FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

NORTHWEST REGION

LOGGING PRACTICES

CLEAN WATER

INDUSTRIAL WASTE GUIDE

on

LOGGING PRACTICES

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PREFACE

Logging is an industrial activity which takes place in the commercial forest lands covering 40 percent of the land area of the Pacific Northwest. Logging can--and at many locations does--degrade the quality of water in the streams draining the forest lands. There is an urgent need for improvement of logging practices in the Pacific Northwest. This publication, Industrial Waste Guide on Logging Practices, is dedicated to the logging practices which must be adopted by the logging industry if water quality is to be protected in the streams of the Pacific Northwest.

By its very nature, logging must disrupt the complex and delicate equilibrium of the forest environment. This is particularly true in clear-cut logging, a method of logging which is appropriate on certain types of forests. Yet trees must be cut to provide the wood products our growing economy demands.

How the logging is done has immediate and long-term impacts on water quality. Well-planned and properly executed logging operations will keep water quality degradation to the minimum. But such careful logging operations may add significantly to the cost of cutting and removing logs from the forests. It is a cost which the forest land owners and the logging industry must recognize as a necessary cost to protect the quality of the waters originating on and flowing through the forests of the Pacific Northwest. It is a cost which is paid in the end by the consumers who purchase the many useful products manufactured from wood.

The logging practices required to prevent degradation are as significant as--and in the same category as--the requirements placed upon pulp and paper mills, chemical plants, and municipalities which are required to treat their wastes to prevent degradation of water quality and the resultant restriction in the use of the waters of the receiving streams.

Logging is a widely dispersed industrial activity. The Atlas of the Pacific Northwest 1/ points out that the Pacific Northwest contains "45% of the Nations's total saw timber volume, 54% of its softwood timber, and in addition millions of acres of young, vigorously growing trees that will provide timber for future generations." The text of the Atlas continues: "The value of this resource extends beyond the provision of wood. Forests are the principal vegetative cover protecting the headwaters of the rivers of the entire region. . . .the forests provide much of the summer range for cattle and sheep, as well as year-round shelter for deer, elk, and other big game. They keep the mountain streams cool and clear as a suitable habitat or 'highway' for fish. . . . Much of this forest land contains scenery of a beauty and grandeur ranking with the best in the United States."

1/ Highsmith, Richard M. (Editor), 1968, 4th Ed., Atlas of the Pacific Northwest Resources and Development, Oregon State University Press, Corvallis, Oregon, p. 53.

The portion of this quotation which reads, "They (the forests) keep mountain streams cool and clear as a suitable habitat or 'highway' for fish," is generally true. Yet, with about 1,000,000 acres of forest land being cut each year (360,000 acres of this by clear-cut logging) in Oregon and Washington alone, there is far too much evidence of improper, low-cost logging operations resulting in debris-clogged streams running turbid with silt-smothered spawning gravels and banks stripped of the shade to protect the cool waters.

Carefully planned and managed logging operations must be the unvarying rule if water quality is to be protected.

The first step toward this objective is a cogent statement on the logging practices which must be followed. The Industrial Waste Guide on Logging Practices is that statement.

The second step is full-scale adoption of these logging practices by forest land owners and a logging industry which recognizes their responsibility to the citizens of the Pacific Northwest.

ACKNOWLEDGEMENTS

The information presented in this report has been drawn from many sources. Much has been extracted from the policies, rules, and regulations developed through the years by the agencies responsible for administering the uses of public waters as related to land use and land management. Special recognition is made of the assistance received from the United States Forest Service, the Bureau of Land Management, the Pacific Northwest Water Pollution Control Council, the Pacific Logging Congress, the School of Forestry of Oregon State University, Oregon Department of Environmental Quality, Washington Water Pollution Control Commission, and various private logging companies.

CONTENTS

LIST OF TABLES

INTRODUCTION

Forest Land Uses

The forest products industries are a cornerstone of the economy of the Pacific Northwest States. The raw materials for this continually growing group of industries are extracted from the forest lands by the activities collectively referred to as "logging." Logging is an activity as widespread as the 70,200,000 acres of commercial forest lands in the Pacific Northwest. Logging operations will continue on an expanding scale as forests are cut and regrown to be cut again under systematic cropping and harvesting of trees to meet the nation's needs for wood products.

Forest lands of the Pacific Northwest are much more than a source of raw wood for industry, important though that forest land use is. The forests which blanket the highlands and mountain zones, where rain and snowfall are the heaviest, are the source of Pacific Northwest rivers. Small streams flow from the forest lands where the heavy vegetative cover conserves and slowly releases runoff to the streams. These small streams combine with many others on the way to the sea to form the large rivers of the Pacific Northwest. Even though relatively small in size, the clear, cold forest streams are essential to the propagation of the region's numerous anadromous and resident species of fish which are of major value as the basis of the commercial and sports fisheries.

The forest lands and the streams they support have great value for recreation. They provide sites of scenic beauty for picnicking, camping, boating, swimming, fishing, hunting, and hiking. In short, they constitute a locale offering opportunities for outdoor recreation needed by the increasingly urban population of the Pacific Northwest.

Forest lands provide habitat for a wide variety of wildlife, summer grazing of livestock, and sites for dams and reservoirs.

The very nature of forest lands makes them lands of many uses. Hence, the concept of multiple use has been established and implemented in the management of forest lands, particularly, but not exclusively, for forest lands in Federal ownership. It is a concept rooted in the conviction that forest lands can and should be managed to preserve a balance among, and a place for, all forest land uses.

The cutting and removal of logs from forest lands is one of the many forest land uses. But, how logging operations are carried out has impacts on all the other uses. Not the least of the adverse impacts of improper logging operations is the degradation of the quality of water in streams originating in the forest lands.

Water Quality Considerations

Logging operations all too frequently result in serious degradation of water quality, which, in turn, results in adverse impacts on many other multiple uses of forest lands, as well as on the uses of the waters of those streams far downstream from the logged areas--even to the estuaries where rivers enter the sea.

Sedimentation

The most obvious and most serious impact of improper logging on water quality is the greatly increased sediment load caused by erosion of the mineral soils from the surface of logged-over areas and from logging roads. Measurements have been made of the sediment loads resulting from accelerated soil erosion in logged-over areas and from undisturbed forest lands. Under natural conditions, sediment loads in the streams measured 10 parts per million (ppm) or less. By comparison, suspended sediment concentrations in a stream immediately downstream from an improperly logged area exceeded 70,000 ppm--a measured increase of 7,000 times the natural sediment content (Fig.1b.).[2/]

Such sediment concentrations in forest streams of initially high quality cause a degrading effect felt for many miles downstream. The multiplicity of logged areas with high sediment inputs from many small streams results in pollutional sediment loads of large magnitude in the main stem rivers which these small streams feed. The damaging effects of excessive sedimentation are numerous and widespread.

2/ All illustrations are assembled in numerical order at the end of this report.

The fresh water habitat for resident and migratory fish is significantly damaged with reduction in the number, size, and general health of fish. Sport fishing opportunities are interrupted by extended periods of excessive turbidity. Sediment loads seriously reduce propagation of fish by the silting of spawning gravels and the smothering of fish eggs and fry (Figs. 2 and 3). This is a consideration of particular significance in small headwater streams.

Suspended sediment increases the cost of treatment of water withdrawn for municipal water supplies and causes excessive wear on turbines, pumps, irrigation sprinklers, and the like, with increased expense to water users.

The deposition of sediments in rivers and estuaries increases the need for, and the costs of, dredging to keep channels open for water-borne transportation. Such sedimentation also can significantly alter the environment in, and productivity of, estuarine areas which are known to be more productive of a high protein food supply per acre than most agricultural land.

Turbid, silt-laden streams impair the beauty of forest lands so that people are deprived of a suitable streamside environment for recreational use.

Beyond these instream and downstream effects, there is fundamental concern for the soil losses from logged-over areas. Such soil losses forecast inevitable reduction in the capability of the land to produce growth of forests for future harvesting.

Thermal Effects

Logging of all trees to the water's edge exposes the stream to the full impact of heating by the sun with increases of water temperatures to levels damaging to the cold water fisheries (Fig. 4). Water temperature increases are particularly damaging in small spawning streams in the summer months when the sun is highest in the sky, cloudless days more frequent, and stream flows lowest.

Measurements of summer temperatures in small streams flowing through logged and unlogged forest areas show water temperature increases of 14-16 degrees Fahrenheit in the unprotected stream (Fig. 5). Temperature increases of this magnitude produce stream temperatures which are far in excess of optimum and are even in the range of temperatures known to be damaging to resident and anadromous fish which spawn, grow, and migrate in the small forest streams.

Organic Leaching Products

Improper logging operations leave organic debris and litter in and adjacent to stream channels in the logged area. As these organic materials, in contact with surface and percolating waters, go through the long-lived process of decomposition, measurable increases in dissolved chemicals and plant nutrients occur in the forest streams. Of particular concern are the wood sugar products readily released by leaching.

The direct evidence of such water quality degradation is the growth of bacterial slimes and algae which thrive on the materials released by organic decomposition. Also evident is the reduction of dissolved oxygen in the intra-gravel waters of the spawning beds in small streams. Measurements reveal reduction of dissolved oxygen from saturation levels of 12 milligrams per liter (mg/l), through debilitating levels, to lethal levels for fish of 2 mg/l.

Water Quality Standards

Most of the forest land waters directly affected by logging operations are intrastate streams. The States of Idaho, Montana, and Oregon have established water quality standards for their intrastate streams. In 1967, Oregon established General Water Quality Standards covering all intrastate streams and is now proceeding with setting Special Water Quality Standards for specific intrastate waters. The State of Washington is also in the process of setting intrastate stream standards on quality.

Implementation of intrastate water quality standards, with regard to degradation of water quality by widespread land use activities, such as logging operations, presents much more difficult problems than the implementation of the treatment of point sources of wastes from industrial plants and municipalities. In this connection, the implementation plans for the Special Water Quality Standards now being established by the State of Oregon for intrastate streams includes the following statement on logging operations:

> In cooperation with the logging industry and other interested agencies and institutions, develop programs to keep logging activities out of streams, leave undisturbed streamside vegetative cover for cooling shade and thereby also minimize resulting vegetative debris and eroded earth in streams.

The Federal agencies involved in the management of forest land areas, including the harvesting of trees, not only must abide by the water quality standards established by the states and the Federal government for inter<u>state</u> waters, but also should abide by the standards set by the states for intrastate waters. As a practical matter, this means that all Federal agencies having administrative jurisdiction over commercial timber lands should incorporate provisions into their timber sales contracts which would prevent pollution of streams through the logging operations over which they have control.

Some 60 percent of the commercial timber lands in the Pacific Northwest are in Federal ownership and under Federal management. Therefore, it is imperative that the Federal agencies utilize their authority to promptly implement procedures which would assure protection and enhancement of water quality through uniform application of proper logging practices.

Forest Land Owners

The role of forest land owners is the key to adoption of logging operations which will prevent, or hold to an acceptable minimum, the degradation of water quality in streams traversing forest lands. The forest land owners own the logs which are to be harvested. They are in a position to control logging operations. It is reasonable to assume that logging firms will carry out the kind of logging operations which they are required to do and for which they receive adequate compensation.

About two-thirds (46,000,000 acres) of the 70,200,000 acres of commercial land in the Pacific Northwest (Washington, Oregon, Idaho, and western Montana), is in public ownership. About 60 percent, or 41,600,000 acres, is in Federal ownership. Of this amount, 36,000,000 acres of Federally owned commercial forest land are in the National Forests. Bureau of Land Management lands account for 3,200,000 acres, and Indian lands managed by the Bureau of Indian Affairs, 2,400,000 acres. About 4,400,000 acres are in non-Federal, public ownership--state, county and municipal.

About 34 percent, or 24,200,000 acres of commercial forest land, is in private ownership. Of this total, it appears that about one-half is owned by the forest industries, such as the lumber companies, pulp and paper companies, and the like. Sizeable acreages are owned by the railroad companies.

In summary, something approaching 85 percent of the commercial forest land in the Pacific Northwest is owned by public agencies, forest industries, or the railroads. By and large, it would seem that these entities would retain ownership of the forest lands over long periods of time and, therefore, be most concerned regarding the long-range productivity of those forest lands. Sedimentation, which causes degradation of the quality of water in forest land streams, also indicates significant soil erosion and losses of the relatively thin mineral soils of the sloping forest lands with the inevitable reduction in the long-range productivity of future forests grown on those lands. Hence, increased efforts by these owners to prevent or minimize water quality degradation are most desirable, not only to prevent damage to fishery, recreational, and aesthetic values which the general public holds in high regard, but also in the interest of the future economic welfare of the wood-products industries of the Pacific Northwest.

With the remaining 15 percent of commercial forest lands owned by miscellaneous private landowners, it is essential that understanding be developed among this group regarding the significance of the effect of logging practices on water quality and the need to prevent soil erosion on forest lands.

Logging Plans

Many factors contribute to the impacts of logging on water quality, such as steep slopes, different exposures, inherent soil erodibilities, rates of vegetative recovery following logging, and climatic factors. The relation between topography and rainfall intensity is especially important. Full application of today's conservation knowledge in all phases of timber harvesting can reduce water quality degradation. To do this, each forested area must be carefully logged using a specific plan so tailored for that area that all tangible and intangible losses and all water quality degradation will be kept within tolerable limits.

An adequate tree harvesting plan includes maps, sketches, or pictures of the area to be harvested. It gives specifications for the building, use, and maintenance of a well-designed transportation system. It specifies the manner in which the trees are to be cut and the way the logs shall be delivered to the transportation system from the point on the watershed where they are felled. It identifies the areas along perennial and major intermittent streams which should be left as buffer or filter strips. It specifies the measures which should be taken to leave the logged area in a repaired condition to prevent undue erosion of the area during the period of regrowth.

Compiled in the remainder of this volume are detailed recommendations for controlling the adverse impacts on water quality which can be caused by logging operations.

LOGGING ROADS

Proper planning, location, design, construction, use, and maintenance of all logging roads--main roads, secondary roads, spur roads, and skid trails--will reduce soil erosion problems in forest watersheds. The following recommendations, pertaining to logging roads, have been assembled under four headings.

Road Location

1. Locate all roads to avoid, or design them to counteract, unstable soil areas. Select the gradient which will provide for a stabilized road prism with proper drainage. Fit road locations to the topography so that minimum alterations of natural conditions will be necessary. Use systematic rather than random layouts (Figs. 6, 7 and 8). An analysis comparing random road layouts with systematic road patterns reveals that substantial savings in cost and increased efficiency in logging operations are realized by use of the systematic patterns (Table 1).

2. Locate roads on natural benches, ridge tops, and flatter slopes to minimize harmful disturbances of the terrain and to enhance the stability of the roads.[3/] Use all available topographic surveys, soil-type maps, and other soils and geologic information to select

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3/ SILEN, Ray R., 1955, "More Efficient Road Patterns for a Douglas-Fir Drainage:" The Timberman, Vol. LVI, No. 6, pp. 82-88.

TABLE 1

A COMPARISON OF RANDOM AND SYSTEMATIC LOGGING ROAD LAYOUTS
(H. J. ANDREWS EXPERIMENTAL FOREST)

Item	Road Pattern	
	Random a/	Systematic b/
Road density, total in planned system--miles per square mile	5.59	4.97
Road density, amount actually constructed--miles per square mile	1.95	1.99
Area needed for road construction, acres per square mile of watershed	93	68
Area outside optimum yarding distance (400 - 900 feet), acres per square mile		
Less than 400 feet	64.4	38.6
More than 900 feet	19.0	10.6
Total	83.4	49.2
Percent of road system having grades of--		
8 to 12 percent c/	51.4	14.0
4 to 8 percent	10.9	40.6
0 to 4 percent	26.2	36.1
Adverse: 0 to 4 percent c/	11.5	9.3

a/ Basis: 38.53 miles of road in layout of 3,273 acres.

b/ Basis: 42.98 miles of road in layout of 5,534 acres.

c/ A few short stretches of road with favorable grades above 12 percent or reverse grades above 4 percent were built to avoid obstacles and are included in these classes.

locations which avoid steep slopes and unstable soils. Field observation and evaluation is advisable in problem areas. Give full consideration to soil strength and cohesion to determine the proper cut-and-fill slope ratios and to specify spacing for relief-drainage culverts.

3. Locate roads on stable areas well away from streams (Figs. 9 and 10). Avoid routes through the bottoms of steep narrow canyons; through slide areas; through steep, naturally dissected terrain; through slumps; through marshes or wet meadows; through ponds; or along natural drainage channels. Where alternative locations through stable areas are not available, incorporate corrective stabilization measures into the road design.

Road Design

Prescribe for each road those design specifications that are best adapted to the given slope, landscape, and soil materials (Table 2 and Figs. 11 and 12). Use a balanced design or provide waste or borrow areas that will produce a minimum of damage to soils and water. Cross streams where channel and bank disturbance will be minimal. Avoid excessive sidehill cuts and fills, especially near stream channels. Design spur roads to follow the contour as closely as possible. Plan for retaining walls or riprap where needed to increase the stability of fill embankments and cuts and to protect fill embankments from water erosion (Fig. 13).

TABLE 2

RELATIVE EROSION HAZARD OF LOGGING AREAS IN RELATION TO SITE FACTORS

Site Factors	High Erosion Hazard	Moderate Erosion Hazard	Low Erosion Hazard
Parent rock	Acid Igneous Granite, diorite, volcanic ash, pumice, some schists	Sedimentary and Metamorphic Sandstone, schist shale, slate, conglomerates, chert	Basic Igneous (Lava rocks) Basalt, andesite, serpentine
Soil	Light textured,[a/] with little or no clay	Medium textured, with considerable clay	Heavy textured, largely clay and adobe
Mantle Stability	Unstable mantles (cutbank stability Class V)	Mantles of questionable stability (Cutbank stability Class IV)	Stable mantles (classes I, II, and III)
Slope	Steep (Over 50%)	Moderate (20 - 50%)	Gentle (0 - 20%)
Precipitation	Heavy winter rains or intense summer storms	Mainly snow with some rain	Heavy snow or light rain
Vegetation and other organic matter on and in the soil	None to very little	Moderate amounts	Large amounts

a/ Soil texture refers to the size and distribution of the mineral particles in the soil, the range extending from sand (light texture) to clay (heavy texture).

1. In critical situations, design for full-bench construction rather than part bench and part uncompacted fill. End haul all excavated waste material to safe bench or cove locations or use it in "through" fills by raising their elevation.

2. Reduce backslope sloughing by rounding the tops of cut slopes.

3. Design fill at an angle less than the normal angle of repose.

4. Clear trees and other vegetation for only the minimum essential width required for construction and maintenance of the road and choose the design alignment and minimum road width necessary to serve traffic needs.

5. Divert or otherwise dispose of all drainage so that it does not pass over or collect in new cuts, fills, borrow areas, or waste dumps. Do this by providing bridges or adequate culverts at all natural water courses both for permanent and temporary access or haul roads. Avoid channel changes and stabilize the fill material of the approaches with riprap or abutments. Where culverts must be installed in large fills, use concrete or heavy riprap headwalls and wingwalls to prevent erosion of the fill and to help direct the passage of debris through the major culverts. To prevent disturbance of stream channel, use riprap, gabions (wire baskets full of large rocks), or other structures where needed to protect roads that must be constructed in canyon bottoms.

6. Design culverts or bridges large enough to carry at least a 25-year frequency storm. West of the Cascades, use a 24-inch or larger diameter culvert for all live stream crossings to minimize fish migration blockages.

7. In order to reduce fish passage problems and pipe abrasion, design to use bridges or "true-arch" (bottomless) culverts on steep slopes (Figs. 14 and 15). In locations where bridges or bottomless culverts are impractical, design for culverts with installed baffle plates to provide for fish passage through the culvert. Orient culverts with natural stream channels and extend them beyond the fill slopes. For anadromous fish passage, provide an entrance pool at least 3 feet deep and 12 feet long at the outflow end of the culvert. Stabilize the pool with barrier logs to prevent erosion (Fig. 16). Place the logs so there is no impassable drop between the culvert and the stream.

8. Provide an adequate drainage system that will reduce both the runoff concentration in the roadway and the saturation of poorly drained soils (Fig. 17). Where justified by the volume of traffic or the type of soil the road crosses, use roadside ditches and culverts. Give each relief culvert a minimum slope of one percent and provide a sediment-catching basin at the entrance. Use downspouts and other slope protection measures to avoid erosion of fill areas (Fig. 18).

9. Provide dips, water bars, and cross drains in order to prevent water accumulations from eroding and gullying skid trails (Fig. 19). Put such structures close enough together so the collected water will be small in amount and can easily be diverted off the road into safe spreading areas.

10. Design temporary roads to drain by outsloping wherever possible. On long slopes, space dips in the road to assure diversion of runoff from the road surface. For fills with culverts, place a dip at the downgrade approach so that in the case of a flood or plugged culvert, the excess water may flow over the road at that point. Use fords or other low level crossings for small streams that have a high upstream debris hazard (Fig. 20).

11. Prevent muddy and turbid waters from draining off the roadbed and into streams. Where necessary, make provisions to build up the surface of dirt roads with rock. Pave, or otherwise stabilize road surfaces in order to minimize subgrade failures, road surface erosion, and road maintenance grading. For temporary paving, use emulsified asphalt where applications of oil or sulfite-waste-liquor type dust inhibitors could possibly wash into and contaminate receiving waters.

12. Obtain all road rock and gravel from dry quarries or from dry channels that are provided with adequate protection against sediment production. Do not "wet" mine such road rock or gravel from live stream channels (Fig. 21).

Road Construction

In many places, careless and improper construction of a high mountain logging road can nullify all the effort expended in well considered design and location. Numerous mud-rock slides and land slumps have started at the edge of such roads and, once started, have carried through hundreds of feet of forested slopes. Poor construction and inadequate drainage have triggered land slumps in watershed after watershed and have resulted in the most serious form of accelerated erosion that occurs during timber harvesting.

High quality road construction should be insisted upon by the land owner or his representative. Regular inspections should be made during construction by a qualified engineer with authority to assure that road construction meets design requirements.

Therefore, during all phases of road construction, protect water quality by using every possible and applicable soil and water conservation measure.

1. Where the road design calls for full bench construction, make the full cut, end-haul excess excavation from the cut, and deposit it in stable locations well above the high water level. Do not deposit waste materials directly into any stream channel. Where necessary, compact all fill material to reduce the entry of water and to prevent the fill material from settling. Do not place any woody or other organic debris in the fill of any road.

2. Collect all construction-area drainage and keep it out of the streams. Use seepage pits or other confinement measures to prevent diesel oil, fuel oil, or other liquids from running into streams. Use drip collectors on oil-transporting vehicles. Divert water for sprinkler trucks a sufficient distance from the source to the filling point to prevent overflow spilling or flushed tank water from reaching the stream.

3. Keep soil disturbances to a minimum by constructing roads only when soil moisture conditions are favorable. Rough grade a new road only as far as that road can be completely finished during the current construction season. Finish ditches and drainage installations on the section being worked upon before opening up another section or before shutting down construction for the season.

4. Fully backslope each graded section except where vertical cut banks are more stable than sloping ones. In critical slump areas, grade large cuts to slopes of not more than 1.75 to 1 and use horizontal drain pipes. Also, protect all large fill areas with surface drainage diversion systems. Place culverts so as to cause the minimum possible channel disturbance and keep fill materials away from culvert inlets and outlets. During road construction do not permit earth moving activities when the soils are saturated. Allow road machines to work in streambeds only for laying culverts or constructing bridge abutments. Divert streamflow from the construction site whenever possible in order to prevent or minimize turbidity.

5. Clear drainage ways of all woody debris generated during road clearing or construction. Windrow the clearing debris and crush it outside the road prism except where burning of the debris is necessary to reduce the fire hazard, prevent insect infestations, or to improve the aesthetics.

Road Maintenance

Fully and thoroughly maintain all portions of the road system to prevent water quality degradation from accelerated erosion during heavy rainstorms. This includes the regular maintenance of drainage diversions, such as cleaning culvert inlets before and keeping them clean during the rainy season to diminish the danger of clogging and the possibility of washouts. It also includes the inspection of revegetation on obliterated spur roads, and reseeding where necessary. As specified for construction activities above, end-haul and deposit all excavated material in safe bench or cove locations well above the high water level. Never deposit such material directly into flowing streams (Fig. 22).

1. On all spur roads that outslope, cross drain them and remove all berms on the outside edge except those intentionally constructed for the protection of road grade fills.

2. Retain outslope road drainage by performing proper maintenance grading. This precludes both the undercutting of newly or partially stabilized cut slopes and the leaving of a berm (except for

fill protection) along the outside edge of the road which might concentrate drainage on the road (Fig. 23). Before spring runoff begins, remove all ice and snow berms created on winter haul roads.

3. Use extreme caution in the selection and application of herbicides for controlling brush encroachment along road edges. Do not let any such chemicals drift or run off into streams to cause objectionable tastes or odors in the waters or to create adverse conditions for aquatic life or human consumption. Use mechanical equipment in preference to herbicides for control of roadside brush.

TREE CUTTING

The total annual amount of wood harvested from the combined States of Oregon and Washington approximates the equivalent of 16,000,000,000 board feet. It is harvested from an estimated 1,000,000 acres of land of which about 360,000 acres are clear-cut. The harvesting of any crop leaves an unused residue. In the case of trees, this residue is made up of foliage, branches, bark, rotten material, roots, and wood that is too small or of too low a quality for any present day use. In Douglas-fir forests the average weight of the logging wastes is about 40 tons per acre, and it constitutes a serious threat to the quality of the water which runs off the cutover land (Fig. 24).

The complex tannin and humic-acid solutes leached from logging slash are a prevalent source of chemical pollution of the water. Hemlock trees, for instance, have a high tannin content in leaves and bark. Leachates from hemlock slash and alder leaves often discolor streamflow. Large pieces of the coarse logging slash can cause debris dams in channels and give rise to changes in the physical nature of the stream course by causing accelerated erosion and deposition. Fine organic material exerts a biochemical oxygen demand that causes dissolved oxygen deficiencies. Wood sugars begin to leach from any piece of new wood, regardless of its size, as soon as it comes in contact with water. Singly or in combination, the above factors pollute many streams in the Pacific Northwest. Such pollution should be prevented.

1. Base the size, shape, and location of clear-cut blocks on an analysis of such things as forest regeneration, logging economics, fire control, wildlife production, soil protection, aesthetic appeal, and water quality maintenance.

2. Reduce soil damage by using a flexible logging plan. Build roads well in advance of tree felling in order to allow flexibility in choice of logging conditions, such as high elevations and northern exposures for summer when the snow has disappeared. Also, reserve marshy ground and steep slopes for summer, low elevations and southern slopes for winter, and the opportunity to select different tree species for harvest during any part of the year.

3. Consult with State and Federal fishery and game agencies to determine the value of each stream as habitat for either resident or anadromous fish. If the watershed contains critical fisheries which would be irreparably damaged by present day logging practices, classify the drainage as unharvestable until suitable logging techniques can be utilized.

4. Limb all logs before yarding in order to minimize disturbance of soil and damage to reproduction and water quality (Fig. 25).

LOG YARDING

Plan thoroughly and then yard the logs carefully in order to prevent soil disturbances and other water pollution hazards along skid trails, on landings, and over the watershed in general.

1. Correlate all skid trail locations with cutting areas, topography, soil types, and climatic factors. Locate such trails carefully and drain them adequately so that muddy and turbid waters will be kept out of stream channels. Keep all skid trails out of stream channels and off stream banks. Use temporary log or metal culverts wherever such trails must cross stream channels, and keep the number of such crossings as few as possible. Use each skid trail only a small number of times in order to avoid soil gouging and compacting and the channelizing of runoff.

2. Avoid tractor yarding on all saturated areas and on all slopes steeper than 30 percent (Fig. 26). On critical soils, limit crawler-tractor yarding to slopes of less than 15 percent (Fig. 27).

3. Suspend tractor logging during rainy days and for a day or so thereafter. Store logs ahead of the loading operation to allow for yarding shutdowns on bad days.

4. Rather than having many long skid roads coming to only one landing within the logging area, utilize a number of landings and service each one with a well constructed road.

5. Locate log landing areas on firm dry ground away from live stream channels wherever possible. Widening of the logging road will permit this in some places. Borrow the material for the extra fill from a long stretch of road rather than from a single spot, thus keeping the cut slopes reduced in extent. Use cull or unmerchantable logs and chunks to form a cribbing on the downhill side to support the fill for the landing and thus minimize the borrow excavation and help control slumping and erosion.

6. Wherever possible, yard logs by lifting them free of the ground. Where this cannot be done, yard them uphill by high-lead cable (Fig. 28) or by fixed or swinging skyline (Fig. 29). Protect all stream banks and channels by bridging or at least by lifting the logs over streams rather than dragging them through the streams. Avoid disturbing steep slopes and shallow soil areas immediately adjacent to stream channels. Avoid undue disturbances of accumulations of decaying vegetation which can wash into and befoul the streams during rainstorms.

7. Minimize logging road construction on very steep slopes or fragile areas by using skyline or balloon yarding systems (Fig 30).

8. Consider the use of helicopters, balloons, or modified cable systems for logging of areas that would have high conventional yarding costs or for fragile, sensitive areas

9. Take all possible care to avoid damage to the soils of forested slopes, and to the soil and water of natural meadows as well. Minimize this damage by operating the logging equipment only when soil moisture conditions are such that excessive damage will not result.

10. Avoid servicing tractors, trucks, and similar equipment on forest lands adjacent to roads, lakes, streams, or recreational facilities. Permit no contaminants to remain in the logging area following completion of operations.

11. Maintain in a clean and sanitary condition all improvements such as camps, mills, quarries, and the grounds adjacent thereto that are used in connection with the timber harvesting process. Locate all buildings, toilets, garbage pits, and other structures in those places that will prevent pollution of the water in streams, ponds, or lakes.

12. Conduct all operations so as to preclude interference with the resident or migratory fisheries of the area. Do not divert the water out of any stream without the written approval of the state fishery biologist who has jurisdiction over the area involved and the state engineer who is concerned with the administration of water rights.

13. Cooperate with research groups in developing improved methods of timber harvest that will reduce soil disturbance, lower the cost of timber removal, and develop more complete utilization of logging slash.

BUFFER STRIPS

Soil erosion on, and logging debris from, roads, landings, skidways, and slopes disturbed by yarding activities during a logging operation can seriously damage streams. Much of this damage can be prevented by using all reasonable means and alternatives that will keep every road and logging activity as far from the stream courses as possible.

Perennial Streams

Logging can cause increased water temperatures in perennial streams. Such increased temperatures make possible the rapid growth of trash fish, slime bacteria, and algae. However, these higher stream water temperatures tend to decrease with time due to stream shade recovery.

Therefore, leave buffer strips of native vegetation, including an overhead canopy, between roads or logged areas, and any perennial streams they parallel (Fig. 31). Buffer strips not only reduce the quantity of sediment and logging wastes that reach the streams, but also help prevent stream water temperature increases and loss of natural stream beauty. Thus, they assist with the preservation of water quality and the attainment of temperature objectives for fish management.

1. Leave all hardwood trees, shrubs, grasses, rocks, and natural "down" timber wherever they afford shade over a perennial stream or maintain the integrity of the soil near such a stream.

2. Carefully and selectively log the mature timber from the buffer strip in such a way that shading and filtering effects are not destroyed. Protect the buffer strips by leaving stumps high enough to prevent any subsequently-felled, up-slope trees from sliding or rolling through the strips and into the streams.

3. Neither an optimum nor a minimum width can be set arbitrarily for buffer strips. It is recommended, however, that a minimum width of 75 feet on each side of the stream be used as a guide for establishing buffer strips. At the same time it must be realized that the necessary width will vary with steepness of the terrain, the nature of the undercover, the kind of soil, and the amount of timber that is to be removed.

4. For effective filtering of sediment, buffer strips should be wide enough to entrap the material that will be eroded from the road or the logged area above. Under some conditions and with careful control in adjacent logging areas, a relatively narrow strip may suffice. On the other hand, where road building or logging allows land slips to occur, the buffer strip may have to be much wider and other precautions may have to be taken to eliminate adverse effects on the stream water quality.

5. One modification of the buffer strip plan calls for the removal of only dead, dying, mature, and high risk trees from strips at least 75 feet wide on medium sized or larger streams. It provides also for removal of all merchantable trees from within a 15-foot

strip along each bank of the stream. Such removal relieves pressure on stream banks and prevents weakening of the support for larger trees and thus prevents stream bank destruction.

6. Where old growth timber must all be removed because it is subject to windthrow (for example, pure western hemlock) and where it is difficult to leave full-width buffer strips of timber to shade the stream, plan to re-establish cover along the stream after cutting is completed. Fast-growing deciduous species will be required to restore shade as quickly as possible. In the meantime, leaving the understory vegetation as undisturbed as possible will result in the filtering of the runoff and the stabilizing of the soil.

Intermittent Streams

Many relatively small tributary streams flow only during the wet season of the year; however, they often produce substantial flows which carry heavy sediment loads during intense or prolonged periods of rain. Therefore, along the channels of intermittent tributaries, preserve adequate widths of undergrowth vegetation as filter strips to prevent washing of sediment into a perennial stream below.

WATERSHED RESTORATION

Watershed restoration is the intensified reclamation or improvement of land and vegetation that has been so disturbed that accelerated erosion with soil losses and stream sedimentation will retard or prevent the regrowth of a protective cover. A good restoration program will re-establish this protective vegetative cover to renew the hydrologic balance by retarding and dispersing runoff. It will conserve the basic soil resource by reducing soil erosion and providing soil stability. It will deter rapid runoff and reduce flood damages by lowering streamflow peaks. It will minimize the amount of sediment carried into the stream. And it will enhance the aesthetic considerations and recreational use of the watershed.

Logged Areas

Clear-cut logging and yarding operations, and the handling and disposal of logging slash, disturb drastically the land surface of steep mountain slopes.

1. Control the erosion at its source on such disturbed areas by hastening their reforestation.

2. Seed or plant adapted species and, where necessary, use terracing, composting, mulching, and fertilizing.

Roads, Skid Trails, Landings, and Firelines

A full restoration program will provide for herbaceous vegetation to be established quickly on such severely disturbed areas as roads, skid trails, landings, and firelines. Seed and plant native vegetation to the fullest extent possible. However, where sufficient seed of native vegetation cannot be obtained, mixtures as shown in Tables 3 and 4 have often been used with success, although other mixtures may be utilized on specific sites.

Permanent Roads

1. Revegetate all road cut and fill slopes (Fig. 32). Use such measures as matting, mulching (Fig. 33), fertilizing, seeding, and planting.

2. Inspect all treated cut, fill, and disturbed areas frequently and apply immediately whatever additional soil stabilization measures may be necessary in order to prevent anticipated soil erosion.

Temporary Roads

1. Obliterate, blockade, and stabilize all temporary spur roads when no longer needed for logging operations (Fig. 34).

Skid Trails

1. Restore stream channels by removing temporary skid-trail crossings.

2. Obliterate and stabilize all skid trails after logging the watershed.

TABLE 3

RECOMMENDED SEED MIXTURES

West of the Cascade Divide

Species	Seed Per Acre
Orchard Grass	2 lbs.
Timothy	2 lbs.
Alta Fescue	2 lbs.
Perennial Ryegrass	2 lbs.
Total per acre	8 lbs.

TABLE 4

RECOMMENDED SEED MIXTURES

East of the Cascade Divide

Species	Seed Per Acre Inches of (effective) precipitation				
	0-9	9-12	12-15	15-18	18-25
Siberian Wheatgrass	5 lbs.	6 lbs.	6 lbs.		
Nordan Crested Wheatgrass	5 lbs.	6 lbs.	6 lbs.		
Pubescent Wheatgrass			8 lbs.		
Durar Hard Fescue				4 lbs.	4 lbs.
Topar Pubescent Wheatgrass				8 lbs.	8 lbs.
Intermediate Wheatgrass				8 lbs.	
Greener Intermediate Wheatgrass					8 lbs.
Total per acre	10 lbs.	12 lbs.	20 lbs.	20 lbs.	20 lbs.

3. If necessary, build special drains on abandoned skid roads to protect stream channels or side slopes.

Landings

1. Locate log loading or log storage areas (landings) along ridge tops, on other areas having gentle slopes, or along widened road areas.

2. Place landings in the channels of intermittent streams only in those emergency situations where no safe alternative locations can be found (Fig. 35). Adequately drain any landing that must be placed in such channels. Immediately after completing all log loadings from these landings, clear the channel to its full capacity, spread the fill material in areas where it will remain stable, and reseed those areas to herbaceous vegetation.

3. Upon abandonment, "erosion-proof" all landings by adequately ditching or mulching with forest litter, as needed. Establish a herbaceous cover on those areas that will be used again in repeated cutting cycles and restock to coniferous species those landings, located in clear-cut areas, that will not be reused for a long time, if ever.

Firelines

1. Limit tractor-built firelines to areas where they will not involve problems in soil instability.

2. Adequately "cross-ditch" all firelines at time of construction and revegetate them with adapted grasses and legumes.

Slash Handling

When planning the harvesting of timber, give full consideration to the disposal of slash to prevent adverse effects on water quality. Avoid creating large continuous areas of heavy slash and facilitate handling and disposal of slash by suitable methods (Fig. 36).

Encourage the reduction of debris, which could potentially become a destructive agent during high streamflow, by insisting on an aggressive salvage and prelogging program, fostering relogging where a market exists, and setting clear, realistic criteria for satisfactory stream clearance. In preparing these guidelines utilize estimates of how much of the area will be flooded so that high hazard areas can be designated, avoided, and protected.

Fit residue treatment to the need, area by area. Extract all large, sound residues and mechanically treat the remainder, if possible, in lieu of burning.

1. Carry out slash disposal and regeneration programs concurrently with logging operations in order to provide maximum protection to the disturbed areas.

2. Treat all slash and logging debris in such ways as may be appropriate in order that the facilities available may provide the same or a better degree of fire protection for the cutover area than that which was available for it prior to logging. Reduce the volume of the debris as much as possible by utilization of the woody portion. Also, incorporate into the soil as much of the finer

portion as possible (Fig. 37). This will, by natural means, improve the soil structure and replace, at least in part, the plant nutrients for the next crop, some of which might otherwise find their way into the streams.

3. Provide for soil protection in all slash reduction plans. If burning is the only practical means of debris disposal, do it in such ways and at such times that the organic litter and the soil surface is not totally destroyed.

MUNICIPAL WATER SUPPLY WATERSHEDS

Undisturbed forested watersheds yield high quality water. In some places in the Pacific Northwest, the water from such areas can be used directly for drinking purposes. In many other locations, the water is suitable for municipal supplies after a simple chlorination treatment.

Some forested watersheds in the Pacific Northwest have been set aside as closed watersheds for the sole purpose of producing municipal water supplies. Access to such areas is carefully controlled. Soil disturbances and other potential water quality degrading activities are kept to an absolute minimum.

Many municipalities rely on water supplies from multiple-use watersheds because they have not been able to wholly or even partially control man's activities on the watersheds that produce their municipal water supplies. Also, a few other communities that do have complete control of their watersheds have contracted to have them logged in order to harvest the renewable, natural timber resource which they support. The logging roads that have been built are considered to be an asset because they permit access to the watershed for the purpose of fighting wildfires.

Special precautions are needed for road building and logging in municipal water supply watersheds.

1. Permit tractor skidding only at locations specified in an approved plan. Do not allow log skidding across live streams or along paths that are parallel to a stream and that are closer than 100 feet of the stream. Use bridges or culverts for all stream crossings.

2. Divert water used for filling truck brake reservoirs or for truck washing a sufficient distance from the source to the filling point to prevent spilling of overflow or waste from reaching the stream.

3. Locate contractor camps completely out of municipal watersheds.

4. At landings and other areas where crews are located, provide sanitation facilities that comply with those Federal, state, or local regulations that are the most stringent.

5. On domestic water supply watersheds, use well maintained chemical toilets for disposing of body wastes and remove all garbage for disposal elsewhere.

6. Provide buffer strips to protect municipal water collection and conveyance facilities.

7. Discourage soil scarification by crawler tractor, but if exposing the mineral soil is the best method for preparing a site that is to be seeded, disturb the soil as little as possible, windrow the cleared material along the contour, limit the cleared area between windrows to 75 to 100 feet of slope distance, and scarify not more than 60 percent of the area.

ILLUSTRATIONS

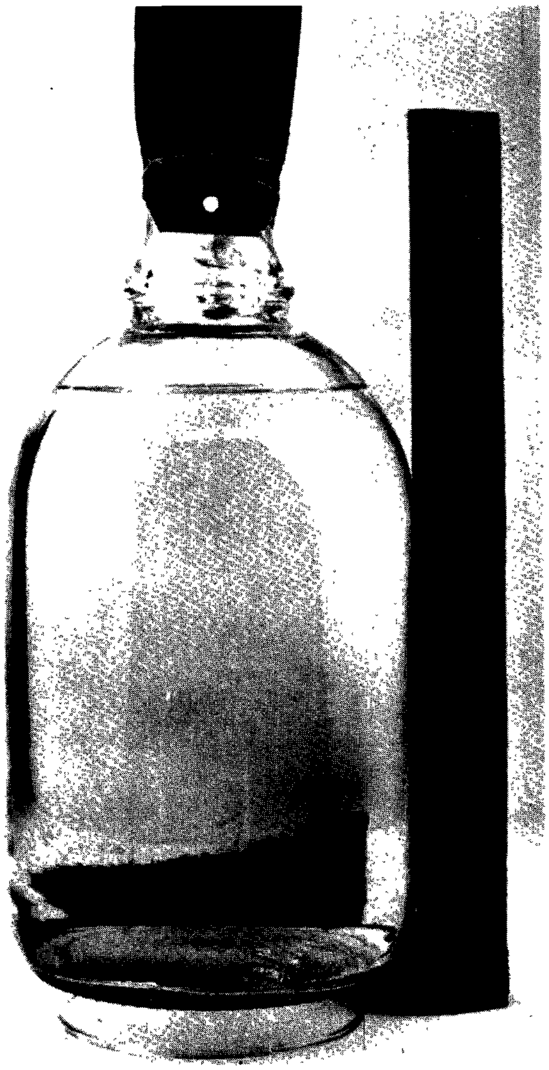


FIGURE 1a. An early-spring sample of water taken from a creek a short distance upstream from its confluence with a small tributary. The water from the creek is used as a municipal water supply. Ordinarily, its quality is so high it needs only chlorination. This sample contained zero parts per million (ppm) of suspended solids.

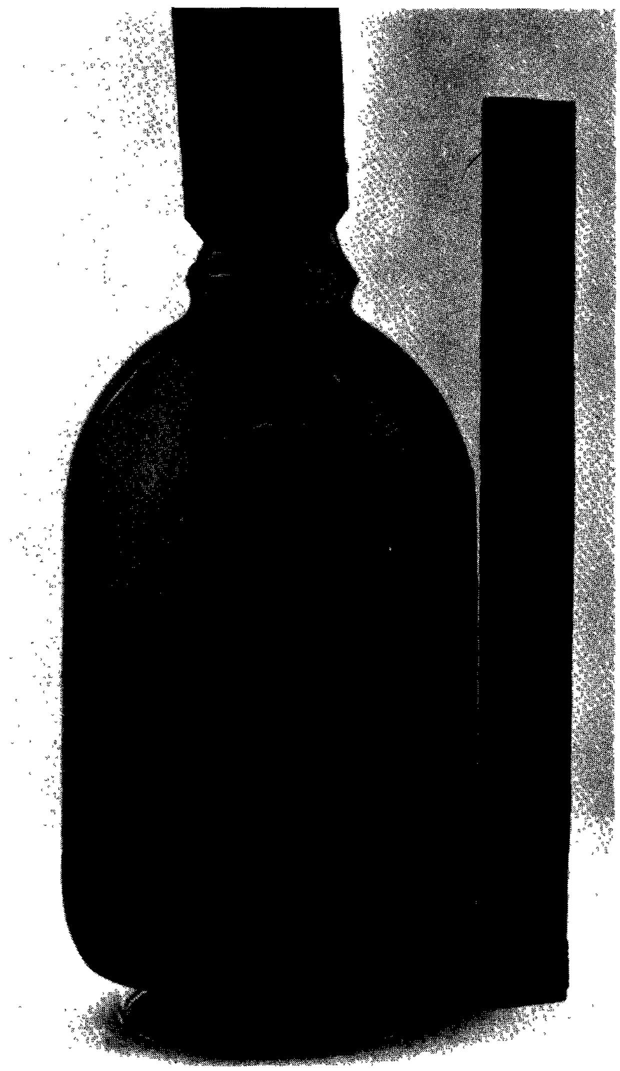


FIGURE 1b. This sample was taken from a small tributary where logging in the stream channel was in progress a short distance upstream from the sampling point. The sample had a total solids concentration of 70,192 ppm. The suspended solids settled out rather rapidly into a 1.5-inch dark layer in the bottom of the jug.

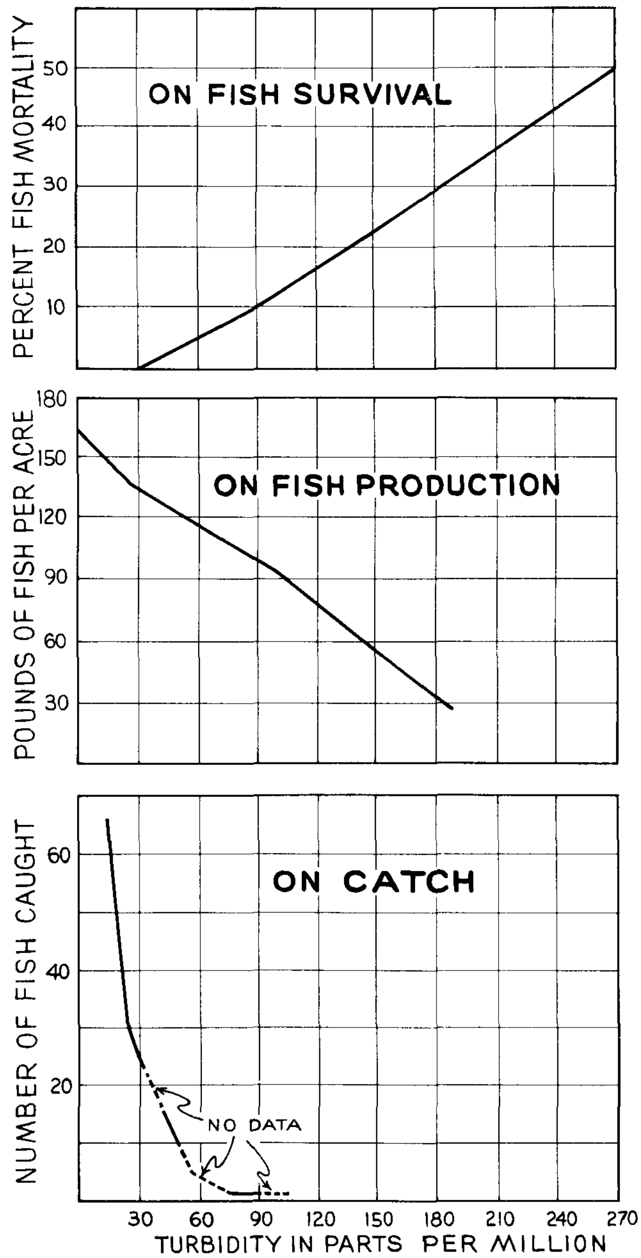


FIGURE 2. Effect of turbidity on the survival, production, and catch of fish.4/

4/ U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 1969. Douglas-Fir Supply Study, p. 48.

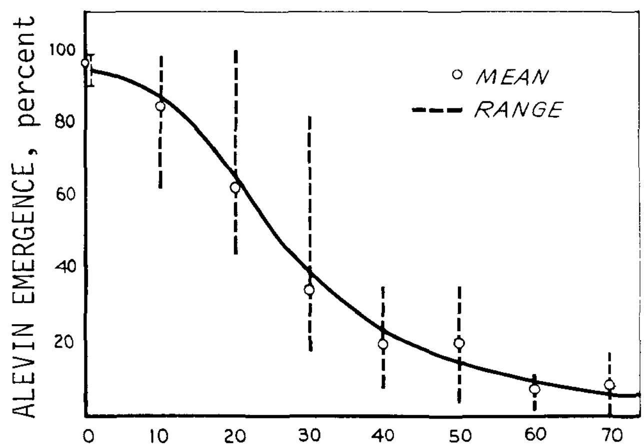


FIGURE 3. The proportion of salmon alevins that develop and emerge from gravel spawning beds decreases as the relative amount of fine sediment in the gravel beds increases.[5]

5/ Ibid., p. 49.

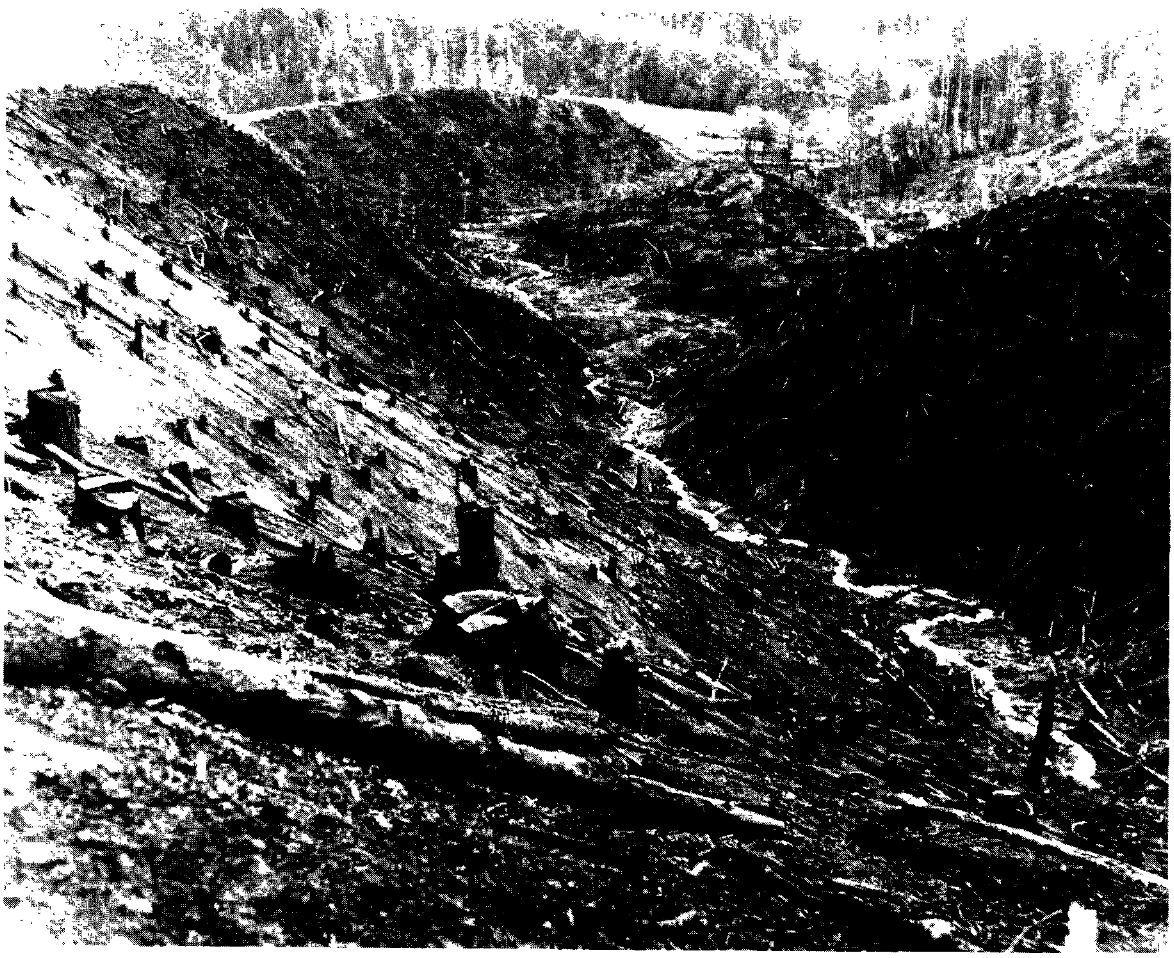


FIGURE 4. Removal of trees and all other vegetation along Needle Branch eliminated the shading effect and permitted peak stream water temperature increases up to 16^{o}F. Needle Branch is a small tributary of Drift Creek, which flows into the Alsea River in Oregon. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior, Nov. 1966.

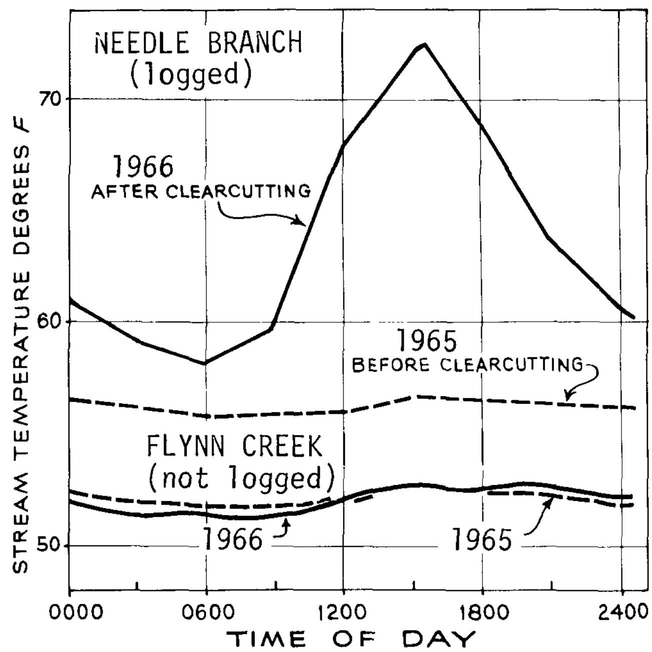


FIGURE 5. Water temperature in Needle Branch in Oregon, varied only some 2°F. during an average summer day before the trees were removed by the clear-cut logging method. It fluctuated about 15°F. (58 and 73 degrees) after logging. In Flynn Creek, a control (unlogged) watershed nearby, the water temperature was 5 to 7 degrees cooler than in Needle Branch even before Needle Branch was logged. The water temperature in Flynn Creek remained about the same throughout the study because this watershed was not logged.[6]

Optimum temperatures for fish life are considered to be:

Resident situations (trout):
Winter: 42 - 58°F.
Summer: 45 - 68°F.

Migration routes (anadromous salmonoids):
45 - 60°F.

Spawning areas (resident and anadromous salmonoids):
45 - 55°F.

Rearing areas (resident and anadromous salmonoids):
50 - 60°F.

6/ Ibid., p. 49.

FIGURE 6. The general characteristics of a random road pattern serving a number of clear-cut logging units in the H. J. Andrews Experimental Forest in central, western Oregon, in a view eastward toward the summit of the Cascade Mountains. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

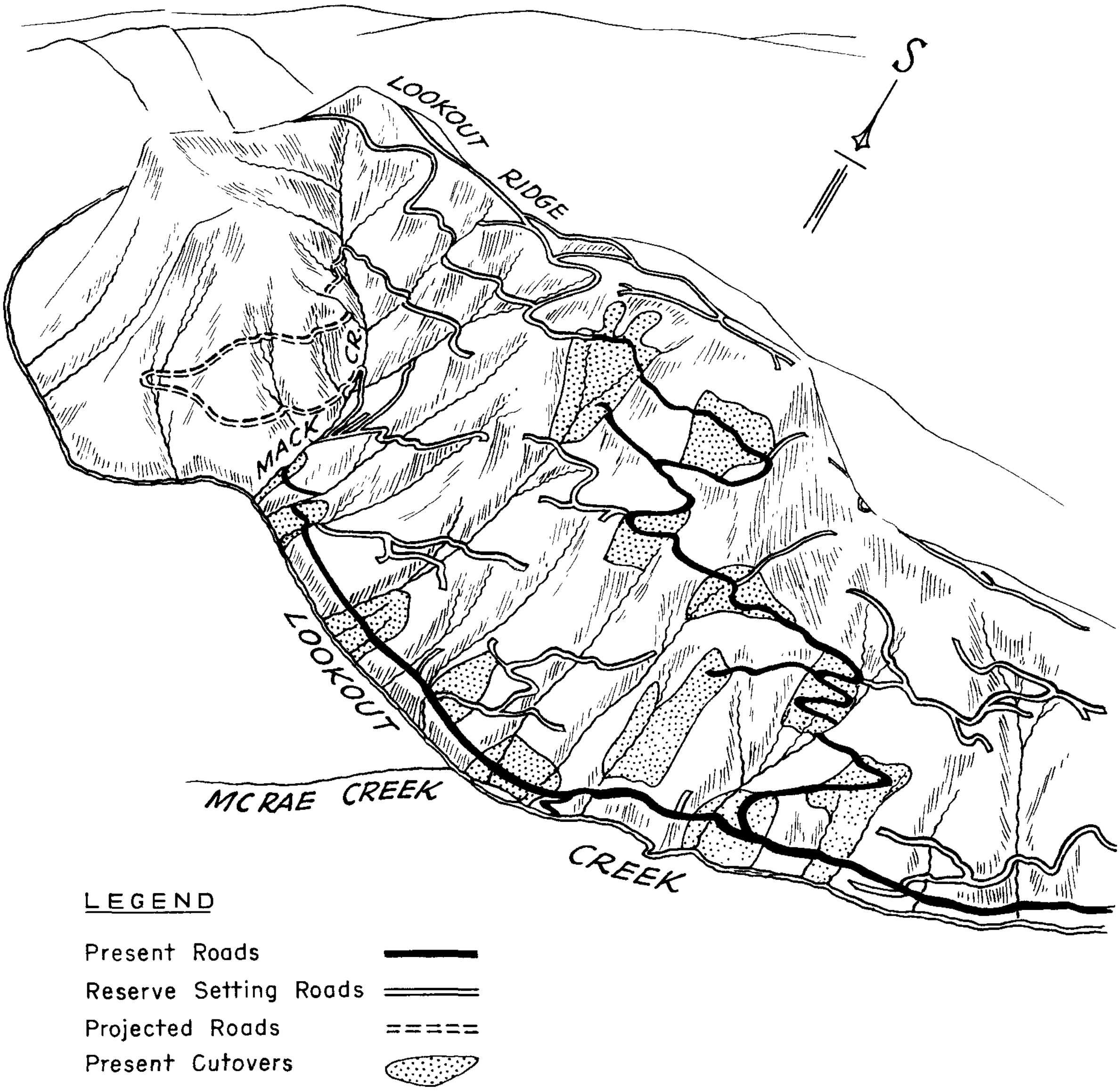


FIGURE 7. The roads on the south side of Lookout Creek in the H. J. Andrews Experimental Forest were located in "random" fashion and built far enough each year to permit an annual cut of 20 million board feet. The roads were constructed according to the best customary practices, utilizing a thorough knowledge of the terrain, a balance of economic yarding distances, and good watershed management principles. However, since a systematic approach was not followed, steep grades were prevalent, road density was high, and the yarding coverage was relatively poor. Drawing courtesy Forest Service, U. S. Dept. of Agriculture.

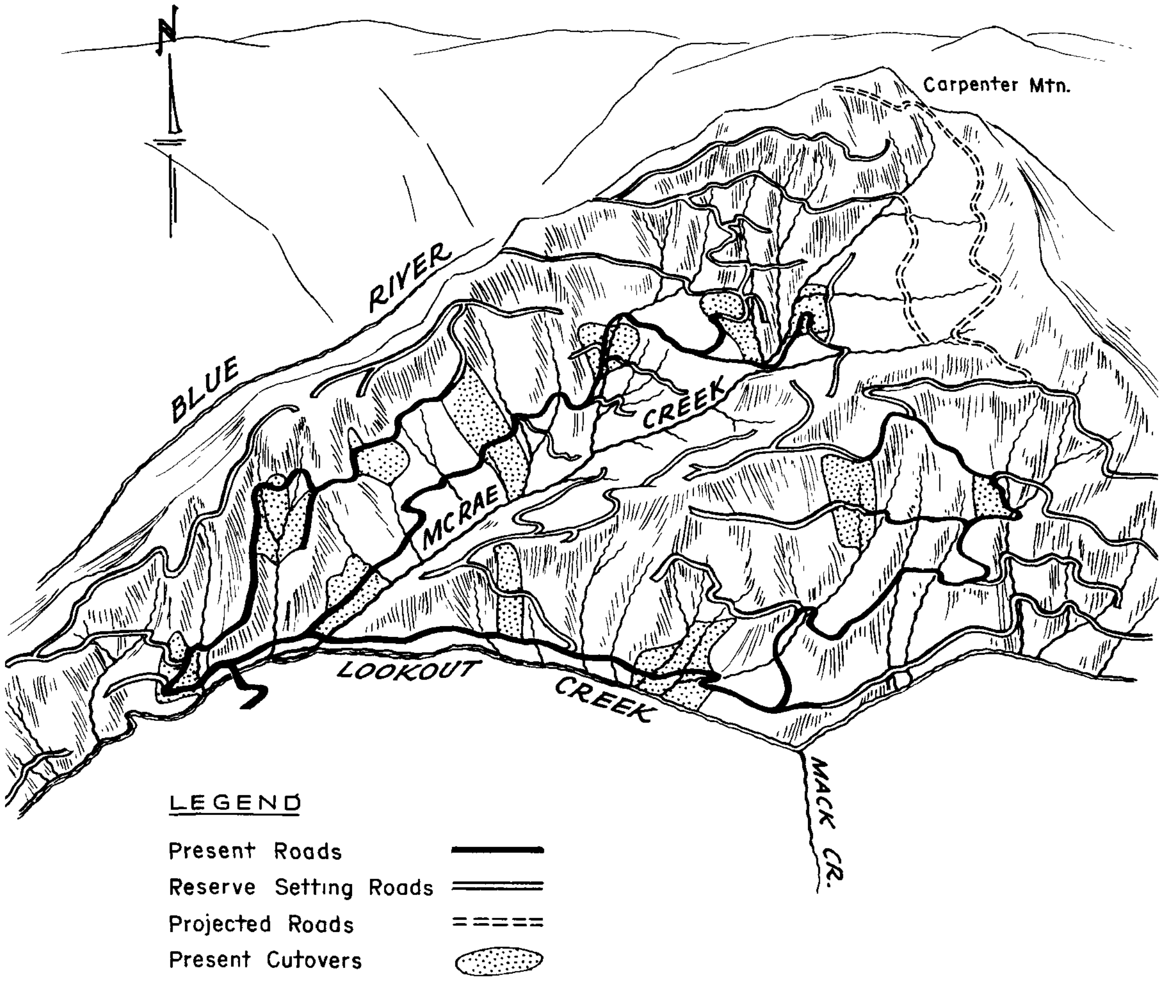


FIGURE 8. A systematic road pattern was used on the north side of Lookout Creek on the H. J. Andrews Experimental Forest. This pattern has distinct road levels, a minimum length of climbing road, a relatively low road density, and good yarding coverage. Drawing courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 9. Stable roads capable of supporting heavy loads can be located and constructed on steep slopes. Note the added safety precaution illustrated here of having the heavily loaded truck driving on the inside of the road when going out of the watershed and the unloaded truck using the outside of the road when coming into the watershed. This gives rise to the driving axiom for some private forest roads of: "outside in, and inside out." Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.

FIGURE 10. Generally, a stream (lower right) should be separated from an access road (upper left) by filter strips of living vegetation. Unfortunately, this temporary road, built during an emergency timber salvage program, did not utilize road construction practices necessary to protect the stream. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

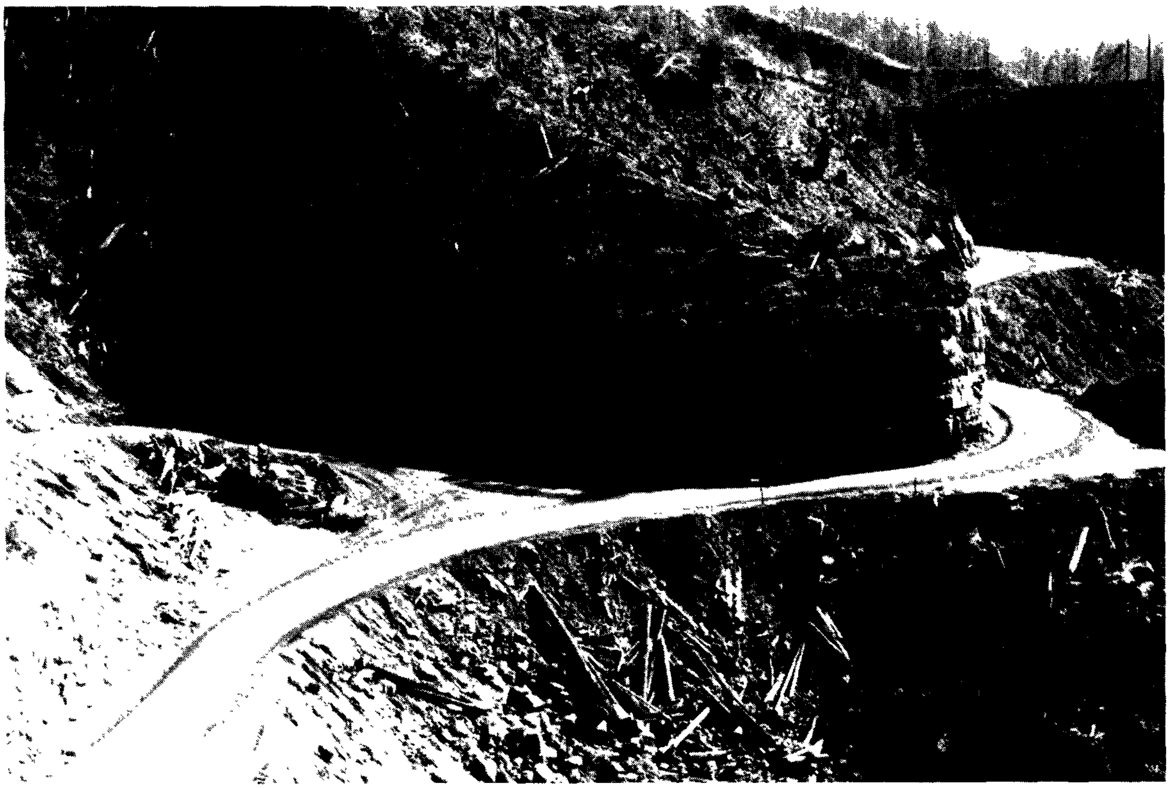


FIGURE 11. Sometimes topographic features allow for little choice in the location of a road. In those cases, special drainage and other stability features must be built into the road in order to prevent its being washed out during heavy storms. This junction of the Esmond Creek-Roman Nose Mountain roads (Sec. 29, T 19 S, R 8 W, Willamette Base and Meridian) required much searching for a suitable location plus much care in construction. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.

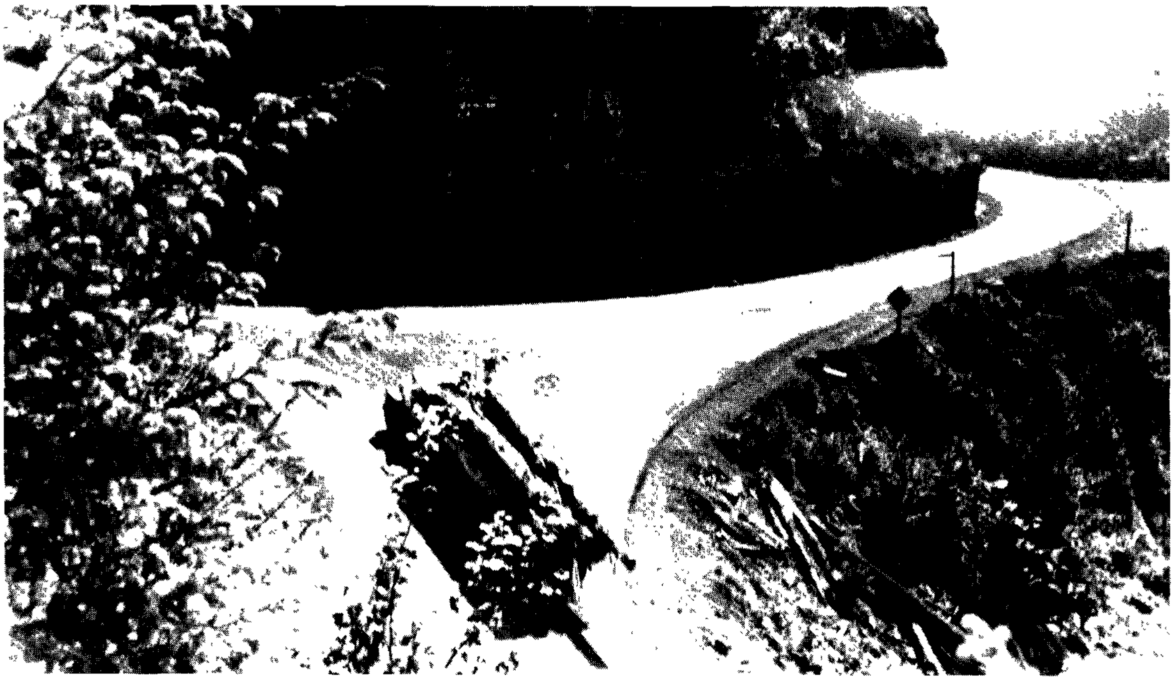


FIGURE 12. Esmond Creek-Roman Nose Mountain road junction after 10 years of use. Continued stability of a difficult location such as this requires constant, complete maintenance, especially of the drainage system. Note the regrowth of vegetation on the fill material and evidence of erosion around the end of the culvert. For full protection of the road fill, this culvert should be provided with a downspout (Fig. 18) or protective riprap. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.

FIGURE 13. Where feasible, safe, alternate locations through stable areas cannot be found, incorporate corrective stabilization measures into the road design. Use those measures that will increase the stability of fill embankments and cuts and provide fill embankments with protection against water erosion. Logs and posts are serving as effective protection barriers for the stream in this difficult location where a protective filter strip or a better location for the road did not exist. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 14. The water flows through this well-placed, pipe-arch culvert as though it were a part of the natural stream. Fish can pass through it easily because nonnegotiable pools were not formed and the velocity of the water was not increased. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 15. A poor culvert installation can block fish migrations even though the culvert is otherwise well-designed, of adequate size, and expensive to construct. Photo courtesy Oregon State Game Commission.

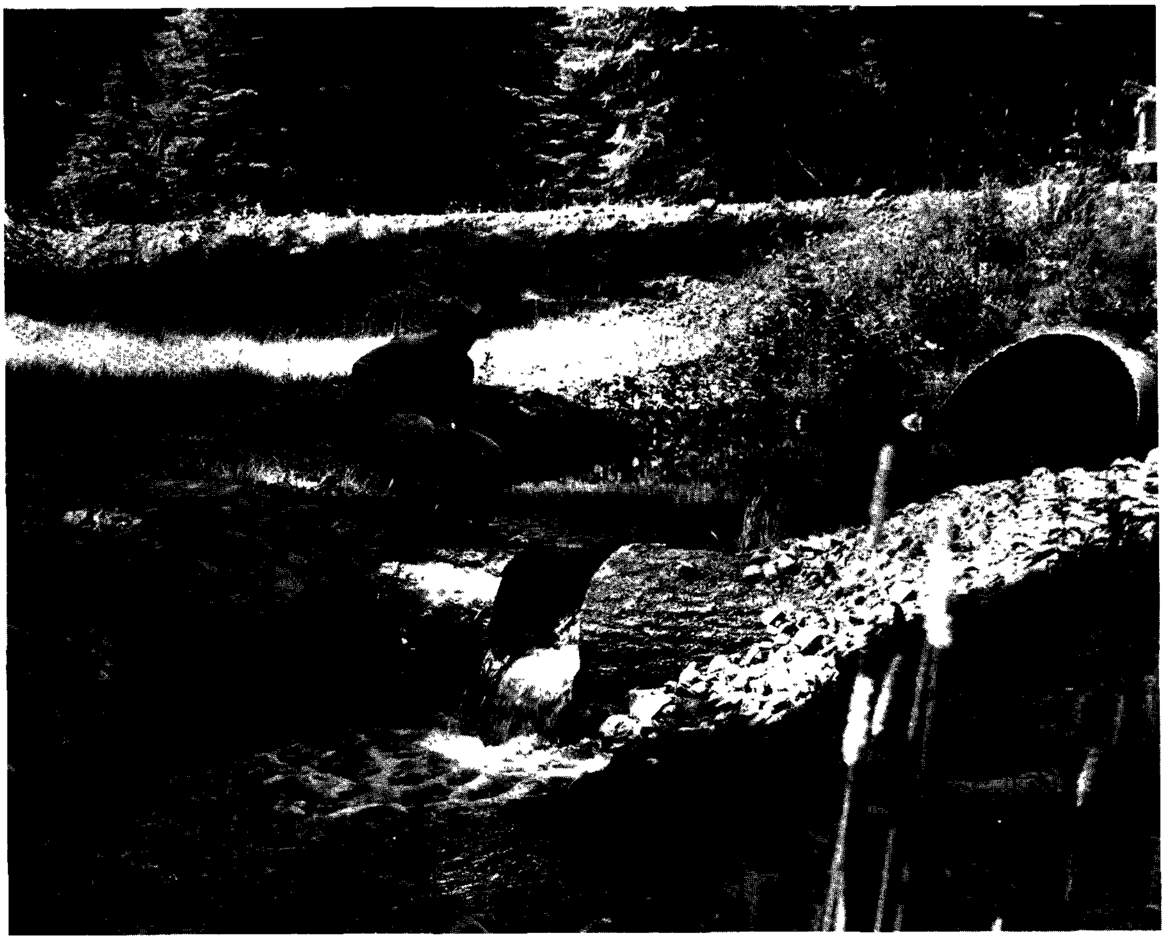


FIGURE 16. Pools formed behind barrier logs installed below a culvert assist fish passage during migrations. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 17. Inadequate design (culvert too small), improper placement (fill not compacted or not protected), insufficient maintenance (culvert clogged with debris), or a combination of these faults, often results in erosion of the fill material and expensive repair bills. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 18. Concentrations of road drainage require special disposal precautions. For instance, this well-anchored, half-round downspout protects a loose road fill from a culvert's concentrated discharges. Note the steel posts with the twisted wire binding which form a secure fixed point for the metal channel. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

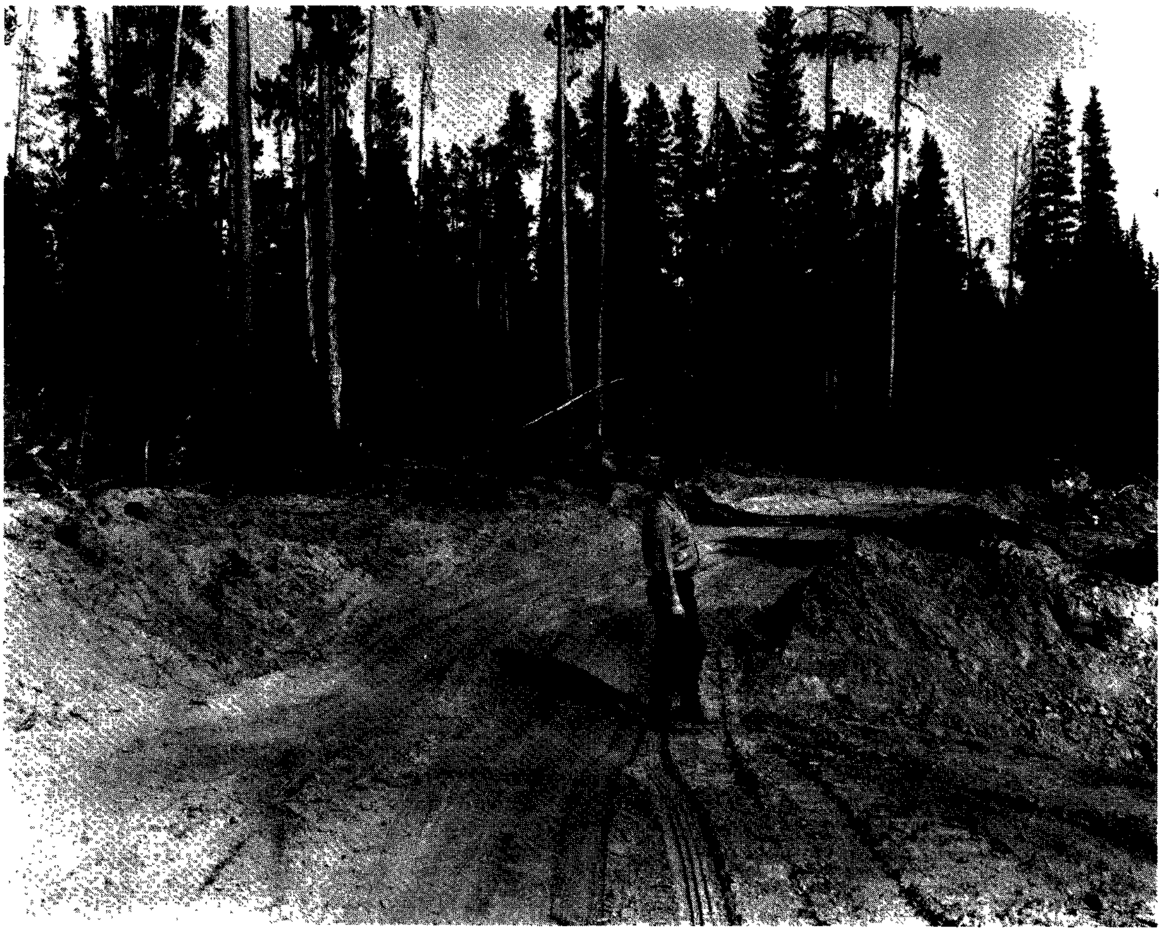


FIGURE 19. At the conclusion of a logging operation, block off all traffic and build water bars across all temporary roads. Do this before the first period of heavy precipitation occurs and while the necessary equipment is still in the area. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

A concrete ford.

A temporary bridge of standard design.

FIGURE 20. Concrete "fords" or easily removed, temporary bridges of standard design may be useful on unstable streams having a high upstream debris hazard such as is indicated by these cobbly stream channels. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 21. "Wet" mining road rock or gravel directly from live streams creates excessive turbidity, which can be avoided by using "dry" quarry mines. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 22. Waste material picked up during culvert cleaning or other road maintenance work should be dumped only in safe bench or cove locations so as to protect stream water quality. Dumping it in streams, as shown here, seriously degrades stream water quality.

FIGURE 23. Well-stabilized roads should be kept fully maintained without undercutting the inside slope or building up a berm on the outside edge. On this road, the berm on the outside extended for several miles and kept the precipitation channeled on the road during an early fall rain. This caused washing away of portions of the tread. The berm was subsequently spread across the full width of the road. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 24. Huge quantities of organic debris are left on the ground after clear-cutting, limbing, and bucking of a dense stand of old-growth timber. Any such organic debris that falls into, is dragged into, or washes into streams immediately begins to degrade the water quality. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 25. Smaller log sections with the limbs cut off cause the least soil gouging and thus minimize soil erosion and stream water quality degradation during the skidding operation. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.

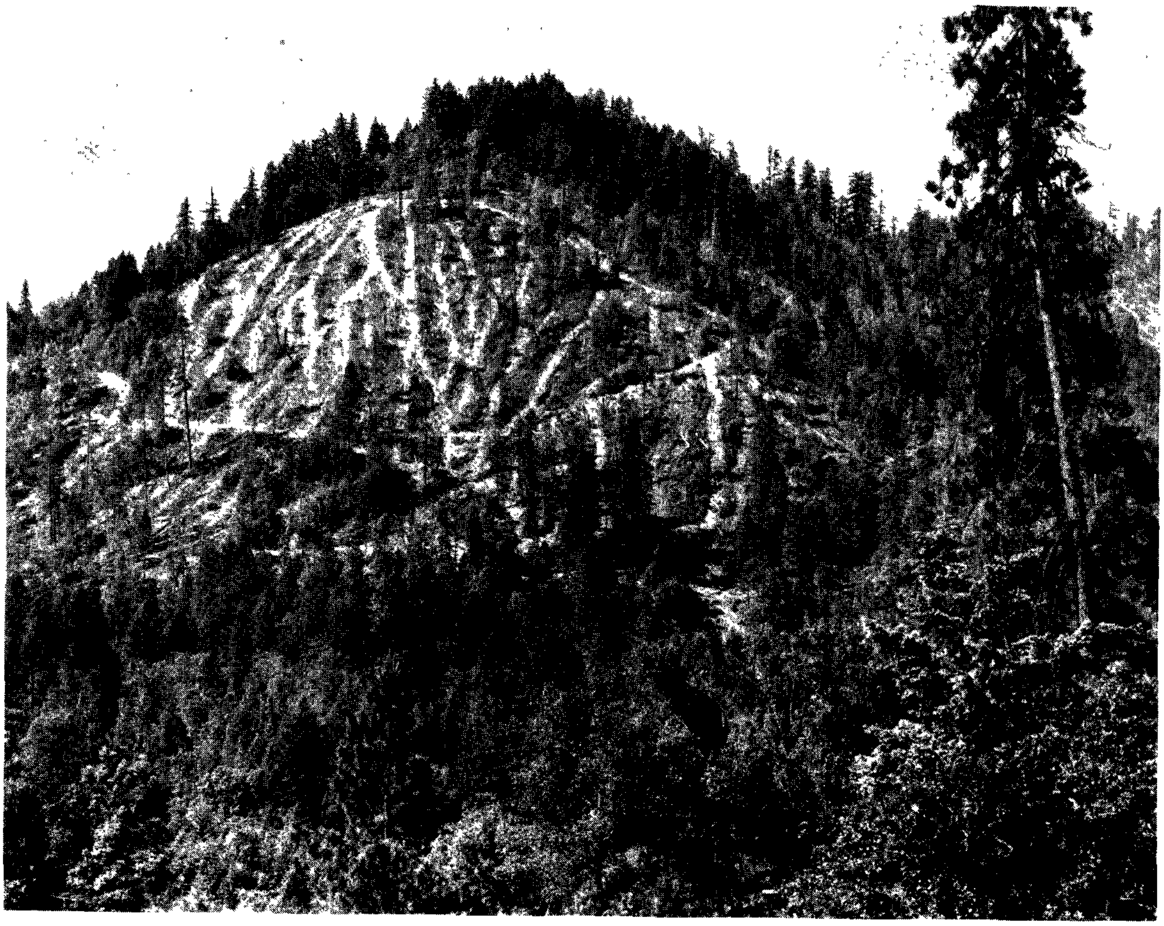


FIGURE 26. Indiscriminate use of tractors on steep hillsides causes excessive soil erosion. Crawler-tractor yarding should not be allowed on any slope steeper than 30 percent. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 27. Yarding logs can often be done economically with track-laying tractors. However, on critical soils, crawler-tractor yarding should be limited to slopes of less than 15 percent. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.

FIGURE 28. Yarding the logs uphill will help disperse rather than concentrate overland flow of runoff. When logging is completed and logging debris has been fully utilized, or otherwise disposed of, this area needs to be reforested to ensure a new timber crop and to protect the quality of inflow to streams. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 29. Swinging skylines with grapples are a fairly recent log-yarding innovation. They are more mobile than fixed skylines, but cause more soil disturbance because the heavier logs may be dragged most or all of the way to the landing. They are similar to high-lead log-yarding systems, but have the big advantage of being able to maneuver the logs past stumps or other obstructions. Swinging skylines can help reduce stream water degradation during the logging operation. Photo courtesy Pacific Logging Congress.

FIGURE 30. Balloon logging may eventually replace some of the older methods. It or helicopter logging may also permit timber harvesting to proceed on fragile areas that should not be logged even by use of today's best systems and equipment. Photo courtesy Lennen & Newell/Pacific, Portland, Oregon.

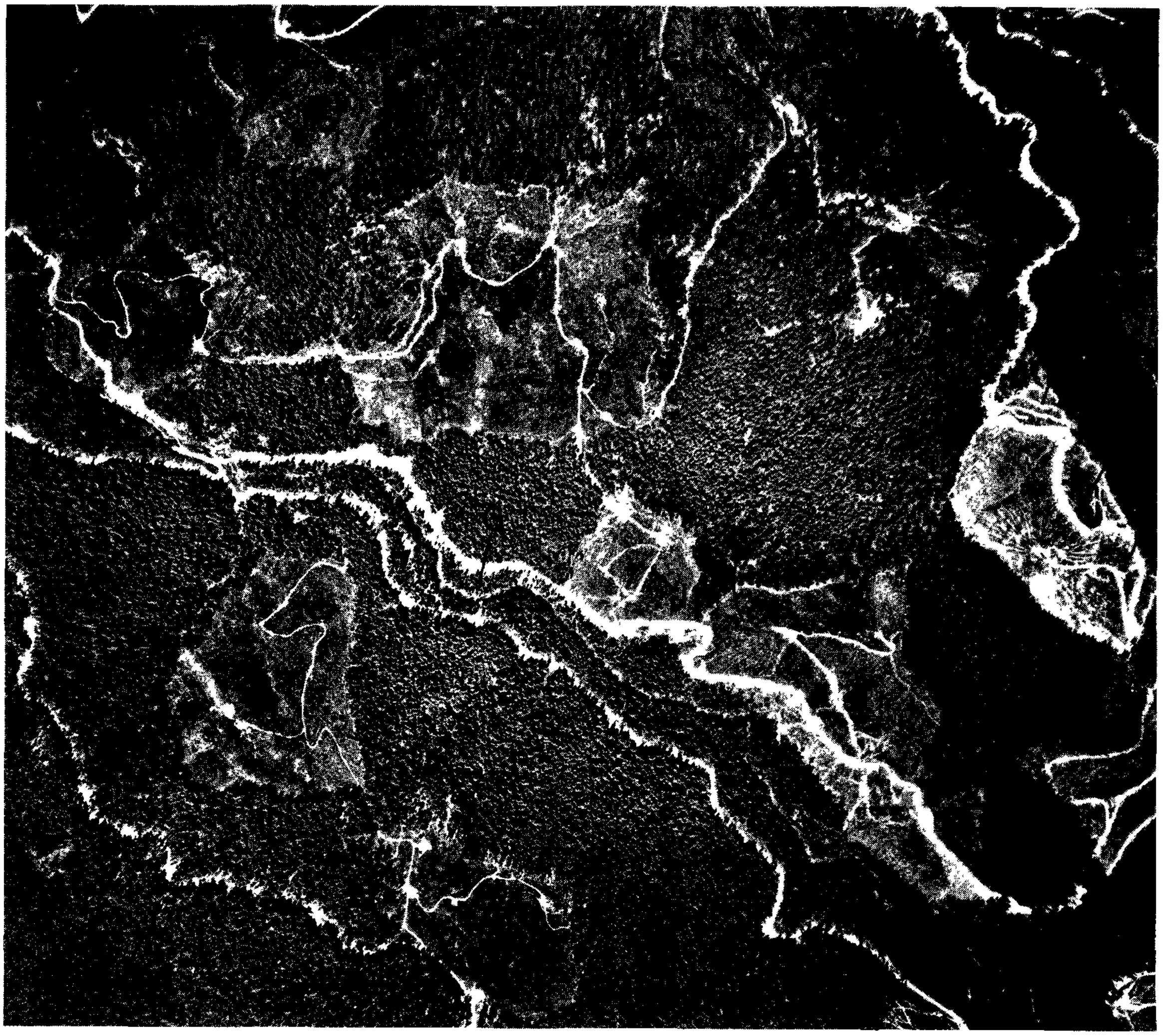


FIGURE 31. Buffer strips of live vegetation between roads, clear-cut areas, and streams help protect water quality. This vertical aerial photo of an area on the Gifford Pinchot National Forest has an approximate scale of 4 inches to the mile.

Pertinent points are:

A. Areas clear-cut logged about 1945-1951 are now well stocked with coniferous trees that are 10-15 feet tall.

B. Areas clear-cut about 1964.

C. Uphill cable yarding trails on recent clear-cuts.

D. & F. Main timber access roads.

E. Canyon Creek.

G. Narrow, fairly short, dark area is strip of timber left to protect stream from road fill. Gray-white areas at either end of buffer strip are places where rocky soil and steep slopes prevented leaving a protective strip of adequate width.

H. Tractor logging trails.

I. Spur roads to landings.

J. Scar in clear-cut area caused by off-road, downhill movement of yarding equipment.

FIGURE 32. Seeded grass gives protection to roadside cuts and fills and reduces the rate of accelerated erosion.

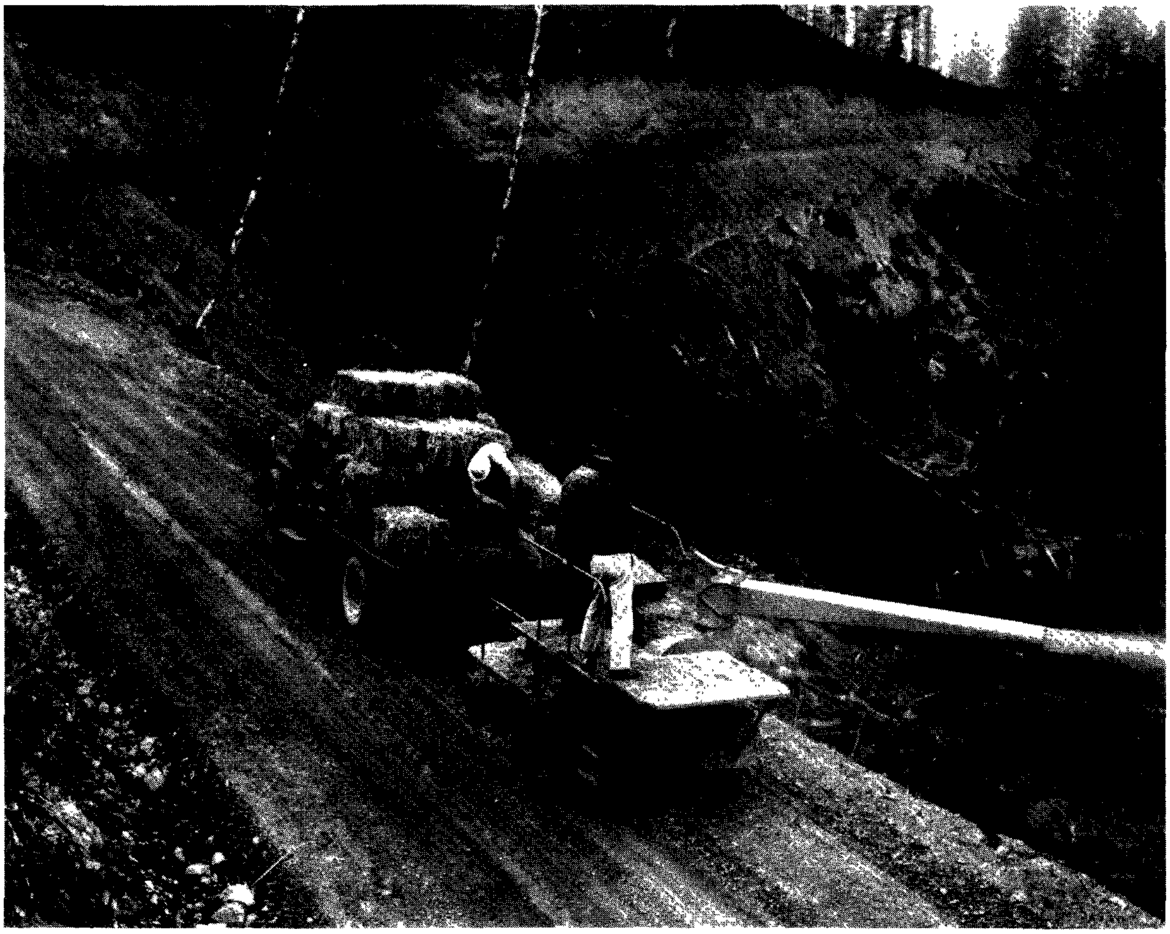
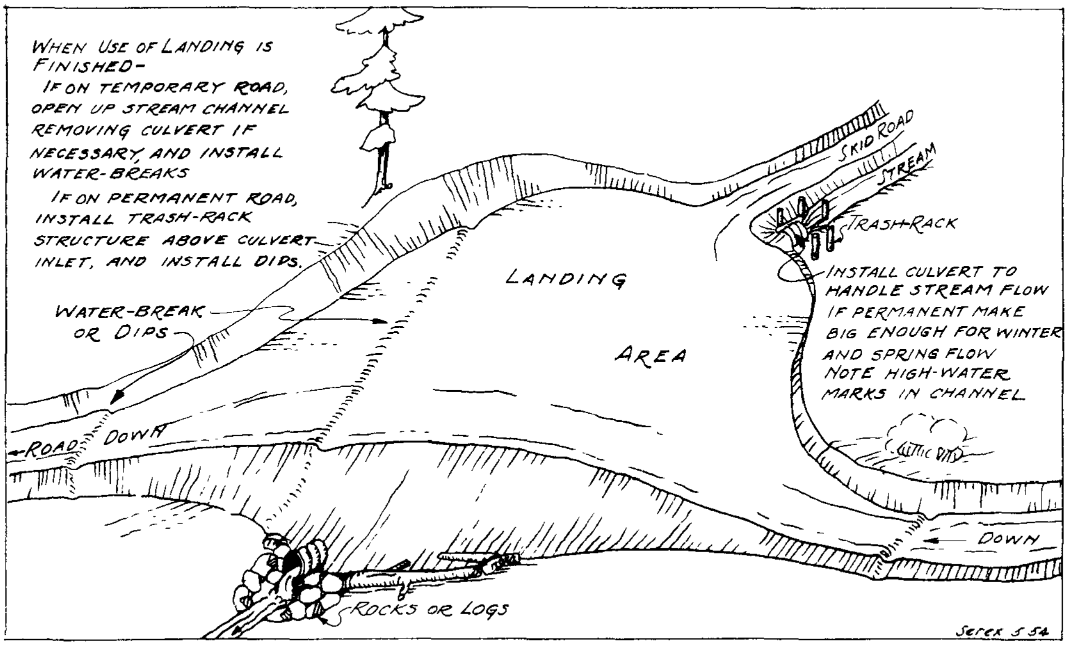


FIGURE 33. Mulching with straw or other organic matter and seeding to adapted plant species helps stabilize raw road slopes. The four-man crew on the mulching machine in operation on this newly constructed road includes a truck driver, supply man (on truck), machine feeder, and nozzle operator. Photo courtesy Forest Service, U. S. Dept. of Agriculture.

FIGURE 34. This temporarily used, now abandoned, log-hauling road was stabilized by seeding to perennial grasses after the road had served the purpose for which it was constructed. If needed later, this well-preserved road could be easily renovated. Photo courtesy Forest Service, U. S. Dept. of Agriculture.



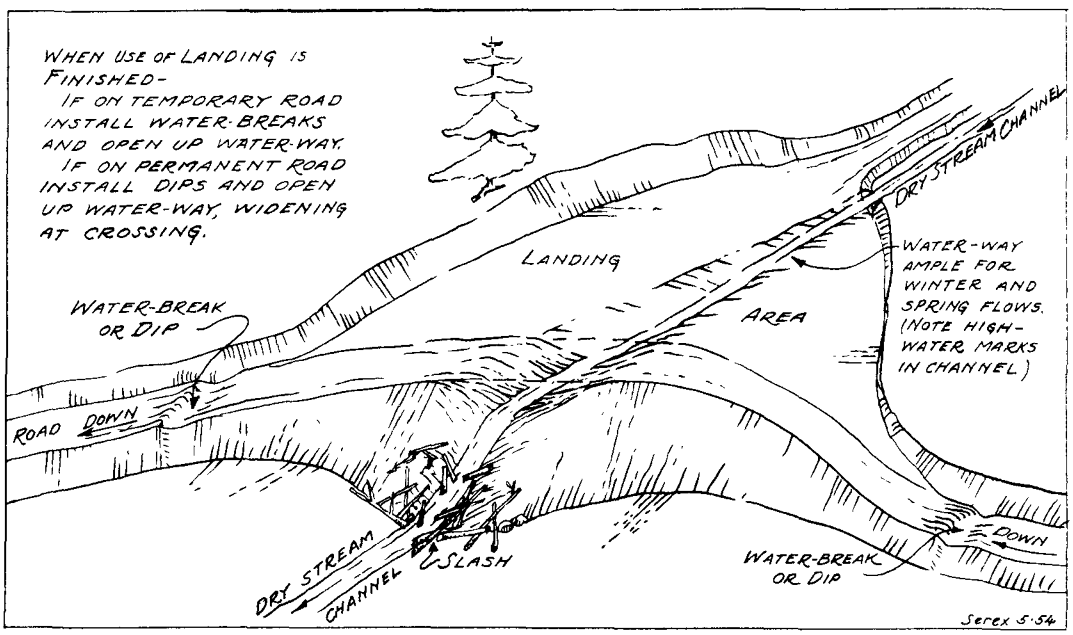


FIGURE 35. When there is no other alternative, a log loading and storage area may have to be placed in a valley location. Such log landings should be planned carefully, drained during use, and obliterated or stabilized after use.5/

5/ U. S. Department of Agriculture, Forest Service, California Region. 1954. A Guide to Erosion Reduction on National Timber Sale Areas. p. 16.

FIGURE 36. Douglas-fir seed germinates best in mineral soil. Disposal by suitable method of most of the small-sized logging slash facilitates the reseeding and replanting of a Douglas-fir clearcut area. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.

FIGURE 37. A protective mat of organic matter on and in the soil helps reduce the sediment load washed into streams. Chopping up the logging debris with a brush or slash cutter will help produce such a protective mat. Photo courtesy Bureau of Land Management, U. S. Dept. of the Interior.