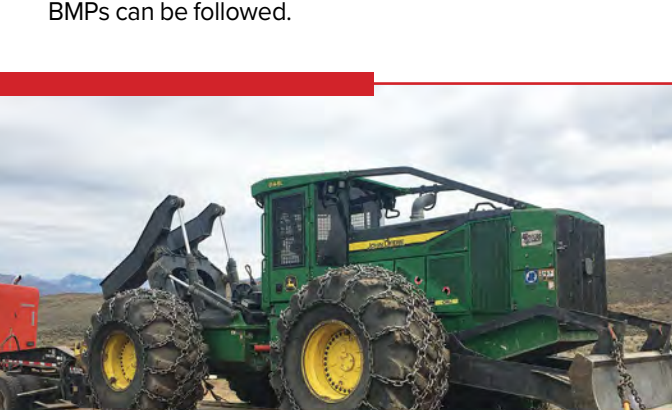
Feller bunchers are mechanical harvesters that move through the forest, harvesting and piling trees in bunches. Due to the extended reach of the harvesting head, feller bunchers can often be used in sensitive areas to thin individual trees with minimal damage to remaining trees, water, soils or wildlife habitat.

Skidders typically follow harvesters during operations to move or “skid” trees from the feller buncher location to a landing using “skid trails.” Skidders typically use a grapple to drag trees along the skid trail or to crane the trees onto a bunk behind the skidder cab.

At the landing, trees are then yarded and processed to appropriate log sizes using a processor and are finally loaded onto a log truck using a log loader.

Modern ground-based harvesting equipment. Photo: CSFS

There are many different types of ground-based harvesters, skidders, processors and loaders. Consider the different impacts of machinery with rubber tires vs. steel tracks, as well as ground conditions, to reduce soil/watershed impacts in the treatment area. Practitioners may have some flexibility in opting for specific equipment types, but harvest design should leave as much flexibility as possible to allow for varied equipment types when BMPs can be followed.



Rubber-tired skidder with chains. Photo: CSFS

Skyline and cable/tethered harvesting

Skyline and cable/tethered harvesting can be used on steep slopes where ground-based equipment cannot operate. These machines are capable of reaching a quarter mile, lifting logs off the ground and moving them to a landing where they are hauled away. Priority treatment areas on steep slopes have been identified across Colorado's landscapes. Ongoing research into these systems and their efficacy may result in supplemental guidance as these systems and their impacts are better understood. In addition to existing BMPs, special

Tethered forwarder operating on Monarch Pass. Photo: Miller Timber

precautions using steep slope treatment methods should be considered:

- Place heavier slash mat where harvester drops on/off shelf roads and other access points.
- Place slash and coarse woody debris in front of harvester path/skid trails to reduce erosion on steep slopes.

Helicopter logging

Helicopter logging can be an effective means of transporting logs where adverse terrain or sensitive areas prohibit traditional skidding methods.

Helicopter skidding logs to a landing. Photo: CSFS

- Locate refueling and landing sites away from wet or sensitive areas.
- Develop and implement fuel spill contingencies.
- Consult with a helicopter operator to understand equipment limitations, yarding distances, traffic control and other variables that may affect harvest timing and planning.

Photo: CSFS

Yarding and skidding

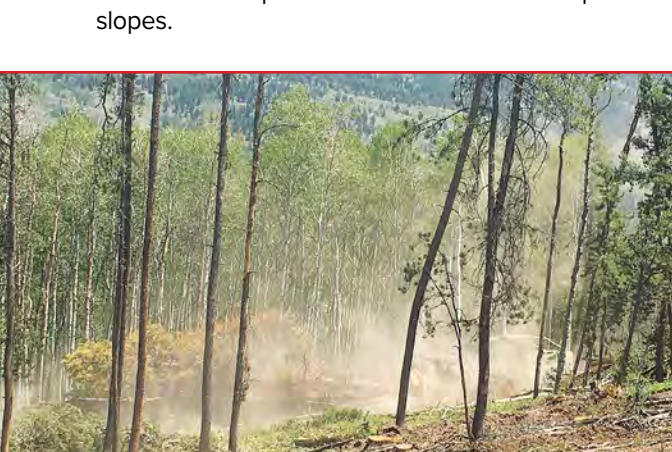
- Use an economically feasible yarding system that will minimize road densities.
- Consider erosion potential and possible alternative yarding systems prior to planning tractor-skidding on steep or unstable slopes.

- As much as 40 percent or more of any area may be covered with skid trails if they aren't planned and marked in advance. While this may be desirable in certain situations (e.g., when attempting to expose mineral soil to improve germination and survival of tree seedlings, or when disturbing aspen root systems to encourage coppice regeneration), it generally is wiser to limit ground disturbance by pre-planning skid trails to minimize potential erosion.

Woody debris placed over skid trail. Photo: CSFS

- Proper planning will help avoid steep skid trails on slopes greater than 30 percent with highly erodible soils. Always install waterbars on skid trails when needed.
- Design and locate skid trails and skidding operations to minimize soil disturbance. Using designated skid trails is one means of limiting site disturbance and soil compaction.
- Minimize the size and number of landings to accommodate safe, economical operation.
- Reuse existing skid trails and landings when feasible to reduce soil impacts.
- Avoid placing landings where skidding across drainage bottoms is required. Don't skid up or down drainage bottoms or use them as turn-around areas during fuels mastication activities.
- Locate skid trails to avoid concentrating runoff; provide breaks in grade.
- Limit the grade of constructed skid trails to a maximum of 30 percent on geologically unstable, saturated, highly erodible or easily compacted soils. Use mitigating measures such as waterbars and grass seeding to reduce erosion on skid trails.
- Tractor-skid when compaction, displacement and erosion are minimal.

- Avoid tractor or wheeled skidding on unstable, wet or easily compacted soils and on slopes that exceed 40 percent.
- Avoid skidding with the blade lowered. Forest soils on steep slopes often are shallow. Scalping the litter layer removes the soil's protective cover and exposes it to erosion. Don't use the blade as a brake or to improve skidder traction on steep slopes.



Skidding operations exposing bare mineral soil. Photo: CSFS

What happens when the forest litter layer is scraped off?

- Nutrients for the next crop of trees are removed.
- Mineral soil is exposed to erosion by rainfall and surface flow.
- Soil doesn't retain moisture as well.
- Ability of the soil to grow trees is reduced.
- Runoff and sediment transport increase.

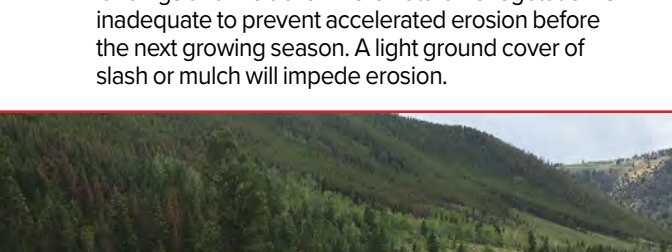
Other harvesting activities

Camps

- Protect surface and sub-surface water resources from nutrients, bacteria and chemicals associated with solid waste and sewage disposal.
- Design and locate fire, spike and logging camps, and their attendant sewage and wastewater disposal facilities, to avoid adverse effects.
- Dispose of garbage and other solid waste at a properly designated, operated and permitted landfill.
- Ensure appropriate permits are obtained and regulations followed if camping on federal or state lands.

Post-treatment activities and drainage management

- Stabilize or reclaim landings and temporary roads when operations are complete. Logging slash and other natural debris can be scattered and disturbed areas reseeded to grass if necessary. Ditches, waterbars or outsloping can prevent water accumulation on landings.
- At every landing, skid trail or fire trail, create and maintain a drainage system to control water dispersal and prevent sediment from entering streams.
- Install necessary waterbars on tractor skid trails; appropriate spacing between bars is determined by soil type and slope. Timely implementation is crucial.
- Apply seed or construct waterbars on skid trails, landings and fire trails where natural revegetation is inadequate to prevent accelerated erosion before the next growing season. A light ground cover of slash or mulch will impede erosion.



Reclaimed landing. Photo: CSFS

Waterbars

Waterbars divert surface water from bare soil to areas where it will not cause erosion; construct waterbars on roads, landings and skid trails. Waterbars can be constructed with a shovel, but mechanical equipment is most common. Cut the waterbar into solid soil to a depth of at least 8 inches. Shape the berm parallel to the cut at least 12 inches above the skid-trail grade. Construct the cut downward, but at no more than a 45-degree angle so that water runs to the outlet. Make sure the waterbar is open at the lower end so water runs out onto slash, vegetation or rocks. When temporary spur roads are waterbarred, connect the waterbar into "cut slope" to intercept all surface flow.

Waterbar diverting surface drainage and reducing velocity of runoff. Photo: CSFS

Recommended Waterbar Spacing Distance for Roads and Skid Trails

Grade of Road or Trail (Percent)	Unstable Soils (High Erosion Hazard)	Stable Soils (Low Erosion Hazard)
2	135’	170’
5	100’	140’
10	80’	115’
15	60’	90’
20	45’	60’
25+	30’	40’

Intervals in feet

When in doubt, reduce the spacing. Soils are non-renewable, and waterbars are inexpensive.

Slash treatment and site preparation – Reforestation

The question “How much soil exposure is enough?” is common when preparing a site for a new forest. New forests need the nutrients and protection supplied by logging slash. Soil compaction is another problem associated with sweeping the forest clean.

Well-planned site preparation techniques will promote a vigorous start for the new forest. Afterward, the site is either planted or allowed to seed-in naturally. In Colorado, natural regeneration generally provides more than adequate restocking of harvested areas.

Consider the following guidelines for slash treatment and site preparation:

- Reduce slash to decrease fire hazard. Consider post-treatment fuel loading targets based on objectives.
- Do not place slash from log processing in the streamside management zone.
- Use brush blades on equipment when piling slash.
- Scarify the soil only to the extent necessary to meet reforestation objectives. Use site-preparation equipment that produces irregular surfaces. Take precautions to preserve the surface soil horizon.
- Low slash and small brush should be left to slow surface runoff, return soil nutrients and provide shade for seedlings. Work around existing small trees and low brush.
- Carry out brush piling and scarification when soils are frozen or dry enough to minimize compaction and displacement.
- Carry out scarification on steep slopes in a manner that minimizes erosion.
- Remove all logging machinery refuse to a proper disposal site (tires, chains, chokers, cable and miscellaneous discarded parts).

- Broadcast burning and/or approved selective herbicide applications are preferred means for site preparation, especially on slopes greater than 40 percent. Herbicide and insecticide use requires special training and state licensing of applicators. For additional information, contact the Colorado Department of Agriculture.
- Limit water quality impacts of prescribed fire: 1) Construct waterbars in firelines; 2) Do not place slash in drainage channels; and 3) Maintain the streamside management zone. Avoid intense fires unless required to meet silvicultural goals.
- Reestablish protective vegetation by rapidly reforesting harvested areas.

Winter activities

Winter harvesting considerations

Colorado's freezing winter temperatures allow opportunities for low-impact logging. With proper precautions, even work in sensitive areas can be done without negatively affecting water quality. Consider snow-road construction and winter harvesting when logging sites are characterized by wet meadows, high water tables, sensitive riparian conditions or other potentially significant soil erosion and compaction hazards. Winter thaws can occur quickly; do not take chances with soil disturbance and possible erosion. Expect to shut down temporarily.

- Conduct winter logging operations when the ground is frozen or snow cover is adequate (generally more than 1 foot) to minimize site disturbance.

Photo: CSFS

- Before logging, mark existing culvert locations and other sensitive features. During and after logging, ensure culverts and ditches are functional.
- Prior to felling in wet, unfrozen soil areas, use tractors or skidders to compact the snow for skid-trail locations. Avoid steeper areas where frozen skid trails may be subject to erosion the following spring.
- Streamside management zones can be obscured by heavy snow; avoid confusion by delineating boundaries before the first snow.
- Do not leave slash and tops in streams.
- Consider residual stump heights and equipment limitations during winter operations.
- Suspend operations if conditions change rapidly and when erosion hazards increase.
- Install waterbars on all skid trails prior to spring runoff. If prohibited by frozen ground, install temporary slash barriers. Later in the summer, install proper erosion barriers. Temporary erosion control barriers consisting of slash can be used until waterbars are installed.

Road and drainage considerations

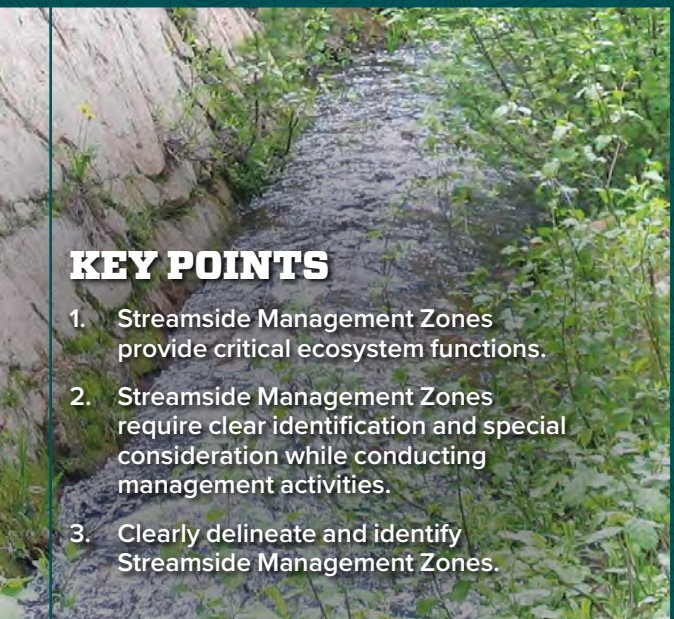
- For road systems that have a poor foundation, haul only during frozen periods.
- During cold weather, plow any snow cover off of the roadway to facilitate deep freezing of the road grade prior to hauling. Use compacted snow for roadbeds in unroaded, wet or sensitive sites. Construct snow roads for single-entry harvests or for temporary roads.
- After snow-road use is done, restore stream crossings to near pre-road conditions to prevent ice dams. Except for crossing, do not use the stream channel for the roadway. Waterbars placed on winter roads just above a drainage crossing will divert snowmelt onto vegetative filters, rather than directly into stream courses.
- Lay logs in streams so that water flows through the spaces between them and they serve as a temporary stream crossing when soils are frozen. Remove temporary log bridges prior to spring runoff.
- Suspend operations if conditions change rapidly and when the erosion hazard becomes high.
- Provide breaks in the snow berms when plowing snow for winter timber harvest, prior to spring breakup, to allow road drainage.

STREAMSIDE MANAGEMENT ZONE

Streamside Management Zones are areas adjacent to and surrounding streams and wetlands that are managed with special consideration for the purposes of protecting water quality and maintaining ecosystem function.

Photo: USDA, Medicine Bow National Forest

STREAMSIDE MANAGEMENT ZONE



KEY POINTS

1. Streamside Management Zones provide critical ecosystem functions.
2. Streamside Management Zones require clear identification and special consideration while conducting management activities.
3. Clearly delineate and identify Streamside Management Zones.

Management in an SMZ

The streamside management zone (SMZ) is not a "keep out" zone; however, timber harvesting in the SMZ should be done with special care to protect these valuable areas. Forest management is a tool that can be used within the SMZ to achieve a variety of resource-desired conditions and objectives when implemented with suitable measures to maintain riparian and aquatic ecosystem structure, function and processes. When treatments are used in the SMZ, a variety of measures can be employed to avoid, minimize or mitigate soil disturbance, damage to the water body, loss of large woody debris recruitment, shading and impacts to floodplain function.

Applicable BMPs

SMZ designation

- Apply adequate minimum SMZ width
- Mark SMZ clearly and adequately
- Maintain or provide sufficient ground cover
- Allow equipment operation in SMZ only per approved practices
- Exclude pile burning in SMZ
- Retain appropriate trees in SMZ (larger trees retained to provide habitat and a source of large woody debris)

- Exclude side-casted road material into stream, lake, wetland or other body of water during road maintenance
- Exclude slash or masticated material in streams, lakes or other bodies of water
- Protect SMZ during site preparation activities

Stream crossings and stream bank protection

- Obtain proper permits (e.g., 404) for stream crossings, if needed
- Cross streams at right angles, when practical
- Properly size structures for stream crossing
- Direct road drainage away from stream crossing site
- Avoid unimproved stream crossings

Installation of stream crossings

- Minimize stream channel disturbance
- Do not place material in stream channels
- Conform stream-crossing culverts to natural streambed and slope
- Place culverts slightly below stream grade

- Prevent erosion of stream-crossing culverts and bridge fills (i.e., armor inlet and outlet)
- Provide minimum cover for stream-crossing culverts
- Plan stream diversions to minimize downstream sedimentation

SMZ function

The function of an SMZ is to protect water quality along streams, lakes and other water bodies by maintaining a natural sediment filter. The riparian area "green zone" around streams, rivers, lakes, reservoirs, springs, seeps and wetlands is an area that stays green long into the summer months. Riparian areas usually have wet soils and high water tables, and they can be identified by the presence of water-loving plants such as alder, willow and cottonwoods. Recognizing these areas and knowing where they are located in the forest will make it much easier to protect water quality with an SMZ.

Designate SMZs to provide shading, soil stabilization, sediment and water-filtering effects, and wildlife habitat.

SMZ terminology

Although the term SMZ uses the word stream in the acronym, the SMZ concept should be applied to all bodies of water including rivers, lakes, reservoirs, springs, seeps and wetlands.

Determining SMZ boundaries

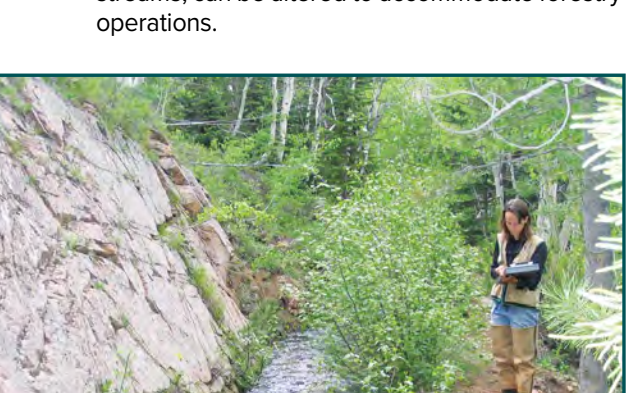
Minimum Recommended Buffer = 50’

- A 50-foot-wide strip on both sides of the stream or water course measured from the Ordinary High Water Mark (OHWM) is the minimum recommended by the Colorado State Forest Service and the Colorado Timber Industry Association for an SMZ. The width of the SMZ extends beyond the 50-foot suggested minimum to include riparian areas along the stream bottom and to provide additional protection in areas of steep slopes or erodible soils.
- Steep slopes, over 35 percent, may require a 100-foot-wide SMZ.
- SMZs should be applied to perennial, intermittent and ephemeral streams.
- SMZs should be applied to rivers, lakes, reservoirs, springs, seeps and wetlands in addition to streams.
- Consult with forestry professionals, soil and water conservation specialists, or biologists if you need assistance in setting appropriate SMZ boundaries.

Irrigation ditches

Irrigation ditches are human-made channels that take water from natural streams for delivery to homes, ranches, businesses and other uses. Colorado, like many Western states, has many active irrigation ditches that often intersect with forestry operations.

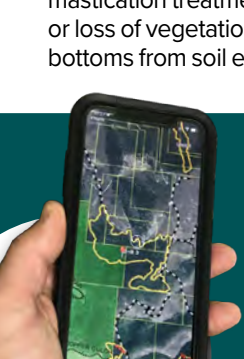
- Forestry activities adjacent to irrigation ditches can have water quality and water delivery impacts.
- If irrigation ditches flow back into natural streams downstream of forestry activities, treat the ditch as an intermittent stream and install SMZ buffers.
- Often irrigation ditch flows, unlike natural streams, can be altered to accommodate forestry operations.



Irrigation ditch flowing through planned treatment area. Photo: USDA, Medicine Bow National Forest

Marking SMZ boundaries

Clearly mark SMZ boundaries so that equipment operators better understand their location. Use plastic flagging, degradable paint or signs at frequent intervals. A walk through the project with the operator may be appropriate before activities commence. Perennial streams are easy to identify; intermittent streams can be more difficult to identify during dry periods. Whether wet or dry, perennial or intermittent, during drought or wet years, streams should be protected with an SMZ. Ephemeral drainages can be highly erosive and they typically direct water into stream channels. Ensure that mastication treatments don't result in disturbed soils or loss of vegetation that protects vulnerable valley bottoms from soil erosion and sediment transfer.



Virtual boundaries

Virtual boundaries using smartphones and GPS devices are becoming more commonplace in modern forestry. If using virtual boundaries, it's still recommended that SMZ boundaries are delineated in the field using the methods described above to clearly delineate SMZs as GPS accuracy may vary for equipment operators.

Smartphone application depicting virtual boundaries. Photo: CSFS

Harvesting and other activities

Trees are important to a healthy SMZ

- Stream bank trees and shrubs are especially important, as they anchor the bank, shade and cool the stream, and supply cover for fish and habitat for birds and other wildlife.

Protect SMZs

- Maintain or provide sufficient ground cover to trap sediment.
- Keep skidder, tractor and mastication equipment out of SMZs.

Harvester working on the edge of an SMZ. Photo: CSFS

Harvesting in the SMZ

If forest management in the SMZ is required for meeting a critical objective, consider the following:

- Don't harvest to the stream edge unless required to accomplish a restoration objective.
- Use directional felling for harvest operations in the SMZ or wetlands. Avoid felling trees in streams or water bodies.
- Avoid use of heavy equipment in the SMZ to minimize ground disturbance. Use winching or end-lining skidding techniques to remove logs from the SMZ and wetlands when ground-skidding systems are employed. Logs should be fully suspended when skyline skidding across a stream and immediately above stream banks.
- Keep slash out of water bodies by removing limbs and tops well above the stream high water mark. Whole-tree or tree-length yarding can reduce the need for slash disposal in the SMZ.

Site preparation near SMZs

- Pay special attention to steep slopes containing material that could roll down-slope and fall into a stream during controlled burning; the same is true when using mastication equipment on steep slopes.

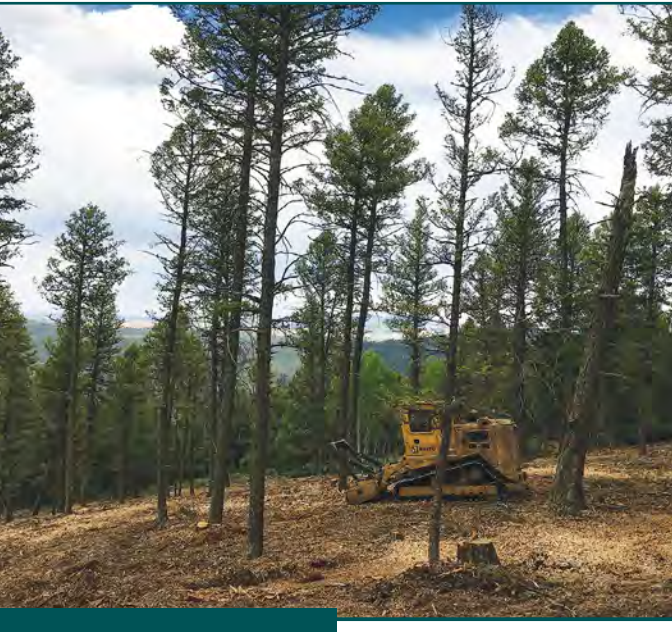
- Do not leave slash or other debris accumulated along the edge of the SMZ, or in a manner that will cause the slash to be eventually deposited within the SMZ. Use high stumps or leave logs positioned in a stable manner along the SMZ border to keep debris from rolling down steep slopes and reaching the stream.
- Retain trees necessary for bank stabilization as a future source of large woody debris to the stream channel and as habitat for cavity-nesting birds and other snag inhabitants.

Mastication/mulching near SMZs

Additional information and recommendations on mulching best practices can be found in the Colorado Forest Restoration Institute's *Mulching: A knowledge summary and guidelines for best practices on Colorado's Front Range.*

- Avoid turning equipment in the bottom of ephemeral areas to maintain vegetation and soil stability, limit the frequency of crossing drainages and cross at right angles when crossing is necessary.
- Monitor chip/masticated material depth in consideration of silvicultural objectives and water/soil chemistry changes as it filters through masticated material.

- Keep masticated material out of stream courses within high water mark to avoid disruptions to stream flows and changes to water chemistry.
- To the extent possible, minimize the amount of masticated material entering the SMZ.



Masticator working in a fuels treatment area. Photo: CSFS

ROADS

Roads produce up to 90 percent of sediment from forest activities, so proper forest road planning, design, location and maintenance are imperative. Roads and landing locations should complement each other to provide an efficient transportation system while minimizing soil erosion.

For detailed information on roads, reference the *Colorado Forest Road Field Handbook* at https://csfs.colostate.edu/.

Photo: CSFS

KEY POINTS

1. Roads have the highest potential for unwanted sedimentation and nonpoint source pollution from forest management activities.
2. Minimize the number of new roads and stream crossings.
3. Design roads and drainage facilities properly to prevent potential water quality problems due to road construction.
4. Construct/reconstruct only to the extent necessary to provide adequate drainage and safety.
5. Maintain roads throughout management activities to reduce sedimentation.
6. Consult the *Colorado Forest Road Field Handbook* for more detailed information on road construction.

Applicable BMPs

Road design and location

- Design roads to minimum standard necessary to accommodate anticipated use and equipment
- Minimize number and length of roads necessary
- Use existing roads unless aggravated erosion will be likely
- Avoid long and/or steep road grades
- Locate roads to avoid high-hazard sites (i.e., wet areas and unstable slopes)
- Minimize number of stream crossings
- Cross streams at stable sites
- Locate roads to provide access to suitable log landing areas
- Locate roads a safe distance from streams
- Keep roads outside of SMZs

Road construction/reconstruction

- Construct/reconstruct only to the extent necessary to provide adequate drainage and safety
- Minimize earth-moving activities when soils appear excessively wet
- Keep slope stabilization, erosion and sediment control work as current as possible, including "slash filter windrows"
- Cut and fill slopes at stable angles
- Stabilize exposed soils (e.g., seeding, benching, mulching)
- Avoid incorporating woody material in road fill
- Leave existing rooted trees and shrubs at the toe of fill slope
- Balance cuts and fills or use full bench construction
- Minimize use of road base or other material from borrow pits and gravel pits
- Avoid placing excess materials in a location that could enter a stream

Road construction/reconstruction cont.

- Avoid excavation into groundwater
- Exclude side-casting of road material into a stream, lake, wetland or other body of water

Road drainage

- Vary road grade to reduce concentrated drainage
- Provide adequate road surface drainage for roads
- Space road drainage outlets so runoff will not exceed capacity of drainage outlets
- For insloped roads, plan ditch gradients of greater than 2 percent, but no more than 8 percent
- Construct drain dips deep enough into the subgrade so that traffic will not obliterate them
- Install culverts at original gradient, otherwise rock armor or anchor downspouts
- Design all relief culverts with adequate length and appropriate skew; protect inflow end from erosion

- Provide energy dissipaters at drainage structure outlets where needed
- Route road drainage through adequate filtration zones before entering a stream

Road maintenance

- Maintain erosion control features if present (dips, ditches and culverts functional)
- Avoid use of roads during wet periods
- Grade roads only as necessary to maintain drainage
- Avoid cutting the toe of cut slopes if present
- Exclude side-casting of road material into a stream
- Abandon roads in condition to provide adequate drainage without further maintenance

Planning, design and location

- Design roads and drainage facilities properly to prevent potential water quality problems due to road construction.
- Minimize the number of roads constructed in a watershed through comprehensive road planning, recognizing intermingled ownership and foreseeable future uses.
- Use existing roads where practical. If existing roads have erosion issues, repair roads to meet BMPs.
- Fit the road to the topography by locating roads on natural benches and following contours. Where practical, avoid long, steep road grades and narrow canyons. (See *Colorado Forest Road Field Handbook* for additional information on steep grades.)
- Review available information and consult with road engineers as necessary to help identify erodible soils and unstable areas and to locate appropriate road-surface materials.
- Locate roads on stable geology, including well-drained soils and rock formations that tend to dip into the slope.

- Attempt to avoid problematic landforms, such as slumps and slide-prone areas characterized by steep slopes, highly weathered bedrock, clay beds, concave slopes, hummocky topography and rock layers that dip parallel to the slope. **Rock layers that slant or dip with, rather than into, the slope are a clue to potentially unstable bedrock conditions. Get expert advice when planning roads in these locations.**
- Avoid seasonally and permanently wet areas, including moisture-laden or unstable toe slopes, swamps, wet meadows and natural drainage channels.
- Minimize the number of stream crossings and choose stable stream-crossing sites.
- Locate or relocate roads to provide access to suitable (relatively flat and well-drained) log-landing areas to reduce soil disturbance and minimize impacts to water quality.
- Locate roads a safe distance from streams when roads are running parallel to stream channels.
- Provide an adequate SMZ to trap sediment and prevent its entry into the stream.

Example of a well-designed road plan

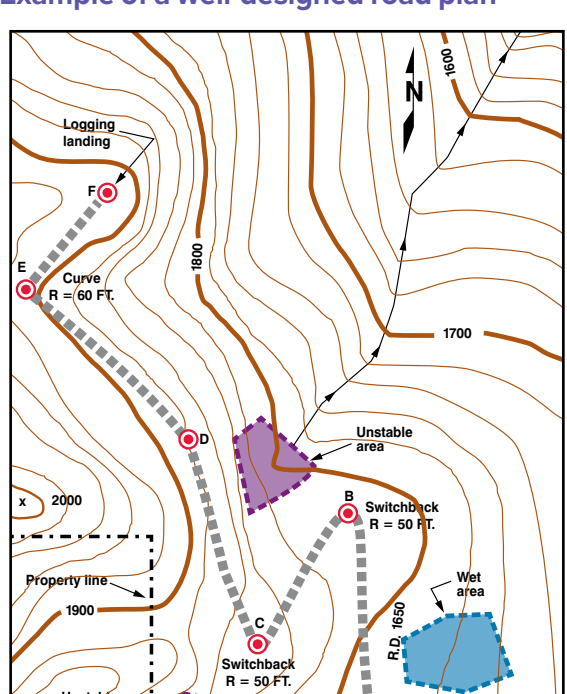


Illustration: Brian W. Kramer, P.E., retired Senior Instructor, OSU, Department of Forest Engineering

Photo: CSFS

Standards and use

- Design roads to the minimum standard necessary to accommodate anticipated use and equipment. Temporary low-standard roads are designed for short-term minimal use during timber harvesting. They can be constructed, used and reclaimed during seasons when precipitation and erosion potential are minimal. Low-standard roads involve only the clearing of vegetation and require minimal construction. The need for higher standard roads can sometimes be alleviated through better road-use management and logging system selection.

- Limit access by using locked gates for road-use management. Seasonal weather conditions also can restrict access.
- Cross only when the ground is frozen where access for forest activities requires crossing moist areas with a poor road base. Return during the dry season to do site preparation and slash treatment.

Photo: CSFS

Road construction

See also **Stream Crossings** section (pg. 74).

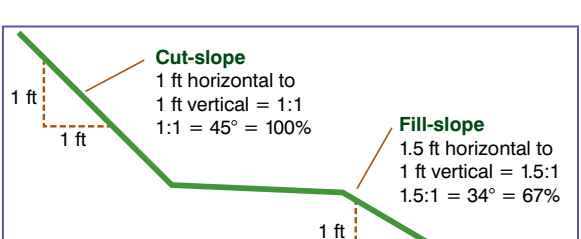
Control erosion during the construction process

- Reconstruct existing roads only to the extent necessary to provide adequate drainage and safety; avoid disturbing stable road surfaces. Evaluate the integrity of existing roads prior to use.
- Minimize earth-moving activities when soils appear excessively wet. Do not disturb roadside vegetation more than necessary to maintain slope stability and serve traffic needs.
- Keep slope stabilization, erosion and sediment control work as current as possible when constructing and maintaining roads. This includes installing drainage features as part of the construction process.
- Complete or stabilize road sections within the same operating season to ensure that drainage features are fully functional prior to spring runoff and that road sections are not left in an unstable condition over winter.
- If the road is a permanent installation that will experience considerable traffic, consider using gravel to minimize erosion and provide a superior running surface.

- When pioneering roads, avoid stream crossings to the extent practical. Use temporary crossings over streams if needed. Several logs placed in the stream channel form a base that water can flow through while protecting stream banks. Replace promptly with a permanent crossing (culvert or bridge).
- Grass seeding of exposed cut-and-fill surfaces is an important erosion control practice. Proper seed mixtures and timing are important for success. Use seed of known purity that has a high germination rate and is free of noxious weeds. Private foresters and local Colorado State Forest Service, Colorado State University Extension and Natural Resources Conservation Service offices can assist in recommending an appropriate seed mix for your particular site. Several vendors in Colorado stock native and introduced grass seed.

Stabilize slopes

- Construct cut-and-fill slopes at stable angles to prevent sloughing and other subsequent erosion. A 1:3 slope is the maximum recommended for stable soils. A 1:1 slope may be necessary in sandy soils to avoid slumping.



Cut-and-fill slope ratios. Source: Kramer, Brian W. 2001. Forest Road Contracting, Construction, and Maintenance for Small Forest Woodland Owners. Research Contribution 35. Oregon State University, College of Forestry, Forest Research Laboratory; Corvallis, OR. 79 pp.

Soil/Rock Condition	Slope Ratios (Horizontal:Vertical)
Most rock	¼:1 to ½:1
Most in-place soils	¾:1 to 2:1
Very fractured rock	1:1 to 1½:1
Loose coarse granular soils	1½:1 to 3:1
Heavy clay soils	2:1 to 3:1
Soft clay-rich zones or wet seepage areas	2:1 to 3:1
Fill of most soils	1½:1 to 3:1
Fill of hard angular rock	1⅓:1 to 1½:1
Low cuts and fills (<6-10 ft high)	2:1 or flatter (for revegetation)

Common stable slope ratios for varying soil and rock conditions. Source: Keller, Gordon and James Sherar. 2003. Low-Volume Roads Engineering Best Management Practices Field Guide. US Agency for International Development (USAID); Washington, DC. 183 pp.

Cut-and-Fill Slope Ratio	Percent Slope	Degree Slope
3:1	33	18
2:1	50	27
1½:1	67	34
1:1	100	45
¾:1	133	53
⅔:1	150	56
½:1	200	63
⅓:1	300	72
¼:1	400	76
Vertical (rock cliff)	Undefined	90

Cut-and-fill slope ratios with percent and degree slope equivalents.

- Stabilize erodible, exposed soils by seeding, compacting, rip rapping, benching, mulching or another suitable means prior to spring runoff.
- At the toe of potentially erodible fill slopes, particularly near stream channels, pile a maximum of 2 feet of slash in a row parallel to the road to trap sediment. When completed concurrently with road construction, this practice can effectively control sediment movement and provide an economical way of disposing of roadway slash. Limit the height, width and length of these “slash filter windrows” so as not to impede wildlife movement or create fuels hazards.

- Geo-textile silt fences can be used as sediment traps until more permanent measures such as reseeding become effective. Remove temporary traps when no longer needed.
- Avoid incorporating potentially unstable woody debris in the fill portion of the road prism. When possible, leave existing rooted trees or shrubs at the toe of the fill slope to stabilize the fill.

Cut-and-fill

Most forest roads are built by excavating a road surface. Use road designs and on-the-ground layout to demonstrate proper cut slopes and to indicate cut slope steepness for machine operators. The bulldozer starts at the top of the cut slope, excavating and "side-casting" material until the desired road grade and width are obtained. Material from cuts often is pushed or "drifted" in front of the blade to areas where fill is needed. Use road fill to cover culverts and build up low areas. Spread and compact fill-in layers to develop strength, as it must support traffic.

Full-bench

While cut-and-fill road construction is commonly used on gentle terrain, full-bench roads are nearly always built on steep terrain with slopes greater than 65 percent. In full-bench construction, the entire road surface is excavated into the hill. The excavated material is pushed or hauled to an area that needs fill or to a disposal area.

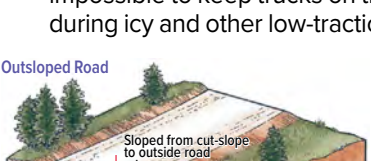
- Design roads to balance cuts and fills or use full-bench construction where stable fill construction is not possible.
- During the process of cut-and-fill, avoid allowing side-cast or waste material to enter streams, and do not place it on unstable areas where it might erode. Where possible, keep roads outside of SMZs to mitigate this problem.
- Borrow pits can contaminate surface water; take precautions to control drainage and escaping sediment.
- Burning can be used to dispose of root wads, slash and vegetative debris during road construction. Avoid piling and burning for slash removal in SMZs to the extent practicable. Minimize effects on soil, water quality and riparian resources by appropriately planning pile size, fuel piece size limits, spacing and burn prescriptions in compliance with state or local laws and regulations if no practical alternatives for slash disposal in the SMZ are available.

Drainage from road surface and road types

- Vary road grades to reduce concentrated flow in roadside drainage ditches and culverts and on fill slopes and road surfaces.

- Provide adequate drainage from the surface of all permanent and temporary roads by using outsloped or crowned roads, drain dips or insloped roads with cross-drains. Use caution in constructing crowned or outsloped road profiles. Excessive crown or outslope may make it impossible to keep trucks on the running surface during icy and other low-traction conditions.

Outsloped Road



Outsloped road is used when:

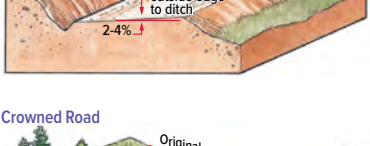
- Road grade is gentle or flat (< 8%)
- Ditch or cut-slope is unstable
- Surface can be kept smooth
- Road is vacated
- Rutting can be controlled
- Road use is seasonal and traffic is light

Insloped Road

Insloped road is used when:

- Road grade is steep (>8%)
- Surface drainage is carried to a ditch or surface drain
- Outslope causes fill erosion
- Outslope is ineffective due to ruts
- Slippery or icy road conditions are prevalent

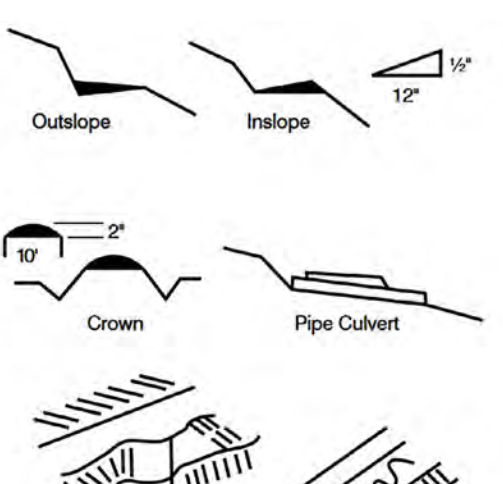
Crowned Road



Crowned road is used when:

- Two traffic lanes are needed
- Single lane road is on steep grade
- Regular maintenance of ditches, crown and cross drains is possible
- Slippery or icy road conditions are prevalent
- Road grade is flat (crown fill)

Outsloped road. Illustration: CSFS



General Types of Surface Drainage

Illustration: CSFS

- **Outsloped roads:** Outsloped roads provide a means of dispersing water in a low-energy flow from the road surface. Outsloped roads are appropriate when fill slopes are stable, as drainage will not flow directly into stream channels, and transportation safety considerations can be met. A smooth surface

is the key to an effective outsloped road. Smoothing and outsloping (from cutbank to outside edge of roadbed) should be kept current so that water can drain across the road without creating channels on the road surface.

- **Insloped roads:** Insloped roads carry road surface water to a ditch along the cutbank. Plan ditch gradients greater than 2 percent, but no more than 8 percent for insloped roads to prevent sediment deposition and ditch erosion. The higher gradients may be suitable for more stable soils, but plan for sufficient culverts, drop structures or armor ditches. Use the lower gradients for less stable soils.
- **Drain dips:** A drain dip is a portion of road sloped to carry water from the inside edge to the outside edge onto natural ground. Properly constructed drain dips can be an economical method of channeling surface flow off the road. Construct drain dips deep enough into the subgrade so that traffic will not destroy them; length and depth must provide the needed drainage but not present a driving hazard. The cross grade should be at least 1 percent greater than the original road grade.

Design roads for minimal disruption of drainage patterns

- Prevent downslope movement of sediment by using sediment catch basins, drop inlets, changes in road grade, headwalls or recessed cut slopes.
- Where possible, install ditch-relief culverts at the gradient of the original ground slope; otherwise, use armor outlets with rock or anchor downspouts to carry water safely across the fill slope.

Temporary road constructed through ephemeral draw. Photo: CSFS

- Skew ditch-relief culverts 20 to 30 degrees toward the inflow from the ditch to improve inlet efficiency. Protect the upstream end of cross-drain culverts from plugging. Drop inlets installed at the head of a ditch-relief culvert slow the flow of water, help settle out sediment and protect the culvert from plugging. Rock-armored inlets prevent water from eroding and undercutting the culvert and flowing under the road.

- Provide energy dissipaters (rock piles, logs, etc.) where necessary at the downstream end of ditch-relief culverts to reduce the erosion energy of the emerging water.
- Cross drains, culverts, waterbars, dips and other drainage structures should not be discharged onto erodible soils or fill slopes without outfall protection.
- Route road drainage through SMZs, filtration fields or other sediment-settling structures that are large enough to accommodate the anticipated volume of water. Install road drainage features above stream crossings to route discharge into filtration zones before entering a stream. To avoid creation of new gullies, diffuse runoff through these filters, rather than allowing concentrated runoff.
- Ditch-relief culverts transfer water from a ditch on the uphill side of a road, under the grade, and release it onto a stable area; these prevent water from crossing the road surface and softening the roadbed. Install culverts at a 30-degree angle to enhance flow. Ensure proper slope of at least 5 inches for every 10 feet (4 percent). Seat the culvert on the natural slope on bedding material that is free of rock or debris, which might puncture the pipe or carry water around the culvert. Cover with soil (avoiding puncture from large rocks) and compact the soil at least

halfway up the side to prevent water from seeping around the culvert. (Rule of thumb for covering culverts: minimum of 1 foot or one-third the culvert diameter, whichever is greater.) Be sure that the outlet end extends beyond any fill and empties onto an apron of rock, gravel, brush or logs.

Maintenance

- Periodically inspect and maintain erosion control features, including cleaning dips and cross drains, repairing ditches, marking culvert inlets to aid in location and clearing debris from culverts. Keep small water collection points drained with a shovel to dry up potential mud holes and remove ice dams in drainage ditches during winter operations.
- Avoid using roads during wet periods if such use might permanently damage the road drainage features.

Road-grading precautions

- Grade road surfaces only as often as necessary to maintain a stable running surface and to retain the original surface drainage.
- Avoid cutting the toe of cut slopes when grading roads or pulling ditches.

- Avoid grading sections of road that don't need it; this creates a source of sediment from the newly disturbed surface. Raise the blade where grading is not needed.

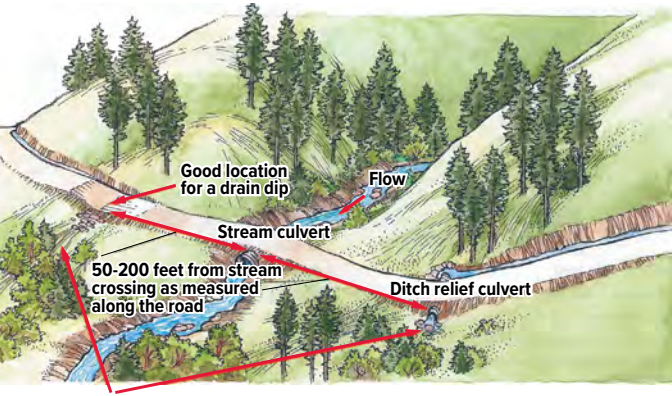
Road closures

- When seasonal operations are completed, crown, outslope, inslope or waterbar the road surface. Remove berms from the outside edge where runoff is channeled.

Forest roads often close during Colorado's mud season. Photo: USDA, Medicine Bow National Forest

- Leave abandoned roads in a condition that provides adequate drainage without further maintenance. Close these roads to traffic, scarify if required and reseed. If necessary, recontour and provide waterbars or drain dips.
- Traffic control on forest roads can be an effective way to reduce road maintenance costs and provide protection of other forest resources. Traffic control can include full road closure, temporary or seasonal closure, or open road restricted to light use. Any degree of control requires maintenance inspections.
- Bridges may present special problems to road closures. Remove all bridge structures unless plans include regular inspections of abutments for erosion and other potential problems.
- If plans do not include regular maintenance of closed roads, plugged culverts will present erosion problems. Remove culverts and create waterbars to divert water on abandoned roads. Space waterbars closer in areas that are more likely to erode. When removing culverts, stockpile earth in a safe place where it can be recovered and won't erode. Reshape banks to a stable slope.

- If bridges and culverts are removed, all drainage features must be restored to their natural condition, including reseeding the road surface and all cut-and-fill slopes.



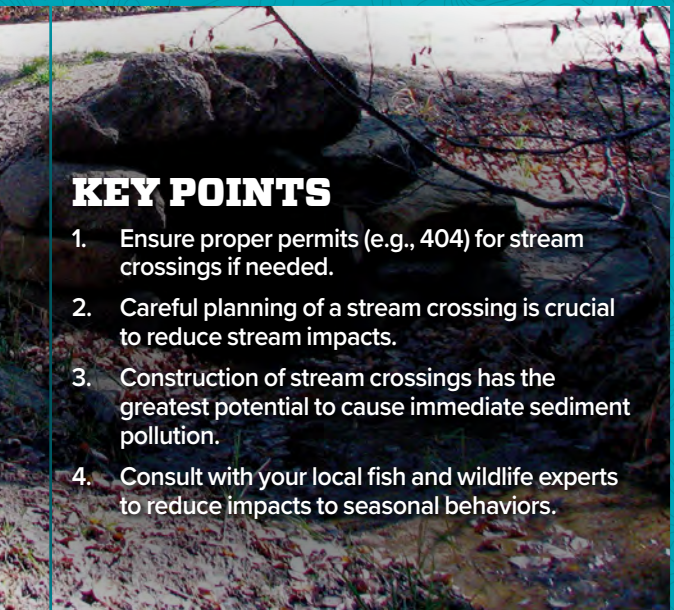
Ditch drainage should be directed into a vegetation filter, and not allowed to continue flowing down the ditch and into the stream.

Illustration: CSFS

STREAM CROSSINGS

Streams can be crossed with culverts, bridges or fords. Culverts are the most common stream-crossing structure. Bridges are best for large streams and areas with floatable debris problems. Bridges can have less of an impact on fisheries than other methods. Fords are less desirable because of continued disturbance to the streambed.

Photo: CSFS



KEY POINTS

1. Ensure proper permits (e.g., 404) for stream crossings if needed.
2. Careful planning of a stream crossing is crucial to reduce stream impacts.
3. Construction of stream crossings has the greatest potential to cause immediate sediment pollution.
4. Consult with your local fish and wildlife experts to reduce impacts to seasonal behaviors.

For more information, reference the ***Colorado Forest Road Field Handbook.*** Choosing the correct stream-crossing method depends on the following considerations:

- Stream size
- Cost of construction and maintenance
- Amount and years of road use
- Lie, pitch and angle of the road approach with respect to the stream
- Soil foundation, type and conditions
- Available equipment and materials
- Applicable permit requirements

Improper stream-crossing method or sizing can result in major damage to both the immediate site and downstream water uses. Well-designed approaches will allow even heavy equipment to use stream crossings with only limited sedimentation.

Applicable BMPs

Stream crossings and stream bank protection

- Obtain proper permits (e.g., 404) for stream crossings if needed
- Cross streams at right angles when practical
- Use properly sized structures for stream crossing
- Direct road drainage away from stream-crossing site
- Avoid unimproved stream crossing

Installation of stream crossings

- Minimize stream channel disturbance
- Do not place material in stream channels
- Conform stream-crossing culverts to natural streambed and slope
- Place culverts slightly below stream grade
- Prevent erosion of stream-crossing culverts and bridge fills (i.e., armor inlet and outlet)
- Provide minimum cover for stream-crossing culverts
- Plan stream diversions to minimize downstream sedimentation

Legal requirements

In some cases, it's necessary to secure certain permits prior to altering a stream channel. Compliance with Section 404 of the Clean Water Act is required if the activity has the potential to impact any water area considered "waters of the U.S." Consult your local U.S. Army Corps of Engineers to determine the need for a 404 permit. Additional permitting may be required depending on local jurisdictions. The consequences for operation without a necessary permit could be significant and may include work stoppage and monetary fines.

Design considerations

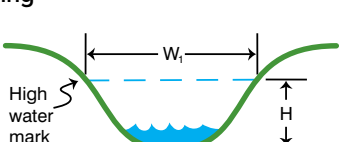
- Design stream crossings and culverts for adequate passage of fish, minimum impact on water quality and to handle peak runoff and flood waters.
- Cross streams at right angles to the main channel, if practical.
- Adjust the road grade to reduce the concentration of water carried by drainage ditches to stream crossings.
- Direct drainage flows through an SMZ and away from the stream-crossing site.

- Avoid unimproved stream crossings. When a culvert or bridge is not feasible, place drive-throughs on a stable, rocky portion of the stream channel.

Portable/temporary bridges

When a stream cuts off short-term access to forestland, portable or temporary bridges may be a solution. These bridges offer convenience at a relatively low cost. Timber harvesting and other forest activities can be implemented over a short period of time, and the crossing can easily be restored to its original condition.

Culvert sizing



W_1 = Channel width at high water (feet)
W_2 = Channel width at bottom (feet)
H = Height of high water above channel bottom (feet)

Culvert area with 100% = H x (W_1 + W_2)
safety factor (square feet)

Hasty method for calculating culvert end area. Source: CSFS

Cross-Sectional Area (square feet)	Required Culvert Diameter (inches)
1.80	18
3.10	24
4.90	30
7.10	36
9.60	42
12.60	48
15.90	54
19.60	60
23.80	66
28.30	72
33.20	78
38.50	84
44.20	90

Round culvert pipe diameter required for given cross-sectional waterway area. Source: Haussman, R.F., Emerson W. Pruett. 1978. Permanent Logging Roads For Better Woodlot Management. USDA Forest Service State and Private Forestry; Broomall, PA. 43 pp.

Installation of stream crossings

Construction of stream crossings has the greatest potential to cause immediate sediment pollution. Complete the work as fast as possible during a time of year when the least damage can occur.

- Minimize stream-channel disturbances and related sediment problems during construction of road and installation of stream-crossing structures.
- Time construction activities to protect fisheries and water quality. Complete the work as fast as possible during a time of year when the least damage will occur. Consult your local fisheries expert to determine ideal timing of construction.
- Don't place erodible material into stream channels. Remove stockpiled material from high water zones.
- Locate temporary construction bypass roads where the stream course will receive minimal disturbance.
- When using culverts to cross small streams, install them to conform to the natural streambed and slope on all streams that support fish.
- Place culverts slightly below normal stream grade to avoid culvert outfall barrier and to assist with fish passage and sedimentation.

- Do not alter stream channels upstream from culverts unless it is necessary to protect fill or to prevent culvert blockage.
- Install culverts to prevent erosion of fill. Compact the fill material to prevent seepage and failure. Armor the inlet and/or outlet with rock or other suitable material where needed. The culvert foundation and trench walls must be free of logs, stumps, limbs or rocks that could damage the pipe.
- Consider dewatering stream-crossing sites during culvert installation.
- To prevent crushing from traffic, use 1 foot minimum cover for culverts 18 to 36 inches in diameter and a cover of 1/3-inch diameter for larger culverts.

WILDFIRE & PRESCRIBED FIRE

Wildfire and prescribed fire activities can have significant impacts to water quality. This section does not provide a comprehensive guide to BMPs for this topic. More detailed information on this topic should be sought when conducting wildfire suppression activities and prescribed fire.

Photo: CSFS

KEY POINTS

1. Prescribed fire and wildfire can be beneficial to resource management goals.
2. Keep slash piles (hand and machine) outside of SMZs and sensitive areas.
3. Use appropriate, low-intensity prescribed fire techniques in SMZs.
4. Maintain and restore firelines and roads used during suppression operations and prescribed fire.
5. Plan and locate fire camps away from sensitive areas.

Applicable BMPs

Protection of soil and water from prescribed burning effects

- Minimize soil erosion. Prevent ash, sediment, nutrients and debris from entering surface water, and maintain **SMZ Applicable BMPs: Installation of stream crossings (p. 45)**

Stabilization of fire suppression-related work damage

- Restore areas disturbed by fire suppression activities

Emergency rehabilitation of watersheds impacted by wildfire

- Apply corrective measures to minimize soil loss, deterioration of water quality, and threats to life and property, both on-site and off-site

Prescribed fire

- Use low-intensity prescribed burns as appropriate in SMZs when needed to address invasive species, improve wildlife habitat or reduce fuel-loading.
- Slash piles should not be placed or burned within SMZs.
- Hand piles should be built in open areas outside of SMZs so that when burned they don't contribute ash to streams.
- Machine piles should be placed on or near landings, well outside of SMZs as they can potentially contribute significant volumes of ash and debris to streams if located near waterways.
- After burning both hand and machine piles, rake nearby forest floor material back over the burned area in order to reintroduce native seed to the area and minimize exposed soil that can be taken over by noxious weeds. If noxious weeds are known to be present, consider seeding as opposed to raking adjacent material.
- Densely vegetated stream corridors are sometimes used as blacklines during broadcast prescribed fire, as they can serve as effective holding locations once they are burned off. However, burning in these dense corridors exposes the stream to increased water temperature due to enhanced solar radiation

on the stream, and the removal of vegetative cover within the SMZ can contribute to stream sedimentation and the introduction of large volumes of ash and nutrients to the stream. Consider blacklining and the construction of holding lines well outside of the SMZ to minimize these impacts to streams.

- When planning prescribed fire, consider fire intensities as the fire moves within densely vegetated draws. Consider prescriptions that ensure minimal soil exposure, allow rapid regeneration of ground cover and maintain drainage bottom stability and resistance to high-intensity rain events.

Fire suppression: Firelines and roads

Stabilize all areas that have significantly increased erosion potential or drainage patterns altered by suppression activities.

Treatments for damage include, but are not limited to, the following:

- Installing waterbars and other drainage diversions in fire roads, firelines and other clear areas
- Seeding, watering, planting and fertilizing to provide vegetative cover

- Spreading slash or mulch to protect bare soil
- Repairing damaged road-drainage facilities
- Clearing stream channels of debris deposited by excessively burned soils
- Scarifying areas where necessary to encourage percolation on excessively burned soils

Fire camps

- Protect surface and sub-surface water resources from nutrients, bacteria and chemicals associated with solid waste and sewage disposal.
- Design and locate fire, spike and logging camps, and their attendant sewage and wastewater disposal facilities, to avoid adverse effects.
- Dispose of garbage and other solid waste at a properly designated, operated and permitted landfill.

Watershed rehabilitation and reclamation

As wildfires continue to burn at high intensities in Colorado, post-fire recovery efforts will remain critical to restoration of critical watershed functions. For more information on post-fire recommendations, see the *Colorado Post-Fire Recovery Playbook* and work with your local experts.

East Troublesome Fire post-fire debris flow. Photo: CSFS

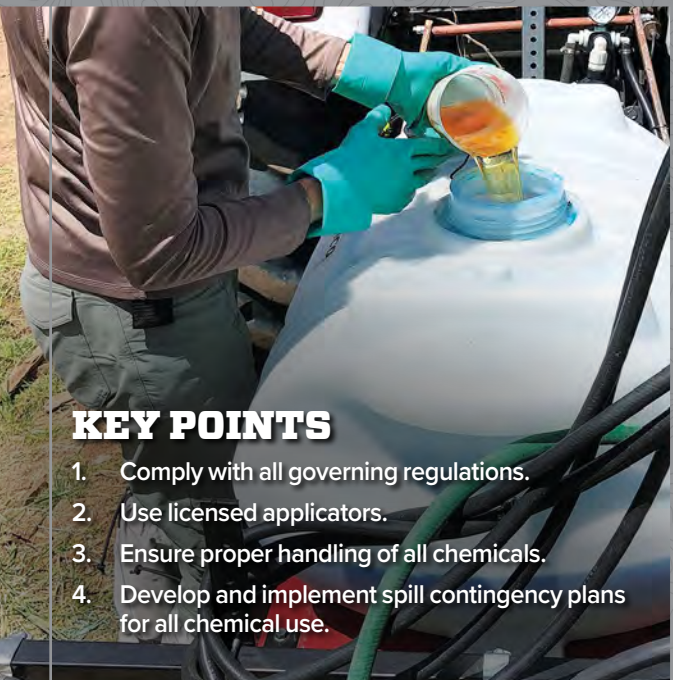
Minimize soil and site productivity loss, threats to life and property, and deterioration of water quality both on- and off-site through these activities:

- Seed grasses or other vegetation to provide a protective cover as soon as possible.
- Fertilize.
- Fence to protect new vegetation.
- Clear debris from stream channels.
- Construct channel-stabilization structures and debris-retention structures.

HAZARDOUS SUBSTANCES & OPERATIONS

Chemicals such as pesticides, insecticides and fertilizers may be important tools to achieving forest management objectives when used appropriately.

Photo: Lucy Bauer, Fireweed Ecological Services LLC



KEY POINTS

1. Comply with all governing regulations.
2. Use licensed applicators.
3. Ensure proper handling of all chemicals.
4. Develop and implement spill contingency plans for all chemical use.

Applicable BMPs

- Know and comply with regulations governing the storage, handling, etc., of hazardous substances
- Select proper sites for servicing and refueling to prevent contamination of waters from accidental spills
- Properly apply pesticide materials and monitor effects
- Properly handle fertilizers to reduce possible adverse effects on water quality

Pesticides and fertilizers

- Be aware of and comply with all regulations governing the storage, handling, application (including licensing of applicators) and disposal of hazardous substances. Pesticide use requires special training and state licensing of applicators. For additional information, contact the Colorado Department of Agriculture.
- Properly handle and apply fertilizers to reduce or eliminate adverse effects on water quality.

- Prevent water contamination and risk to humans and aquatic life by properly cleaning and disposing of pesticide containers. (Cleaning and disposing of containers and equipment must follow federal, state and local laws. Records should document how and where containers are disposed.)
- Improper storage and handling of oil products and fuel can be a water-quality hazard. Locate facilities away from riparian areas and clean up spills.
- Machine maintenance in the forest can result in water contamination. Do not allow waste oil and anti-freeze to drain on the soil; instead dispose of used oils, filters and parts responsibly – pack it out.
- Develop a spill contingency plan, including cleanup, to manage accidental spills.

Prevent the entry of hazardous substances into surface waters

- Always follow chemical label instructions for additional guidance on use near water and buffer zones.
- An adequate vegetative buffer zone is needed to ensure the chemicals are not sprayed or drained into any surface water, either directly or through water runoff.

- If aerial application of pesticide is required, check the label for restrictions.
- Develop a spill contingency plan to handle accidental spills and cleanup.
- To enhance effectiveness and prevent transport into streams, apply chemicals during appropriate weather conditions (generally calm and dry) and during the optimum time for control of the target pest or weed.

Photo: Lucy Bauer, Fireweed Ecological Services LLC

CONCLUSIONS

It's critical that we safeguard the future of our water resources. With the cooperation of all forest users and adherence to the guidelines described in this publication, we can protect the quality of water that flows from Colorado's forested lands.

Best management practices (BMPs) will improve as knowledge of our forests increases over time. Forest managers and timber industry professionals continually develop new techniques and equipment to meet various needs.

Thank you for doing your best to put BMPs to work in Colorado's forests!

Photo: CSFS

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RESOURCES

Colorado Department of Public Health and Environment
Colorado Department of Agriculture
Colorado Forest Restoration Institute
Colorado Parks and Wildlife
Colorado State Forest Service

- Colorado Forest Action Plan
- Colorado Forest Road Field Handbook
- BMP Field Monitoring Reports
- Other Publications

Colorado State University Extension
Colorado Timber Industry Association
Environmental Protection Agency
Local Conservation Districts

For information about ordering this publication contact:

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