BEST MANAGEMENT PRACTICES

FOR

MAINTAINING WATER QUALITY

IN HAWAII

State of Hawaii
Department of Land and Natural Resources
Division of Forestry and Wildlife
February 1996

FOREWORD

Best Management Practices (BMPs) are effective, practical, structural or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects of silvicultural activities. These practices are developed to achieve a balance between water quality protection and the production of wood crops within natural and economic limitations.

A thorough understanding of BMPs and the flexibility in their application are of vital importance in selecting BMPS which offer site specific control of potential nonpoint source pollution. With each situation encountered at various sites, there may be more than one correct BMP for reducing or controlling potential nonpoint source pollution. Care must also be taken to select BMPs that are practical and economical while maintaining both water quality and the productivity of forest land.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500 (and as amended by Sec. 319, 1986), require the management of nonpoint sources of water pollution from sources including forest-related activities. BMPs have been developed to guide forest landowners, other land managers and timber harvesters toward voluntary compliance with this act. Maintenance of water quality to provide "fishable" and "swimmable" waters is central to this law's objectives. The Environmental Protection Agency (EPA) recognizes the use of BMPs as an acceptable method of reducing nonpoint source pollution.

Nonpoint source is diffuse pollution that comes from almost everywhere; it even occurs naturally to a certain extent. The amount of pollutants from any particular spot is small and insignificant, but when combined from over the landscape, can create water quality problems. **Although it is unrealistic to expect that all nonpoint source pollution can be eliminated, BMPs can be used to minimize the impact of forestry practices on water quality. These practices must be reasonable, achievable and cost effective.** The adoption and use of BMPs will provide the mechanism for attaining the following water quality goals:

* to maintain the integrity of stream courses;

* to reduce the volume of surface runoff originating from an area of forest management disturbance and running directly into surface water;

* to minimize the movement of pollutants i.e. pesticides, nutrients, petroleum products, etc. and sediment to surface and ground water;

* to stabilize exposed mineral soil areas through natural or artificial revegetation means.

The intent of this guide is to promote better stewardship of the forest resources. This guide delineates environmentally responsible land management methods which, when applied properly, minimizes adverse impacts on the forest ecosystem and maximizes landowner objectives. Unusual situations may arise or pollution control measures other than those recommended here may be found. In these cases, common sense is most often the best guide.

Information presented in this guide is not to be used as the basis for setting water quality standards or as the basis of required use of watershed protection practices. Compliance with any watershed protection practices would be on a voluntary basis backed up with a public water quality education and awareness program. Changing of water quality standards or the required use of protection practices should not be attempted without careful study of the beneficial effects gained from modifying existing silvicultural practices now in use.

INTRODUCTION

The Division of Forestry and Wildlife (DOFAW) is mandated by HRS, Chapter 183 to "...devise ways and means of protecting, extending, increasing, and utilizing the forests and forest reserves, more particularly for protecting and developing the springs, streams, and sources of water supply to increase and make that water supply available for use..."

The number one resource that is generated by the forest is water. Since the establishment of the Department of Agriculture and Forestry in 1900, the concern for the protection of forest lands for the purpose of water has been a high priority. Fencing to keep out wild cattle and other feral animals and reforestation efforts to re-establish watersheds have been the key to the continuance of the production of high quality water.

In 1961, Hawaii created, by law, the nation's first statewide zoning districts, and today approximately 95% of the Hawaii's four million acres are zoned for agricultural or conservation uses. The Conservation district, which is under the jurisdiction of the Department of Land and Natural Resources (DLNR), encompasses almost one-half of the State, of which one million acres is state-owned. The majority of Conservation lands are covered by forests, but also contain grasslands, coastlines, cliffs, offshore islets, and wetlands. Vegetative communities include lowland and montane rainforests and unique examples of tropical biodiversity, much of it endangered.

The Division of Forestry and Wildlife recognizes the need for responsible stewardship of the natural resources, which include soil and water. **The success of BMPs to protect water quality within Hawaii depends on mutual cooperation and trust among landowners, industry, environmentalists, wood producers, regulatory agencies, governmental officials, and the general public.** All have an interest in good land management as it relates to water quality.

THE FOREST/WATER RELATIONSHIP

The forest and water resources are mutually dependent upon one another. Forests depend on water, namely rain, surface water, and groundwater for their growth and reproduction. Major long-term changes in the water supply can cause permanent changes in the content, quality and vitality of forest lands.

On the other hand, surface and groundwater quantity and quality are largely influenced by the surface on which rain falls and through which it percolates. The tremendous filtering capacity of forest lands provide effective and high quality groundwater recharge.

Hawaii's streams and aquifers all benefit from the presence of forests. In addition to these water quality benefits, forests provide needed wood and fiber products, wildlife habitat, aquatic resources and habitat, recreation values and aesthetic benefits. It is in managing forests for these benefits that damage to the water resource can result. Following is a brief discussion of the most commonly used forest management practices and the impacts they can have on the quality of the water resource.

Timber Harvesting

The removal of trees from a site has little impact on water quality, as long as the trees do not provide vital shade to streams and as long as the slope of the land is not excessive. The natural warmth of many streams can be exaggerated by removing shading vegetation from their banks. Increased water temperature promotes lower dissolved oxygen levels, placing stress on fish and other aquatic organisms.

Removing timber per se does not directly cause significant water quality changes, since ground cover is not excessively disturbed during proper logging operations. On steep slopes, however, careless timber removal can increase the likelihood of runoff and soil loss. This may lead to water quality degradation as well as a loss of site productivity. Steep areas should therefore be logged carefully using proper harvesting techniques for the sake of both water quality protection and site protection.

Road Construction and Drainage Techniques

All facets and phases of a sound forest management program rely heavily on accessibility to the forest. Consequently, temporary and permanent access roads are necessary components of all management programs. They are also one of the most costly investments made in a forests.

Temporary access roads are constructed to facilitate harvesting operations, site preparation and planting and often abandoned after the new stand is established. When abandoned, these temporary roads are normally allowed to revegetate naturally or are planted with trees.

Pollutants from Silvicultural Activities

The major types of water pollutants that can be generated from forest management disturbances to the forest ecosystem include sediment, nutrients, pesticides, and debris.

1) Sediment

Sediment is the most common pollutant resulting from silvicultural activities. Sediment principally results from erosion of soil, but may also include organic matter. Excessive sediment upsets balanced ecology within streams by smothering bottom dwelling organisms in the water, interfering with photosynthesis by reducing light penetration, serving as carriers of nutrients and pesticides, inhibiting fish reproduction and altering stream flow.

2) Nutrients

Nutrients, primarily phosphorous and nitrogen fertilizers, are sometimes applied to the forest to stimulate tree growth. Soluble nutrients may reach surface or ground water through runoff, seepage, and percolation. Insoluble forms may be absorbed on soil particles and reach water by direct wash-off of debris and recently applied fertilizer. Excessive nutrients lead to an imbalance in natural life cycles of water bodies.

3) Pesticides

Pesticides, if applied during silvicultural activities, may be soluble or insoluble. Pesticides in surface or ground water may result in toxicity problems, affecting water quality and food sources for aquatic life.

4) Debris

Tree limbs, tree tops, and other waste materials are the principal organic pollutants from silviculture. They reach streams through direct pushing or felling into water drainages, and washout during storms. Organic materials may place an oxygen demand on the receiving water body during the decomposition process. In addition, associated problems may include odor, color, taste and nutrients. Inorganic material such as oil cans and pop bottles are also considered nonpoint source debris.

BEST MANAGEMENT PRACTICES

1.0 Forest Roads

Standards and Use

Forest roads are managed to provide adequate access to lands for timber management, fire suppression, wildlife habitat improvement and a variety of dispersed and developed recreational activities. Generally, these are low volume roads that must carry heavy loads for short periods of time. The potential for adverse impacts from forest roads exists in areas where steep slopes, erodible soils, or where forest roads are located near water. **Forest roads cause more erosion than any other forestry activity.** Most of this erosion can be prevented by locating, constructing, and maintaining roads to minimize soil movement and pollution of streams. The need for higher standard roads can be alleviated through better road-use management. Design roads to the minimum standard necessary to accommodate anticipated use and equipment.

Planning, Design, and Location

A well planned access system is a sound method of reducing erosion and sedimentation in areas requiring frequent or temporary access. Proper location and construction of roads will provide for safety, longer operating periods, lower maintenance and operating costs, and minimal impacts to water quality. The value of the resource served and site characteristics will influence the choice of road construction standards and maintenance activities. The following practices are recommended:

(1) Use a design to minimize damage to soil and water quality.

(2) Roads should be designed no wider than necessary to accommodate the immediate anticipated use.

(3) Design cut and fill slopes to minimize mass soil movement.

(4) Provide culverts, dips, water bars, and cross drainages to minimize road bed erosion.

(5) Design bridge and culvert installations using stream flow data, with a margin of safety proportional to the importance of the road and the protected resources.

(6) Provide drainage where surface and groundwater cause slope instability.

(7) Avoid diverting water from natural drainage ways. Dips, water bars, and cross drainage culverts should be placed above stream crossings so that water can be filtered through vegetative buffers before entering streams.

(8) Locate roads to fit the topography and minimize alterations to the natural features.

(9) Avoid marshes and wetlands.

(10) Minimize the number of stream crossings.

(11) Cross streams at right angles to the stream channel.

(12) A road may not be located in a Streamside Management Zone (SMZ) except where access is needed to a water crossing, or where there is no feasible alternative. A road in any SMZ must be designed and located to minimize adverse effects on fish habitat and water quality.

Construction

Once the road's location and design is staked out, road construction begins. Timber is out, logs and vegetation are removed and piled along the lower side of the right-of-way.

Most forest roads are built by excavating a road surface. Road design and layout on-the-ground show machine operators the proper cut slopes and indicate cut slope steepness. The bulldozer starts at the top of the cut slope, excavating and sidecasting material until the desired road grade and width is obtained. Material from cuts is often pushed in front of the blade to areas where fill is needed. Road fill is used to cover culverts and build up flat areas. Since fill must support traffic, it needs to be spread and compacted in layers to develop strength. The following practices are recommended:

(1) Construct roads when moisture and soil conditions are not likely to result in excessive erosion or soil movement.

(2) The boundaries of all SMZs shall be defined on the ground prior to the beginning of any earth-moving activity.

(3) Construct a road sufficient to carry the anticipated traffic load with reasonable safety and with minimum environmental impact.

(4) When using existing roads, reconstruct only to the extent necessary to provide adequate drainage and safety.

(5) Avoid construction during wet periods, when possible, to minimize unnecessary soil disturbance and compaction.

(6) Road grades should be kept at less than 10%, except where terrain requires short, steep grades.

(7) Minimize the number of stream crossings. Stream crossing construction should minimize disturbance of the area in which the crossing is being constructed.

(8) As slope increases, additional diversion ditches should be constructed to reduce the damages caused by soil erosion; ditches, adequate culverts, cross drains, etc., should be installed concurrent with construction.

(9) To control erosion, cut and fill slopes should conform to a design appropriate for the particular soil type and topography.

(10) Stumps, logs, and slash should be disposed of outside of the road prism; in no cases should they be covered with fill material and incorporated into road beds.

(11) Stabilize the side banks of a road during construction to aid in the control of erosion and road deterioration; this may require mesh or other stabilizing material in addition to planting and/or seeding and other structural measures.

(12) Water bars should be located to take advantage of existing wing ditches and cross drainage. Water bars should be constructed at an angle of 30 to 45 degrees to the road. Water bars should be periodically inspected and damage or breeches should be promptly corrected. Install water bars at recommended intervals to provide the drainage. Water bar spacing recommendations are as follows:

Grade of Road	Distance Between Water bars
2%	250 ft.
5%	135 ft.
10%	80 ft.
15%	60 ft.
20%	45 ft.
25%	40 ft.
30%	35 ft.
40%	30 ft.

Water bars may need to be spaced closer together depending on soil type and rainfall.

(13) Bridges and overflow culverts should be constructed to minimize changes in natural stream beds during high water.

(14) Culverts on perennial streams should be installed low enough to allow passage of aquatic life during low water.

Maintenance

Maintenance of active and inactive roads shall be sufficient to maintain a stable surface, keep the drainage system operating, and protect the quality of streams. The following are recommended:

(1) Maintenance should include cleaning dips and crossdrains, repairing ditches, marking culverts inlets to aid in location, and clearing debris from culverts.

(2) Keep culverts, flumes, and ditches functional before and during the rainy season to diminish danger of clogging and the possibility of washouts. This can be done by clearing away any sediment or vegetation that could cause a problem. Provide for practical and scheduled preventative maintenance programs for high risk sites that will address the problems associated with high intensity rainfall events.

(3) Conduct road surface maintenance as necessary to minimize erosion of the surface and subgrade.

(4) During operations, keep the road surface crowned or outsloped, and keep the downhill side of the road free from berms except those intentionally constructed for protection of fill.

(5) Avoid using roads during wet periods if such use would likely damage the road drainage features.

(6) Water bars should be inspected after major rain storms and damage or breeches should be promptly corrected.

Harvesting - Temporary Access Roads and Landings

(1) The location of temporary access roads (logging roads) should be planned before operations begin.

(2) Road construction should be kept to a minimum.

(3) Landings should be located to minimize the adverse impact of skidding on the natural drainage pattern.

(4) Logging roads and landings should be located on firm ground.

(5) Landings should be kept as small an area as possible.

(6) When operations are completed, provisions should be made to divert water run-off from the landings and roads.

2.0 Pre-Harvest Planning

Pre-harvest planning is the collection of information about the area to be harvested and the synthesis of that information into an effective environmental plan. This plan will consider the silvicultural prescription for the species and site, the best estimate of the time and method of harvest and any post-harvest site preparation and reforestation activities.

At this stage, it is assumed that all federal, state, and local government regulations regarding harvesting have been met.

An effective pre-harvest plan will take into consideration all aspects of the timber harvest which may lead to water quality degradation and plan for the implementation of BMPs which will minimize or avoid the adverse effects of the operation. The objective of pre-harvest planning from the perspective of non-point source pollution is to determine which BMPs are necessary to protect water quality and how those BMPs will be implemented. The following is recommended:

(1) A pre-harvest plan should include the following information:

A. Physical and administrative description

1. Property boundaries & administrative boundaries (zoning, etc.)
2. Topography
3. Location of streams and drainages
4. Location of SMZs and buffer strips
5. Forest types
6. Soil types
7. Areas of ecological and/or archaeological concerns

B. Management Activities

1. Design and construction techniques for all new roads, skid trails, and landings or modification of existing roads, skid trails and landings.
2. Felling and bucking techniques
3. Yarding systems and layout
4. Planned stream crossings
5. Disposal of waste materials (machine lubricants)
6. Post-harvest site preparation
7. Reforestation activities

(2) The use of topographic maps, road maps, aerial photos, forest type maps, and soil surveys in combination with field reconnaissance is essential to determine site conditions and plan operations.

(3) Field reconnaissance with a trained forester or one who is knowledgeable about the specific area is highly recommended.

(4) Preliminary planning should consider the maintenance of existing drainage patterns and the location of environmentally sensitive areas such as streams, wet areas, and high erosion hazard areas.

(5) The design of roads, skid trails, and landings shall be integrated to minimize their impact.

(6) The grade of logging roads and skid trails should be less than 10% when possible, with 3-5% being the norm. Long, straight, unbroken grades are to be avoided. Adequate surface drainage shall be provided.

(7) Time the harvesting activity for the season or moisture conditions when the least impact occurs.

(8) A final pre-harvest site review shall be conducted by management so that road alignments and other considerations can be visually checked prior to road construction. The reconnaissance plan shall be modified as necessary to make desirable adjustments based on the final site review.

2.1 Timber Harvesting

Standards and use

Timber harvesting is an integral part of most forest management programs. Harvesting operations cause a temporary disturbance in the forest as well as diminish water quality. However, it can be conducted in a manner where the impact to water quality is minimized and the re-establishment of vegetative cover is realized. Guidelines to help reduce the potential for nonpoint source pollution from harvesting trees are as follows:

Felling and Bucking

(1) Careful felling can minimize the impact of subsequent phases of the logging operation.

(2) Trees should not be felled into streams, except where no safe alternative exists. In the latter case, such trees should be removed promptly.

Skidding

(1) Skidding should be done so as to avoid disrupting natural drainage and to prevent excessive soil displacement.

(2) Stream channels or road ditches should not be used as skid trails.

(3) Skid trails on steep slopes should have occasional water bars.

(4) Servicing of equipment involving fuel, lubricants, or coolants should be performed in places where these materials cannot enter streams. Spent oil should be collected for proper disposal, never poured on the ground.

(5) Upon completion of logging, erosion-prone areas should be mulched or seeded.

Mechanical Site Preparation

(1) Avoid excessive soil compaction.

(2) Minimize erosion and the movement of sediment into waters.

(3) Prevent accumulation of debris in ponds, streams, or rivers.

(4) Windrows, disking, bedding, and planting with "furrow" type mechanical planters should follow contours.

(5) Avoid complete disking of steep slopes with extremely erodible soil.

(6) Plant trees on contour.

Disposal of Debris and Litter

(1) Logging debris in streams should be removed immediately.

(2) Debris from landings should not be pushed into drains, streams or Streamside Management Zones (SMZs)

(3) All trash associated with the logging operation should be promptly removed (not buried) and hauled to a legal disposal site.

3.0 Silvicultural Chemical Management

Description and Purpose

Pesticides are used on forest lands to facilitate meeting forest management objectives. The purpose of a pesticide application is to rid an area of undesirable vegetation or control insects or diseases to promote the establishment, survival, growth or maintenance of a desired species or condition.

Planning Considerations

Planning is an essential first step in reducing pest problems. A plan is needed by which the application of pesticides is utilized in an efficient manner that produces no adverse impacts on the environment. The maintenance of water quality is an important consideration in all aspects of pesticide operation planning.

Pesticide Selection

When the decision is made to use pesticides, choose products suitable for use on the target species and registered for the intended uses. Use only pesticides registered by the Environmental Protection Agency. Prior to using any pesticide, carefully read and follow all label directions.

When selecting pesticide options, more than effectiveness and cost should be evaluated. Consideration should be given to site factors, application conditions and techniques and products that can influence impacts to water quality.

Three main characteristics can greatly affect a pesticide potential to contaminate surface or ground water. They are solubility, absorption and breakdown rate.

1) Solubility

Solubility is the ability of a pesticide to dissolve in water. The greater the solubility, the greater the chance that the chemical will leach to ground water.

2) Absorption

Absorption is the inherent ability of a pesticide to bind with soil. Some pesticides stick very tightly to soil while others are easily dislodged. A greater absorption means a pesticide will remain longer in the soil and thus be less likely to leach down into the ground water before it has degraded. Absorption increases as soil organic matter increases.

3) Breakdown Rate

Breakdown rate or half-life is the time a pesticide takes to degrade or breakdown into other chemical forms. Pesticides that do not break down quickly can be hazardous if they move to ground water or surface water.

In a given situation, pesticides with the highest water solubilities, greatest persistence, lowest affinities for absorption to organic matter and other soil components, and highest application rates have the greatest potential for movement in surface water or to ground water. An alternative means of minimizing the potential movement of a pesticide is to select a non-broadcast application

technique for the same pesticide that reduces the amount of the chemical applied directly to the soil.

Procedures for Chemical Use

Proper pesticide management practices make efficient use of chemical while preventing contamination of surface water or ground water. Residues of pesticides used in forestry can affect water quality at several phases of the chemical use cycle. These phases are: 1) transportation, 2) storage, 3) mixing and loading, 4) application, and 5) cleanup and disposal. To minimize potential impacts on water quality, use of the following practices is encouraged.

A) Transportation

(1) Inspect all containers prior to loading and ensure all caps, plugs and bungs are tightened.

(2) Handle containers carefully when loading them onto vehicles.

(3) Secure containers properly to prevent shifting during transport.

(4) Check containers periodically enroute.

(5) Limit access to containers during transport to prevent tampering.

(6) Educate and inform the driver of the proper transportation precautions.

(7) Never transport pesticides unless arrangements have been made to receive and store them properly.

B) Storage

(1) Chemicals should be managed and stored in accordance with all applicable federal, state, or local regulations. These would include:

(a) The EPA container registration label, as printed on the label;

(b) Label instruction for use as provided by the manufacturer;

(c) Requirements or the use, application, and registration of pesticides;

(d) Requirements relating to the licensing of applicators.

(2) All containers should be labeled in accordance with applicable federal, state and local regulations.

(3) Apply pesticides under favorable weather conditions. Never apply a pesticide when there is a likelihood of significant drift.

(4) Always use pesticides in accordance with label instruction, and adhere to all Federal and State policies and regulations governing pesticide use.

E) Cleanup and Disposal

(1) Before disposal, containers should be rinsed as described in equipment cleanup.

(2) Cleanup should be in a location where chemicals will not enter any stream, pond, or where stream pollution might occur.

(3) Rinse empty pesticide containers and mixing apparatus as many times as needed. This flushing should be applied in spray form to the treated area, NOT into the ground near streams.

(4) Dispose of pesticide wastes and containers according to federal and state laws. Some pesticide wastes are specifically identified as hazardous wastes by law and must be handled and disposed of in accordance with hazardous waste regulations. For more information about proper management of waste pesticides, contact the Department of Health, Environmental Health Administration.

Other chemicals

Improper storage and handling of oil products and fuel can be a water quality hazard. Improper disposal of oil or fuel can contaminate ground water and seep into streams. The following are recommended:

(1) Locate facilities away from streams and be prepared to clean up spills.

(2) Know and comply with regulations governing the storage, handling, application (including licensing of applicators), and disposal of hazardous substances.

(3) Do not transport, handle, store, load, apply or dispose of any hazardous substance or fertilizer in such a manner as to pollute water supplies or cause damage or injury to land, including humans, desirable plants and animals.

(4) Do not store, mix, or rinse hazardous substances or fertilizers within the streamside management zone or where they might enter streams or waterways.

(5) Develop a contingency plan for hazardous substance spills, including cleanup procedures.

(6) Report all spills to the Department of Health, Environmental Health Administration.

4.0 Streamside Management Zone (SMZ)

The Special Management Zone (SMZ) is a specific area associated with a stream, lake, wetland or other waterbody that is designated and maintained during silviculture operations. The purpose of the SMZ is to protect water quality by reducing or eliminating forestry related ouputs, i.e. sediment, nutrients, logging debris, chemicals, and water temperature fluctuations that can adversely affect aquatic communities. SMZs provide shade, streambank stability and erosion control, as well as detritus and woody debris which benefit the aquatic ecosystem in general. In addition, the SMZ is designed to maintain certain forest attributes that will provide specific wildlife habitat values. Snags, den and cavity trees as well as mast producing trees, left in the SMZ, are necessary to meet habitat requirements for certain wildlife.

The SMZ has specific criteria, that defines operational restrictions and special management objectives. In addition, the SMZ has a specific width which is based on the size and type of waterbody involved.

A Streamside Management Zone (SMZ) is an area covered with vegetation or ground cover on both sides of perennial, intermittent streams and other bodies of open water, where extra precaution is used in carrying out forest management practices. The SMZ also provides shade and functions as a buffer when fertilizers, pesticides, etc. are applied to adjacent lands. For practical purposes, an SMZ must be wide enough to protect water quality and stream characteristics. Precaution is needed in carrying out forest management practices in order to protect bank edges and water quality. Determining the necessary width involves in part a judgement factor based on reliable local experience.

SMZs should be used where: 1) water quality is impaired and adjacent land use contributes to that degradation, 2) good water quality exists and protection against potential future impairment is desired, 3) streambank erosion is a concern, 4) wildlife habitat enhancement is desired, and/or 5) silviculture practices are to be implemented, and 6) the lower edge of cropland, grassland, or forest land is adjacent to permanent or intermittent streams, or border streams, rivers, ponds or intermittent or permanently flooded, open-water wetlands.

SMZ benefits include the following:

(1) Shade - Trees within the SMZs provide shade to maintain cool water temperatures which aid in the spawing of fish. Without trees and overhanging shrubs, stream temperatures would increase during the summer. Some fish species and aquatic organisms would then be unable to live in the streams. In the summer, water from shaded streams eventually flows into larger bodies of water and helps maintain its fish and aquatic life by keeping these waters cool all the way downstream.

(2) Food - Leaves and insects drop into streams from overhanging trees and shrubs. In fact, 90% of the food in the forested streams comes from bordering vegetation.

(3) Protection of Streambanks - Many streambanks are stabilized by streambank trees. They anchor banks and prevent erosion during periods of high water. Removing trees and shrubs and substituting shallow rooted grasses can lead to streambank collapse and stream sediment. Bank overhang is created by stream flows undercutting the stream bank and tree roots. Fish can rest, hide from predators, and feed in these protected areas.

(4) Flooding - Healthy SMZs stabilize floodplains. During times of high water, SMZs reduce the velocity of floodwaters. Their dense vegetation and deep humus slow down racing waters. Forest floodplains suffer less damage when SMZs are protected during harvesting activities.

(5) Recreation - The recreational activities that we enjoy in and around streams are many. This includes swimming, fishing, camping, hunting, and backpacking to name a few.

(6) Timber Production - For those who grow and harvest trees, the fact is that trees often grow best in SMZs. Trees respond to those deep, fertile, and moist soils. Logging activities should not be eliminated within SMZs but modified to insure that stream channels and banks are protected from disturbance. SMZs are not timber harvest "keep out" zones, but there are locations where timber harvesting activities must be modified to protect the many benefits mentioned above.

Recommendations

SMZs should be maintained along all perennial streams or where forest disturbances occur and surface runoff will carry sediment loads. SMZs should be maintained around streams, ponds, perennial flowing natural springs, and all springs and reservoirs serving as domestic water supplies. The following best management practices are recommended:

(1) The width of SMZs should be determined depending on the following conditions: slope of land adjacent to stream, soil erodibility, precipitation, knowledge of particular area, sensitivity of stream, etc. These factors can be obtained from soil maps, on-the-ground evaluation and measurements, weather data, etc.

(2) SMZs should be designed on a case-by-case basis. Most important is that SMZs be consistent with stream characteristics and wide enough to protect water quality.

Soil Type	Percent Slope	SMZ Width (each side)
Slightly erodible	0-5	35'
Slightly erodible	5-20	35-50'
Slightly erodible	20+	50-160'
Erodible	0-5	35-50'
Erodible	5-20	80' minimum
Erodible	20+	160' minimum

Table 1. Recommended Widths for Streamside Management Zone

[NOTE: Please contact your local Natural Resources Conservation Service office to determine the erodibility factor of the soil before determining the proper width of the SMZ.]

(3) On relatively flat terrain (0-5%) on slightly erodible soils, the width of an SMZ should be at least 35 feet wide on each side of a stream.

(4) On relative flat terrain (0-5%) on erodible soils, the SMZ width should range between 35 to 50 feet on each side of a stream.

(5) On slightly erodible soils with slopes ranging between 5 and 20 percent, the SMZ width should range between 35 to 50 feet wide on each side of a stream.

(6) On erodible soils with slopes ranging between 5 and 20 percent, the SMZ width should range between 50 to 160 feet on each side of a stream.

(7) On slightly erodible soils with slopes exceeding 20 percent, the SMZ width should be at least 80 feet on each side of a stream.

(8) On erodible soils with slopes exceeding 20 percent, the SMZ width should be a minimum of 160 feet on each side of a stream.

(9) Partial harvesting is acceptable. A minimum of 50% of the original crown cover or 50 square feet of basal area per acre, evenly distributed, should be retained in the SMZ. This may be adjusted to meet on-site conditions.

(10) Clearcutting is always prohibited within the SMZ.

(11) Designate SMZs to provide stream shading, soil stabilization, sediment and water filtering effects, and wildlife habitat.

(12) Strive to protect the forest floor and understory vegetation from unnecessary damage. Do not remove (harvest) trees from banks, beds or slopes if it will destablilize the soil. Trees on the south and west banks provide the most critical shading of water.

(13) Access roads should cross perennial or intermittent streams at or near a right angle.

(14) Drainage structures such as ditches, cross drain culverts, water bars, rolling dips, and broad-based dips should be used on all roads prior to their entrance into an SMZ to intercept and properly discharge runoff waters.

(15) SMZs may be desirable on intermittent streams for large drainage areas where wildlife is a major landowner concern or for other reasons.

5.0 Fencing

(1) Fencing out livestock, pigs, and other animals in certain areas will help to prevent water quality degradation of streams, protect threatened and endangered plants, reduce soil compaction and maintain soil productivity. Fencing is applicable where desired forest reproduction, soil hydrologic values, existing vegetation, aesthetic values, and recreation are prevented or damaged by these animals.

(2) Pastures should be fenced separately from woodlands. Consider maintenance as well as ease of construction when planning a fence location. By taking advantage of natural barriers such as cliffs, the cost of animal exclusion can be reduced. Also consider use of fences to protect vegetation that provides wildlife food and cover.

(3) Fences should be permanent stock fences built in accordance with good construction principles and workmanship.

6.0 Wildfire Damage Control and Reclamation/Prescribed Burn

The prevention, control, and extinguishment of all wildfires on grass, brush, and watershed lands and the implementation of a prescribed fire program is a desirable goal. Where wildfires do occur, the first and foremost concern is to control the fire and limit the damage. Fire suppression activities can add to the problem of water quality protection.

The loss of vegetative cover, destruction of soil-holding feature of root masses, the exposure of bare mineral soil, is a combination that makes the area burned a highly erodible one. The effects of suppression efforts and equipment operations necessary to control and stop the fire can magnify the erosion problem.

The following are best management practices for wildfire control and reclamation:

(1) The first and foremost concern in wildfire control is to prevent harm or damage to people and property. Fireline best management practices should incorporate minimum impact strategies, which meet land and resource management objectives;

(2) Areas with bare mineral soils should be revegetated and areas where vegetative cover has been killed or severely degraded should be regenerated with plant species appropriate for the soil conditions;

(3) First priority for revegetation/reforestation should be given to banks of surface water bodies so that the SMZ is reestablished;

(4) Firelines should be stabilized and, if necessary, revegetated. Erodible areas altered by suppression equipment activities should be repaired and revegetated as necessary;

(5) Access road surfaces should be repaired and stabilized as necessary.

(6) Whenever possible, avoid using fire suppression chemicals over watercourses and prevent their runoff into watercourses. Do not clean application equipment in watercourses or locations that drain into watercourses.

(7) Provide advance planning and training for firefighters that considers water quality impacts when fighting wildfires. This can include increasing awareness so direct application of fire suppression chemicals to waterbodies is avoided and firelines are appropriately placed.

(8) Include rehabilitative practices as part of suppression and post-suppression tactics and strategies to mitigate non-point source pollution.

6.1 Fireline Construction and Maintenance

Fireline construction and maintenance is an essential part of forest and other land management activities. It deals with site preparation burning, prescribed burning, and wildfire defense and control. A number of control practices can be implemented during fireline construction to prevent unnecessary erosion. Periodic inspection and proper maintenance can prevent potential erosion on established firelanes. The following are best management practices for fireline construction and maintenance:

(1) Firelines should be constructed on the perimeter of the burn area and along the boundary of the Streamside Management Zone. The purpose of protecting the Streamside Management Zone from fire is to safeguard the filtering effects of the litter and organic matter;

(2) Firelines should follow the guidelines established for logging trails and skid trails with respect to waterbars and wing ditches, and should be only as wide and as deep needed to permit safe prescribed burns or fire suppression needs;

(3) Firelines which would cross a drainage should be turned parallel to the stream or have a wing ditch or other structure allowing runoff in the line to be dispersed rather than channeled directly into the stream.

(4) All firelines should be assessed after the fire is controlled for appropriate stabilization, and if necessary, proper rehabilitation should be done while equipment and people are in place.

6.2 Prescribed Burn

(1) Intense prescribed fire for site preparation shall be conducted only if it achieves desired results with minimum impacts to water quality.

(2) Burning on steep slopes or highly erodible soils should be conducted when they are absolutely necessary and should follow carefully planned prescriptions.

(3) Carefully plan burning to adhere to time of year, weather, topography, and fuel conditions that will help achieve the desired results and minimize impacts on water quality. With proper planning, prescribed fires should not cause excessive sedimentation due to the combined effect of removal of canopy species and the loss of soil-binding ability of the subcanopy and herbaceous vegetation roots, in streamside vegetation, small ephemeral drainages, or on very steep slopes.

(4) Site preparation burning creates the potential for soil movement. Burning in the SMZ reduces the filtering capacity of the litter. All efforts should be made to plan burns to minimize impacts on the SMZ.

(5) All bladed firelines, for prescribed fire and wildfire activities, should be built so as to minimize erosion. If necessary, the firelines should be stabilized with water bars and/or other appropriate techniques to control excessive sedimentation or erosion of the fireline. Include any erosion control practices in the construction of firelines.

7.0 Reforestation

Reforestation refers to those operations undertaken to establish a new forest. Site preparation, for the purpose of forest regeneration, is a basic silvicultural tool where for competing vegetation and

reduction of logging debris are necessary. Common site preparation techniques include, manual, mechanical, fire, and herbicides.

Regeneration includes hand and machine planting and direct seeding. Since hand planting and direct seeding pose no water quality problems, BMPs are not necessary. Some mineral soil exposure does occur with machine planting and BMPs are offered.

1) Sites should receive the minimum preparation necessary to successfully control competing vegetation and establish a desirable timber stand. In general, the more intensive the treatment, the more concern for water quality.

2) When working on slopes, mechanical operations such as ripping, shearing, etc., should follow contours.

3) Hand planting, direct seeding or natural regeneration should be used on protected areas adjacent to streams or on slopes too steep to machine plant.

APPENDICES

1. Definition of Terms
2. Road Construction Applications
3. Streamside Management Zone
4. Available Assistance
5. Suggested Readings

definition of terms

DEFINITION of TERMS:

Best Management Practices -- effective, practical, structural or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects of silvicultural activities. These practices are developed to achieve a balance between water quality protection and the production of wood crops within natural and economic limitations.

Bucking -- to saw felled trees into predetermined lengths.

Clearcutting -- the removal of all standing trees within a designated area.

Cross drain -- a cross ditch used to move water from one side of the road to the other side to prevent accumulation of runoff without the need of a culvert or bridge.

Culvert -- a conduit through which surface water can flow under roads.

Diversion ditch - a ditch built across the top of a slope to divert surface water from that slope.

Felling -- the process of severing trees from stumps.

Firebreaks -- naturally occurring or man-made barriers preventing the spread of fire.

Fireline construction -- the construction of a barrier used to prevent the spread of fire.

Intermittent streams -- streams that provide water flow continuously during some seasons of the year but little or no flow during the remainder of the year.

Landing -- an area in the field where logs are collected.

Non-point source -- a source of water pollution which are induced by natural processes, including precipitation, seepage, percolation, and runoff; and not traceable to any discrete or identifiable source.

Perennial streams -- streams which provides water flow at all times except during extreme drought.

Pesticides -- any herbicide, insecticide, or rodenticide, but does not include non-toxic repellents or other chemicals.

Pre-commercial thinning - the removal of selected trees within an established forest destined for commercial use.

Prescribed burning -- the controlled application of fire as a management tool in forest management.

Reforestation -- the successful reestablishment of tree species following harvest.

Silvicultural practices -- all forest management practices, including the establishment, composition, constitution, and growth of forests.

Site preparation -- the removal of unwanted vegetation and other material prior to reforestation.

Skid trails -- routes over which logs are moved to a landing or road.

Streamside Management Zone -- an area on each side of the banks and above the head of intermittent streams, perennial streams, and other drains or bodies of water where extra precaution in carrying out best management practices is needed to protect bank edges and water quality.

Waterbar -- a cross drainage diversion ditch and/or hump in a trail or road for the purpose of diverting surface water runoff into roadside vegetation, duff, ditch, or dispersion area to minimize the volume and velocity which can cause soil movement and erosion.

Wetlands -- geographic areas that are inundated or saturated by surface or groundwater at a frequency or duration sufficient to support (and under normal circumstances do support) a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wing ditch -- a water turnout or diversion ditch constructed to move and disperse water away from the road and side ditches into adjacent undisturbed areas so that the volume and velocity of water is reduce on slopes.

Yarding -- the method of log transport from the harvest area to the storage area.

BROAD BASED DIPS

Definition:

A dip and reverse slope in a truck road surface with an outslope in the dip for natural cross drainage.

Purpose:

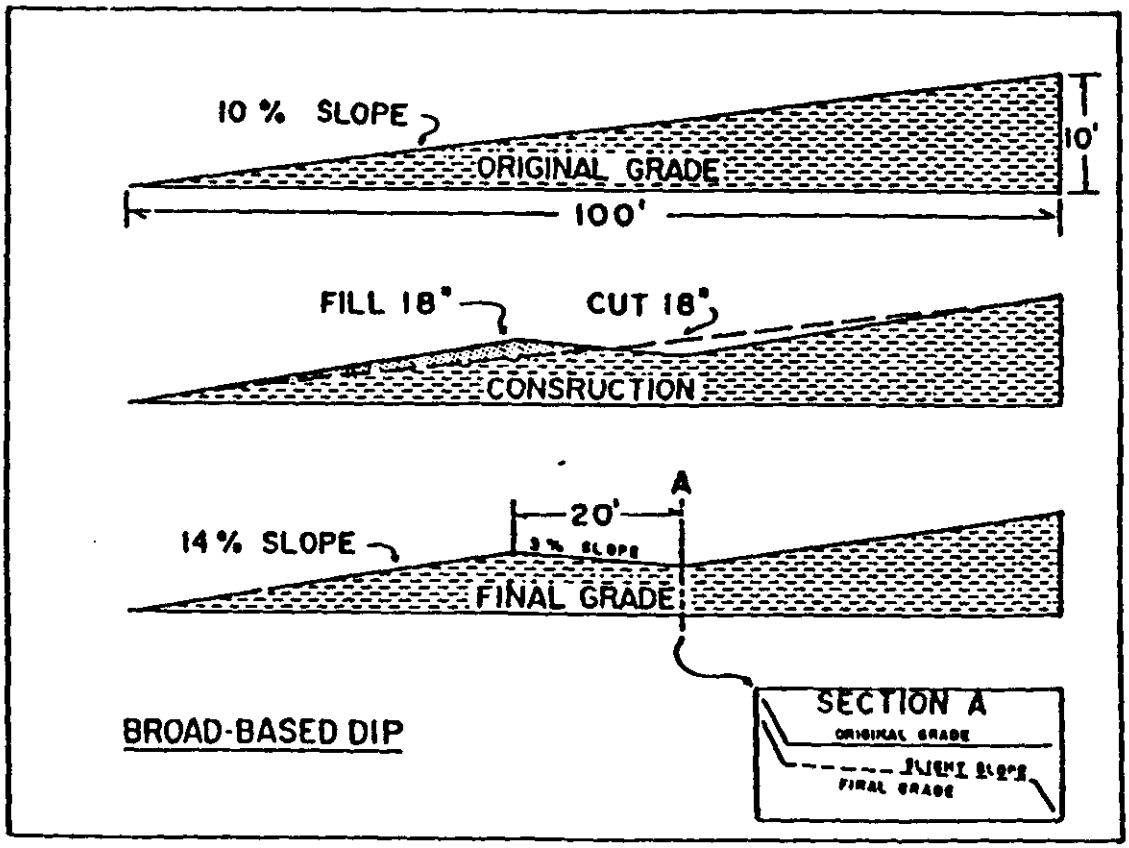
To provide cross drainage on insloped truck roads to prevent build-up of excessive surface runoff and subsequent erosion.

Conditions Where Practice Applies:

Use on truck roads and heavily used skid trails having a gradient of 10% or less. May be substituted for other cross drainage structures where no intermittent or permanent streams are present.

Guidelines:

* Proper construction requires an experienced bulldozer operator.
* Installed after the basic roadbed has been constructed and before major hauling use.



- On grades steeper than 8%, surface dips with stone (approx. 3" diameter) or gravel.
- Use dips on approaches to steep declines in heavily used skid trails.
- Discharge area should be protected with stone, grass sod, heavy litter cover or slash and logs to reduce the velocity and filter the water.

SPACING FOR BROAD BASED DIPS

Road Grade (percent)	Spacing Between Dips (feet)
2	300
4	200
6	165
8	150
10	140
12	130

WATER BARS

Definition:

An earthen or reinforced berm constructed across a truck road or skid trail.

Purpose:

To intercept and divert water from side ditches and truck road or skid trail surfaces, therefore minimizing erosion by decreasing the slope length of surface water flow.

Conditions Where Practice Applies:

Utilized on any sloping truck road or skid trail where surface water runoff may cause erosion.

Guidelines:

* Start placement of water bars at the farthest skid trail and work back to the log landing and then to the truck road.
* Install water bars with a skidder blade, dozer blade, or by hand.
* Install water bars at the top of any sloping road or trail and at proper spacing along steep sections.

* Water bars may be shallow or deep depending on the need.

* Soil should be left along the lower side of the water bar.

* Should be constructed at a 30° - 35° angle downslope from a line perpendicular to the direction of the truck road or skid trail.

* Should drain at a 3% outslope onto undisturbed litter or vegetation.

* The uphill end of the water bar should extend beyond the side ditch line of the road or trail to fully intercept any water flow.

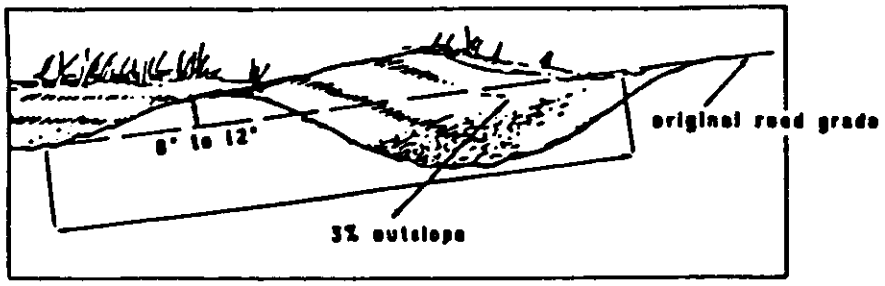
* The downhill end of the water bar should be fully open and extended far enough beyond the edge of the road or trail to disperse runoff water onto undisturbed forest floor.

* Place rocks, slash, or logs to disperse water coming from a water bar.

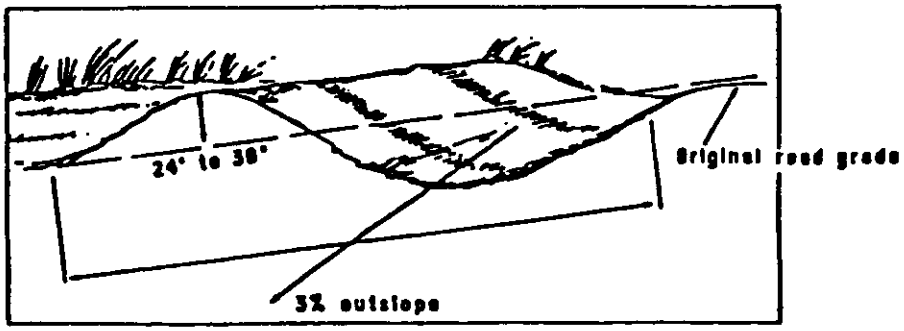
* If the road or trail is to be kept open after the harvesting operation, the following guidelines should be used in order to preserve effective water bars.

  - Reinforce the water bars
  - Keep travel to a minimum
  - Use only in dry weather
  - Make frequent inspections
  - Maintain as needed

SHALLOW WATER BAR



DEEP WATER BAR



SPACING FOR WATER BARS

Road/Trail Grade (percent)	Spacing Between Water Bars (feet)
2	250
5	135
10	80
15	60
20	45
30	35

CROSS DRAINAGE CULVERTS

Definition:

Corrugated pipe, well casing, dredge pipe, or other suitable material placed under a truck haul road or major skid road to transmit ditch runoff and seeps from a drainage area of less than 10 acres.

Purpose:

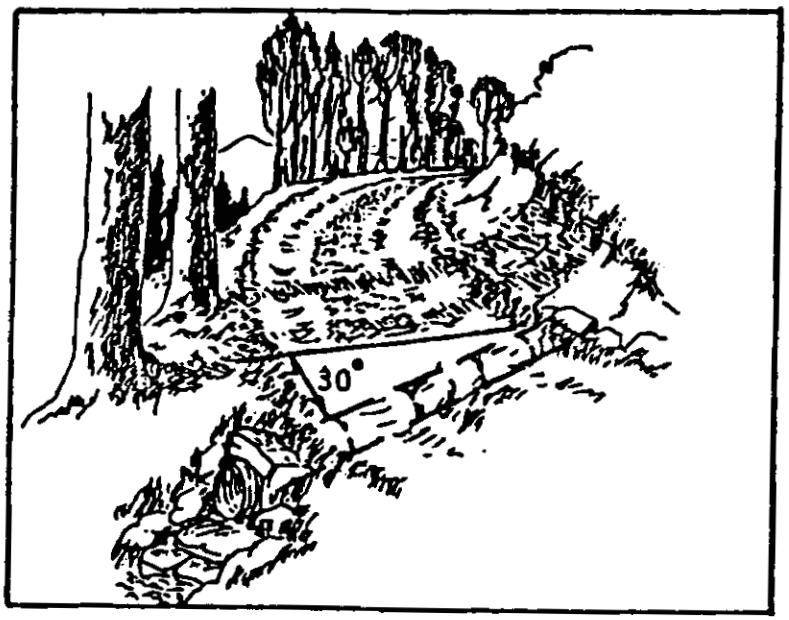
To collect and transmit water flows from side ditches and seeps, under truck haul roads and major skid trails safely without eroding a drainage system or road surface.

Conditions Where Practice Applies:

For any size operation where cross drainage of storm water is required temporarily or permanently.

Guidelines:

* This is the most expensive method of road cross drainage and should be used where heavy road use is anticipated during and after the harvesting operation.



* When sizing culverts for temporary roads, allow for periods of high flow, such as spring runoff or cloudbursts.

* The minimum size culvert to be installed is 12 inch diameter and 20 feet in length.

- When constructing roads on sidehill locations, ditch uphill side of the roadway to intercept surface runoff.

- Allow inlet end of culvert to extend into side ditch so that it intercepts water flowing in the ditch. Construct a berm across the side ditch to assist in diverting water into the culvert.

- Allow outlet end of culvert to extend beyond any fill and empty onto an apron of rock, gravel or logs.

- Space culverts according to road grade:

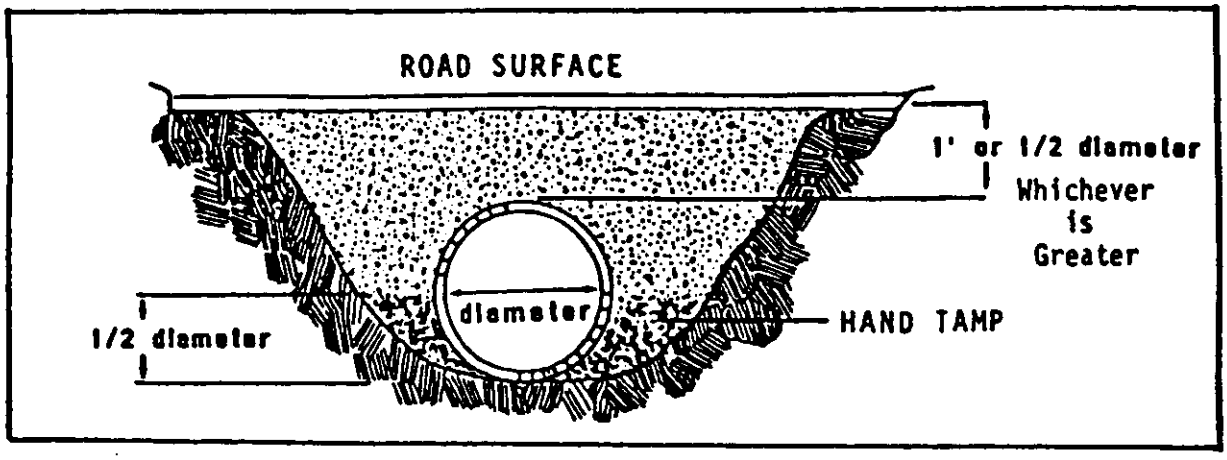
On gentle slopes (1-2%)	300 feet
On moderate slopes (3-10%)	150 feet
On steep slopes (10%+)	100 feet or less

- Culverts should be installed at a 30-35 degree angle downgrade.

- Culverts should be sloped at least 5 inches for every 10 feet of length to permit self-cleaning.

- When harvesting operation has been completed, the road should be stabilized by installing water bars and removing all pipe culverts from truck roads which will not be maintained.

- Culverts, when not maintained, are very likely to become blocked with rocks, ice or other debris. Runoff water can become rerouted over and around the culvert and may wash out sections of road into brooks, streams, ponds or wetlands. It is important to clean culverts regularly. Check after every storm.



- Culvert size selection should be based on the size of the drainage area of a forested watershed and should be able to handle the largest flows.

- Estimating drainage area by taking measurements on a USGS topographic map, using contour lines to define the drainage limits. The Soil Conservation Service can assist you with determination of drainage area.

OPEN TOP CULVERTS

Definition:

A wooden culvert placed across truck haul roads to convey surface runoff and side ditch flows across to downslope side.

Purpose:

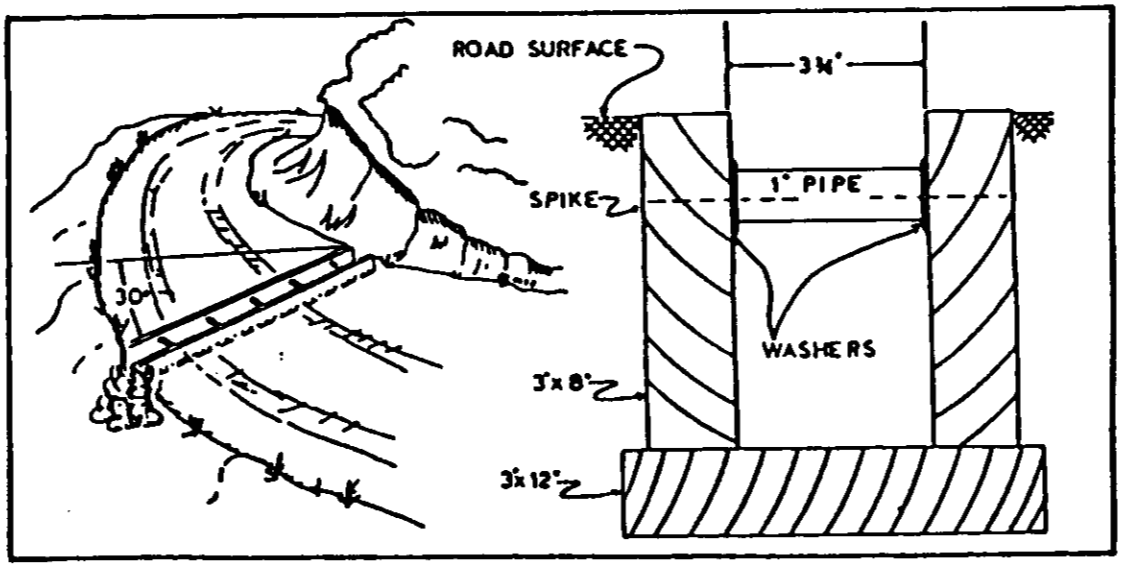
To collect and direct road surface storm runoff and upslope side ditch flows across road without eroding drainage system or road surfaces.

Conditions Where Practice Applies:

This is a temporary drainage structure for on-going harvesting operations. Property built and maintained, it can be used for cross drainage on roads of smaller operations as a substitute for a pipe culvert. This practice should not be used for handling intermittent or live streams or skid trail cross drainage.

Guidelines:

* Can be constructed of cull logs or from sawn lumber. If made of durable wood or treated material, these culverts will give many years of service.



- To be installed flush with the road surface and skewed at an angle not less than 30 degrees downgrade.
- Allow the inlet end to extend into the cut slope or side ditch so that it intercepts water.
- Allow outlet end to extend beyond any fill and empty onto an apron of rock, gravel or logs.
- Open top culverts must be cleaned regularly to remove sediments, gravel, and logging debris to allow normal function of structure at all times.

SPACING FOR OPEN TOP CULVERTS

Road Grade (percent)	Spacing Between Culverts (feet)
2	300
4	200
6	165
8	150
10	140
12	130

road construction applications

OUTSLOPING

Definition:

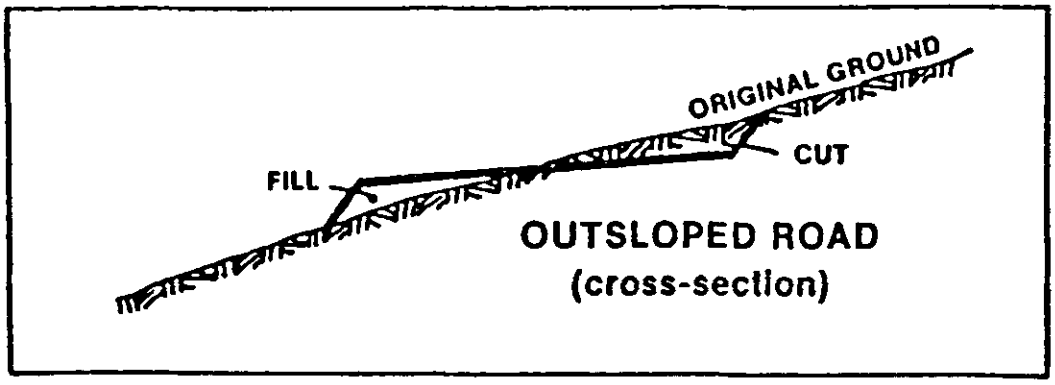
A section of road is sloped slightly (1-3%) from the cut bank to the outside edge of the road bed.

Purpose:

Effective way of limiting erosion because water is removed from the road surface quickly and diverted on to the forest floor.

Condition Where Practice Applies:

Used when the area is entirely rock, or when water can be diverted on to undisturbed forest floor.



INSLOPING

Definition:

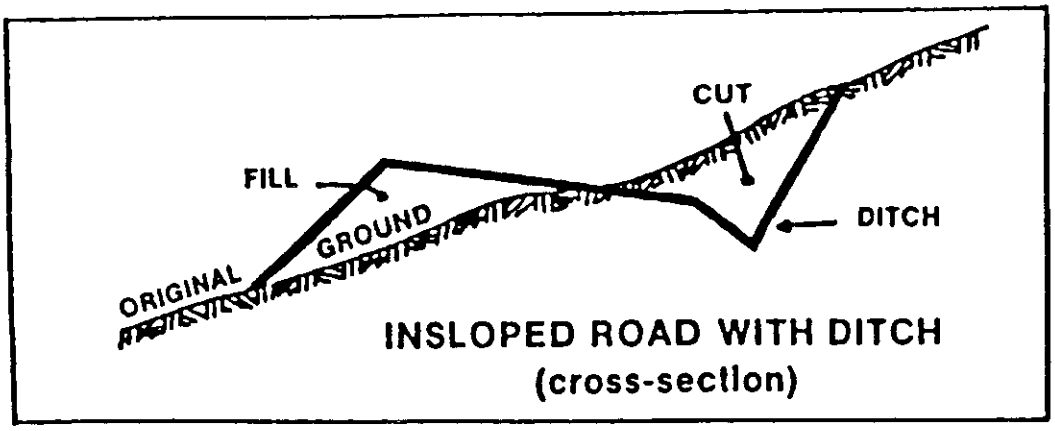
A section of road is sloped slightly (1-3%) toward the cut bank.

Purpose:

Effective way of limiting erosion because water is removed from the road surface quickly and diverted directly to the inside ditch which will carry the water into a culvert.

Condition Where Practice Applies:

Used when the soils are easily saturated or highly erodible. This will limit the amount of ditch water which will flow on to unstable fills.



INSLOPED ROAD WITH DITCH
(cross-section)

CROWNING

Definition:

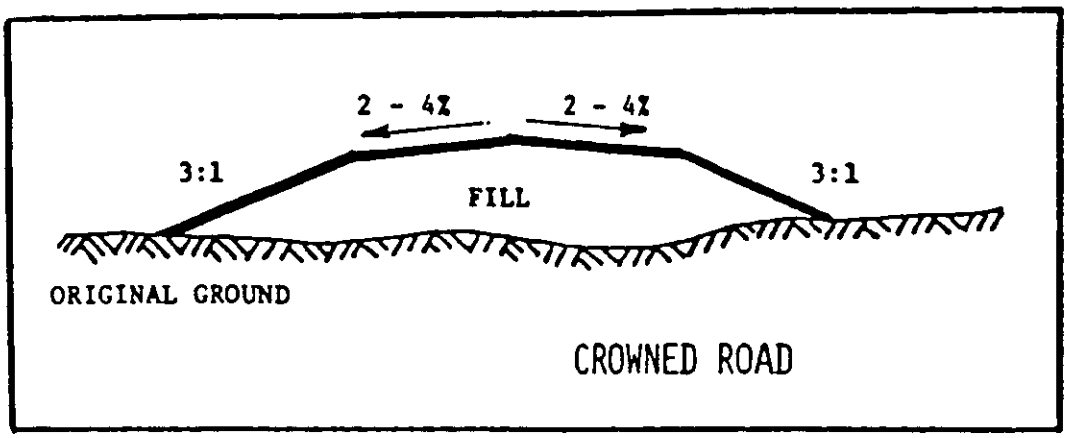
A section of road is sloped slightly (2-4%) from the center line of the road to the outside edges of the roadbed.

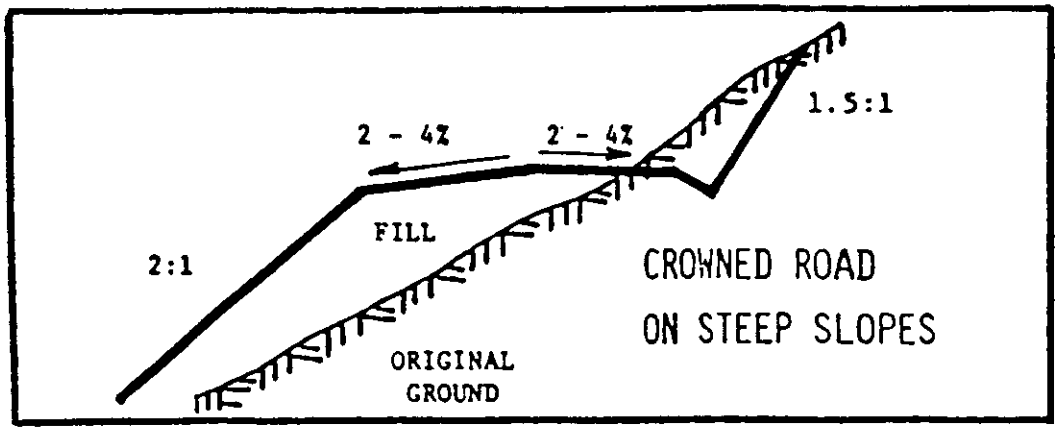
Purpose:

Effective way of limiting erosion because water is removed from the road surface quickly and diverted directly onto the forest floor or into a ditch which will carry the water into a culvert.

Conditions Where Practice Applies:

Used when soils are easily saturated or highly erodible when adjacent areas are relatively level with roadbed or on steep side hills.





streamside management zone

STREAMSIDE MANAGEMENT ZONE

Streamside Management Zones (SMZs) should be maintained along all perennial streams or where forest disturbances occur and surface runoff will carry sediment loads. SMZs should be maintained around streams, ponds, perennial flowing natural springs, and all springs and reservoirs serving as domestic water supplies.

The width of SMZs should be varied, depending on the following conditions: slope of land adjacent to stream, soil erodibility, precipitation, knowledge of particular area, sensitivity of stream, etc. These factors can be obtained from soil maps, on-the-ground evaluation and measurements, weather data, etc.

SMZs should be designed on a case-by-case basis. Most important is that SMZs be consistent with stream characteristics and wide enough to protect water quality.

The following is offered as a guideline:

Soil Type	Percent Slope	SMZ Width (each side)
Slightly erodible	0-5	35'
Slightly erodible	5-20	35-50'
Slightly erodible	20+	50-160'
Erodible	0-5	35-50'
Erodible	5-20	80' minimum
Erodible	20+	160' minimum

[NOTE: Please contact your local Natural Resources Conservation Service office to determine the erodibility factor of the soil before determining the proper width of the SMZ.]

available assistance

Available Assistance

Department of Land & Natural Resources
Division of Forestry and Wildlife
1151 Punchbowl Street, Room 325
Honolulu, HI 96813
Telephone: (808) 587-0166 Facsimile: (808) 587-0160

Hawaii Branch

P.O. Box 4849
Hilo, HI 96720-0849
Telephone: (808) 974-4221
Facsimile: (808) 974-4226

Maui Branch

54 High Street
Wailuku, Hi 96793
Telephone: (808) 984-8100
Facsimile: (808) 984-8111

Oahu Branch

2135 Makiki Heights Drive
Honolulu, HI 96822
Telephone: (808) 973-9778
Facsimile: (808) 973-9781

Kauai Branch

3060 Eiwa Street, Rm. 306
Lihue, HI 96766-1875
Telephone: (808) 274-3433
Facsimile: (808) 274-3438

Natural Resources Conservation Service
Prince Kuhio Federal Bldg., Rm 4-118
Honolulu, HI 96850
Telephone: (808) 541-2600

Hawaii District Offices

Hilo Office
154 Waianuenue Avenue
Hilo, HI 96720
Telephone: (808) 961-5502

Kealakekua Office
P.O. Box 636
Kealakekua, HI 96750
Telephone: (808) 322-2484

Kamuela Office
P.O. Box 1089
Kamuela, HI 96743
Telephone: (808) 885-6602

Pahala Office
P.O. Box 807
Pahala, HI 96777
Telephone: (808) 928-6185

Natural Resources Conservation Service, cont'd.

Maui District Offices

Wailuku Office
70 S. High Street
Wailuku, HI 96793
Telephone: (808) 2444-3729

Molokai Office
P.O. Box 376
Kaunakakai, HI 96748
Telephone: (808) 567-6530

Kauai District Office

Lihue Office
4334 Rice Street, Rm. 104
Lihue, HI 96766
Telephone: (808) 245-6513

Consulting Foresters

Contact the Division of Forestry and Wildlife at (808) 587-0166 for the latest list.

NOTES

Suggested Readings

1. "Logging Roads and Skid Trails, A Guide for Soil Protection and Timber Access," Indiana Department of Natural Resources - Division of Forestry, 21 pp.

2. Dellberg, Robert A., "Road Building for Small Private Roads," Mendocino County Resource Conservation District, Ukiah, CA., July 1992, 73 pp.

3. Walbridge, T.A. Jr., "The Direct Location of Forest Roads," Virginia Polytechnic and State University, Blacksburg, VA., 1990, 70 pp.

4. Walbridge, T.A. Jr., "The Paper Location of Forest Roads," Virginia Polytechnic and State University, Blacksburg, VA., 1990, 75 pp.

5. Walbridge, T.A. Jr., "Field Tables for the Direct Location of Forest Roads," Virginia Polytechnic and State University, Blacksburg, VA., 1991, 15 pp.

6. Wenger, Karl F., "Forestry Handbook, Second Edition," Society of American Foresters, 1984, 1,335 pp.

7. "Erosion and Sediment Control Guide for Hawaii," Soil Conservation Service, 1981, 178 pp.