A GUIDE TO EROSION REDUCTION ON NATIONAL FOREST TIMBER SALE AREAS

U.S. FOREST SERVICE
CALIFORNIA REGION
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Cover Photo

Tractor logged area on National Forest timber sale Stanislaus National Forest

A GUIDE TO EROSION REDUCTION ON NATIONAL FOREST TIMBER SALE AREAS

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FOREST SUPERVISORS:

As California's population continues to grow, we must expect corresponding increases in the demand for services from our forest areas. It is timely to recall, therefore, that the basic policy under which the national forests were established placed the "securing of favorable conditions of water flows" on a par with the furnishing of a "continuous supply of timber for the use and necessities of citizens of the United States."

In the California Region we have been steadily increasing our annual cut of national forest timber. And, as our access roads reach into the rougher back country, the watershed problems associated with timber harvesting become more pronounced.

This Guide has been prepared in response to the need for more specific help for land managers who must deal daily with soil and watershed protection problems. These guidelines have been developed primarily by observation of methods and results.

Good results don't just happen - they come from adequate planning, good timber appraisals and through the skill and cooperation of the timber operator who puts the planning into effect. Don't hesitate to enlist the aid of your timber operators in planning for a good logging job which will minimize soil and water damage. Many of the approved methods or guidelines described were developed with their assistance.

Just remember too, that the objective is always prevention of damage and by the most economical means with appraisals giving recognition to necessary costs.

We sincerely hope this set of guidelines will be helpful to you. Those who have put them together freely admit it doesn't cover all situations. It is our hope that as the recommended measures are used they will be improved or replaced with better innovations to be recorded and illustrated in future revisions of this Guide. Our present goal is a comprehensive review in two years to be followed by desirable revisions for improvement.

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PREFACE

This handbook is the outgrowth of the experience and ideas of many men. Good ideas in forestry, as in other fields, often grow into practice without record or even knowledge of their originators. In California, the record of action to reduce watershed damages associated with logging is incomplete, and it is possible to set down only a few incidents that are of record.

In 1946, an informal team, including T. R. Littlefield, Duncan Dunning and Charles Kraebel, examined a going sale on the Tahoe Forest, and recommended measures to safeguard the soil and water resources in a prospective extension of the sale on an adjacent area. The next year, in response to a request from the Sequoia Forest, a larger team, including the same three men plus Russell McRorey and D'Arcy Bonnett, did a similar but more detailed job for a proposed sale in the Hume Lake area. Copies of their recommendations were sent to all R-5 forests by Regional Forester P. A. Thompson on November 12, 1947.

During 1952 and 1953, a field examination of representative timber sales throughout the Region was carried on by N. F. Meadowcroft, McRorey and Kraebel, with a view to gathering material for a handbook that would have Region-wide application. In 1953, the Forest Supervisors of the Region, at their annual meeting, formally requested the issuance of such a handbook.

The Guide was prepared under the direction of T. R. Littlefield by the last-named three-man team, most of the photographs were taken by them, and the sketches were drawn by Jack Serex. The manuscript was reviewed by several divisions in the Experiment Station and the Regional Office. Review and revision of the final draft of the Guide was made by C. N. Strawn and W. R. Howden. Revisions have been freely made, but all who have had a hand in the book appreciate that it could well be amplified at many points. They realize, however, that in many situations a book can be only suggestive, and that the real job of developing an adequate technique of watershed protection in logging areas will be done by the men in the forest.

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I. INTRODUCTION

In the process of harvesting national forest timber in California, 80,000 acres are presently being cut-over each year to provide lumber and other forest products. Removal of the older trees usually results in timber stand benefits in the form of new tree seedlings, and of accelerated growth that may accrue on trees left after a partial cut. By contrast, the disturbances to the soil and water resources are often harmful. The kind and extent of damage vary greatly, depending on the amount of timber removed, method of logging, type of soil, roughness of terrain, and weather conditions.

The injuries to soil and water, collectively termed watershed damages, are briefly described as follows: Soil is loosened and often extensively displaced by road construction and skidding. In places, compaction by heavy machinery, and changes in configuration of the soil surface by roads and landings, cause increased water movement over the surface and the formation of new water courses. Eroded soil and logging slash lodged in streams may cause serious damage to fish life. During high water stages some of the soil may be carried into water storage reservoirs miles away from the logging areas.

Not all timber sale operations will involve equally all these forms of watershed injury, of course, but every sale will involve some of them. Since most sale operations are located in major water source areas of the region, special efforts are justified to conserve the soils and safeguard the water yield of the sale areas. It is the purpose of this guide to provide practical aids in the form of photographs, sketches, specifications, and other information that will be helpful to those concerned with harvesting timber with the least possible damage to the soil and water.

II. PRINCIPAL FACTORS INFLUENCING WATERSHED CONDITIONS

For purposes of this guide, the chief indicators of watershed condition are the stability and permeability of soils, and the quality and regularity of water flow. The principal factors influencing these characteristics of soil and water are of two broad types: Those imposed by nature, and generally beyond man's control; those introduced by man's use, and generally subject to his control. Both must be considered in planning a timber harvesting operation to be carried out with minimum watershed damage.

A. Natural Physical Factors

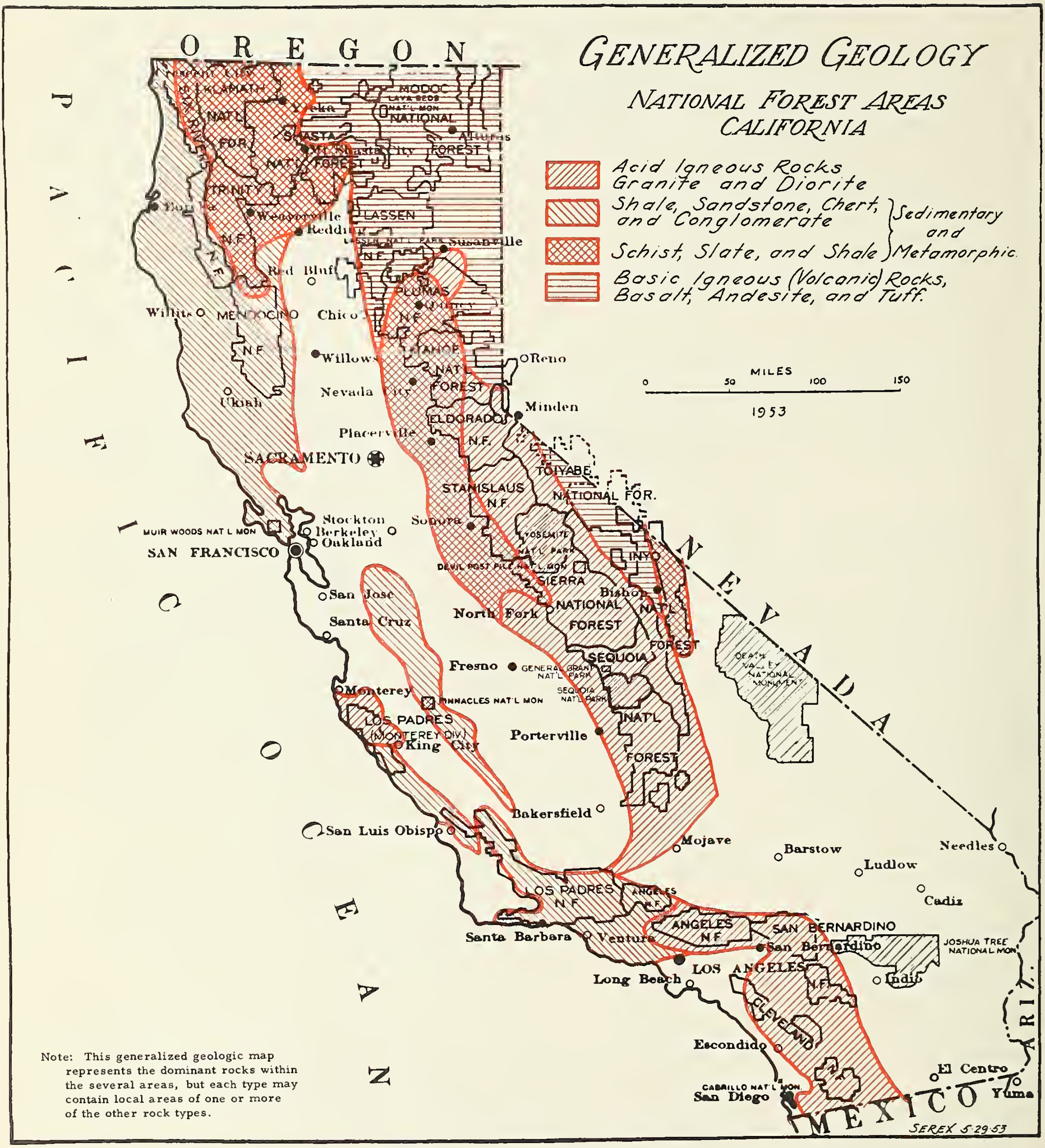
The principal natural factors which influence soil stability are geology, soil, slope, precipitation, and vegetation. In any prospective logging area these factors can be evaluated to provide a basis for estimating the risks of erosion involved in harvesting the timber.

To facilitate such evaluation the tabulation on page 3 provides a rough comparative rating of erosion hazard based on various combinations of the natural factors affecting erosion. Used with judgment, this key will serve as a check list in appraising the erosion potential of any particular area. The map on page 4 showing the broadly generalized geology of the forest areas of California is to be used with the tabulation.

RELATIVE EROSION HAZARD OF LOGGING AREAS
IN RELATION TO SITE FACTORS

SITE FACTORS	HIGH EROSION HAZARD	MODERATE EROSION HAZARD	LOW EROSION HAZARD
Parent rock [1]	Acid igneous Granite, Diorite, Volcanic ash Some schists	Sedimentary and Metamorphic Sandstone, schist shale, slate, conglomerates chert	Basic Igneous (Lava rocks) Basalt, Andesite Serpentine
Soil [2]	Light textured, with little or no clay	Medium textured with considerable clay	Heavy textured, largely clay and adobe
(Examples)	(Holland, Decomposed Granite)	(Hugo and Josephine)	(Aiken, Underwood)
Slope	Steep (Over 50%)	Moderate (20 - 50%)	Gentle (0 - 20%)
Precipitation	Heavy winter rains or 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

1. To be used in conjunction with accompanying map - "Generalized Geology of California."
2. Soil texture refers to the size and distribution of mineral particles in soil, the range extending from sand (light texture) to clay (heavy texture).



National forests of the California Region

B. Factors Introduced by Use

In contrast to the natural physical factors which are beyond control by man, there are other factors influencing erosion on every logging operation, which are introduced by man's use and are subject to his control. These include such things as cutting practices, yarding of logs, and road construction and maintenance. Each may create problems of soil and water damage, but careful planning can minimize their effects and reduce the amount of corrective work needed after logging. Specific prevention and protection measures are presented in the following pages, arranged in the order in which they will usually be considered or encountered.

1. Cutting Practices (Timber Marking) and Slash Disposal.

There are timber areas where natural conditions are in such critical balance that any disturbance of cover or soil would result in irreparable damage, and the land manager must be alert to recognize and exclude them from cutting areas. In most cases, however, a cutting practice which assures the maintenance of proper watershed conditions can be developed.

The amount of soil disturbance in selective logging has been found to vary proportionately with the intensity of cutting. It follows that a light or moderate selection cut is generally desirable for soil maintenance and watershed protection.

However, in some areas, and in certain forest types, there are sound economic and silvicultural reasons for heavy cutting or even clear cutting. This is particularly true in the coastal Douglas fir type where steep topography and heavy rains aggravate the hazard of erosion from truck and tractor roads. In localities where clear cutting in patches is a desirable silvicultural system, uphill cable logging may cause less disturbance than a heavy selection cut with tractor logging.

Where clear cutting or exceptionally heavy cutting is employed, it should be recognized that special precautions for watershed protection may be required. It should be possible to plan and execute a clear cutting layout so that roads, landings and yarding trails are just as satisfactory as in a partial cutting.

Logging slash is an important item in prevention of erosion and watershed damage. Slash and logging debris allowed to accumulate in natural drainages can stop the free circulation of fish and destroy the fish themselves. By diversion of stream flow, slash tangles can cause severe erosion damage. On the other hand, some slash can be used effectively as a mulch on road fill slopes, skid trails, and other exposed ground surfaces to prevent undue soil movement and to promote stabilization.

2. <u>Yarding and Skidding</u>

This phase of the logging operation must receive special attention in order to minimize erosion. Skidding or yarding may cause damage in several ways: Loosening and moving of soil in ridges at the sides of skid trails, compaction of soil by movement of equipment and logs, and the "channelling" of the ground surface by repeated passes of equipment and logs to the landings. The resulting erosion damages vary with the amount of timber cut per acre, type of equipment used, care in logging, and natural vegetation ground cover.

3. <u>Road Construction and Maintenance</u>

Properly located, constructed and maintained, roads need have only a minor adverse effect on watershed conditions. When location, construction and maintenance are not given the careful attention they should have, however, roads can become a major problem in watershed management. Details of the problems involved and the various methods of solving them are brought out in Part III, Section C.

For the purposes of this Guide, logging roads are classified as follows:

Main Roads - The important main access roads leading from the logging operation to an outside point, and the main haul roads within the logging operation. They are permanent roads, and usually are on the Forest Road System.

Secondary Roads - The principal lateral and more important spur roads largely within the logging operation area. Usually permanent Forest Road System projects, but may be non-system in some cases. If "on system," and retired between timber cuts, they should be given M4 maintenance classification.

Temporary Roads - All other roads within the logging operation which are used for one or two seasons only and then retired or "put to bed." These roads are seldom Forest Road System projects, but when on the system are given M4 maintenance classification.

1.

Cut-over area on very steep ground with slopes up to 70 percent. As the result of careful planning, advance location and construction of the road and tractor trails, logging has been done without serious erosion or other damage to the watershed.

2.

Protective strip of vegetation about 50 feet wide left along a stream to protect banks and preserve natural conditions for fish, wildlife, and attractive appearance. A very desirable practice anywhere, but especially so near recreation areas and adjacent to highways. The surrounding area in this instance was heavily logged.

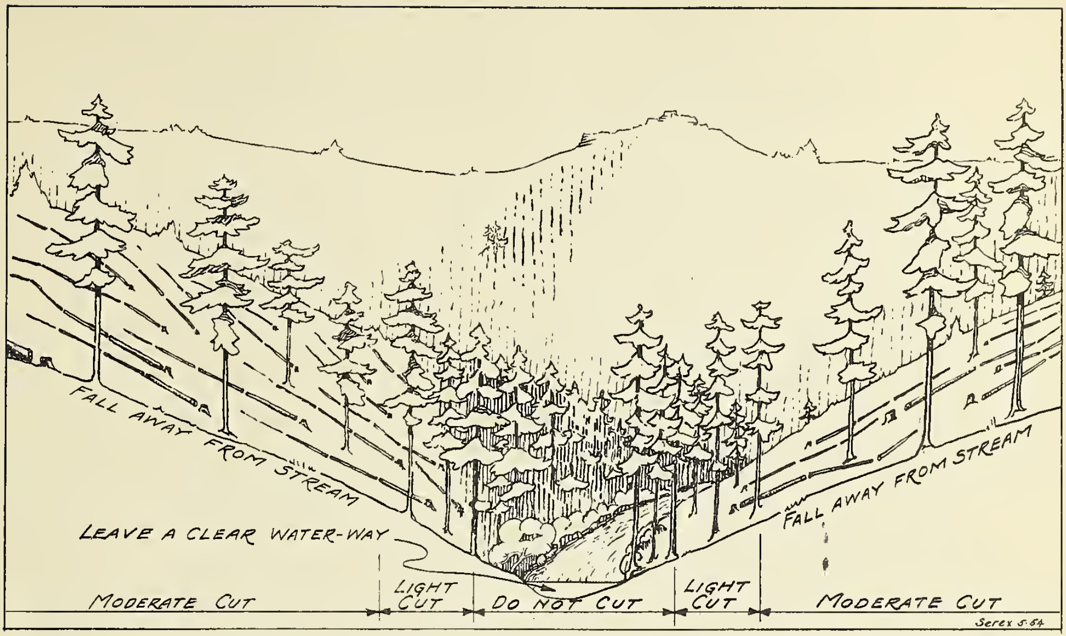


Fig. 2, Felling Near Streams and Water Ways.

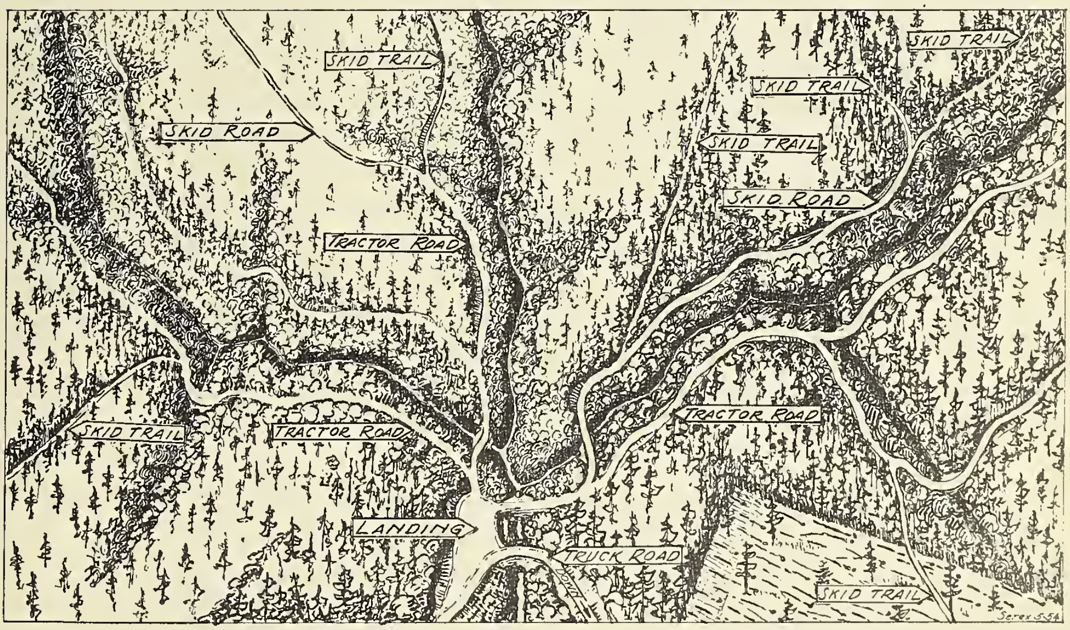


Fig. 1, Typical Yarding Plan for Local Area.

III. WATERSHED PROTECTION MEASURES

A. Advance Planning of the Logging Operation

A detailed advance plan coordinating the economic, silvicultural, engineering, and protection needs of the sale area results not only in less damage to the watershed but also in a more efficient logging operation. Field examinations made in connection with this Guide have disclosed that where watershed disturbance has been least, and the amount of required erosion control work minor, the logging operation had been well planned in advance and the plan well carried out. Photo No. 1. Such planning can best be coordinated with the collection of data for stumpage appraisal. The finished plan should be put in the hands of the officer responsible for the administration of the sale well ahead of the start of road construction, felling and skidding. Some refinement of generalizations may properly be left for the project sale officer, and this should be specified in the plan which forms a part of his written instructions.

The first step in planning is to evaluate the critical features of the whole logging and timber harvesting operation. The proposed timber sale is analyzed in relation to its effect on site values (soil productivity, vegetation cover, forage for game and livestock, and recreation) and on downstream interests (fish life, reservoirs, irrigation). Watershed protection requirements for the logging operation and post logging treatment, if any, are determined in consideration of the several natural factors which affect the erosion potential. Aerial photos, particularly when used stereoscopically, in conjunction with on-the-ground examination of the area will be found helpful in selecting landing sites and road and skid road locations.

The second step is to set up guides or specifications for erosion prevention or control measures for each successive stage in the logging operation. The specific requirements should be set down in text form, and keyed to a map of the sale area, to guide the project sale officer in administering the following:

1. Timber marking (cutting)--including such items as the designation of areas to be left uncut, or to receive special marking to minimize erosion or prevent the clogging of streams.

2. Transportation system--including standards and locations of permanent and temporary roads and stream crossings (bridges, fords, culverts), construction methods and restrictions thereon, drainage and stabilization of road slopes or other disturbed areas, watering and blading of unsurfaced roads when necessary.

3. Skidding or yarding--including location or restrictions on location of skid trails, skid roads, tractor roads, and landings.

   For the purpose of this Guide the several types of skidding or yarding roads used exclusively by tractors to move logs from the stump to the landing in logging operations are described below:

   (a) Tractor Road - A road constructed or graded in advance for the actual log skidding operation.

   (b) Tractor Trail - A route not constructed in advance but developed by much tractor skidding.

   (c) Skid Trail - A trail not constructed in advance and used only a few times by tractors.

4. Corrective and preventive measures required of the operator, or to be done by the Forest Service where applicable. These include any necessary treatment of cut-over area, skid roads and trails, disposal or use of slash in preventing erosion, removal of temporary log and dirt fills from drainage channels and of logging debris from streams, cross ditching of roads and skid roads, restoration of landing surfaces, etc. The disposal of slash not used for erosion control, should be in accordance with current Regional slash disposal policy.

3.

Protection or "leave" strip along slope adjoining a creek. Area upslope at left was heavily cut. Protection strips like this help preserve favorable conditions for fish, wildlife, and recreation where these values are important.

4

A clear cut "unit area," well handled, on a moderate slope at head of a ravine with intermittent streamflow. After logging, the ground surface was stripped of competing brush and undesired trees. Most of the slash was burned, but a small amount was pushed into the draw to check runoff and trap any eroded material, then the cleared area was seeded and planted. For good watershed management this method is not advisable for areas larger than about 5 acres, nor for very steep slopes, or erodible soil, unless special precautions are taken to control runoff and erosion.

5.

Washout of fill across a stream in salvage area, after logging, necessitated reconstruction of the road to give access for planting and seeding. Such washouts occurred at a score of crossings on three contour roads in this burn, the eroded material coming to rest in a power reservoir 3 miles away.

6.

Severe erosion in a burned area aggravated by a timber salvage operation. Note the rill erosion down the skid trails and edge of a large gully in foreground caused by a road. In the interest of good watershed management, careful consideration should be given as to whether logging in such an area is justified, and whether adequate treatment can be provided to prevent excessive damage.

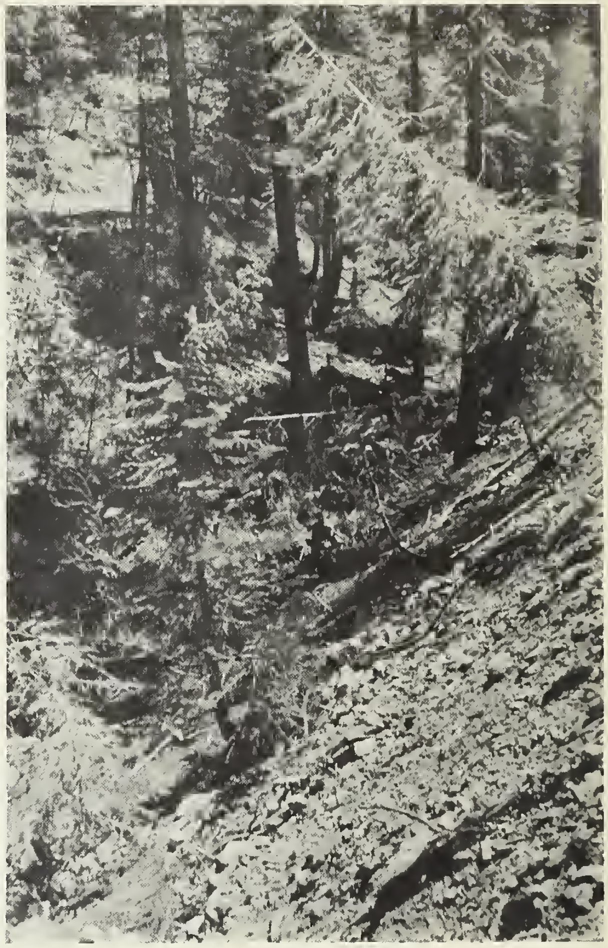
7. 

Stream channel heavily obstructed by logging slash and erosion debris from heavy cutting. Logging waste dumped indiscriminately in streams in this manner destroys their fishing and recreation values and creates a severe fire hazard.

8. 

Heavy cutting along this main stream was done with very little disturbance of banks or channel. The trees were felled away from the stream and hauled out over the tractor road at left, located well above water level. Most of the logs on the far side of stream were skidded to a road 200 to 300 feet up the slope at right. Broadleaf vegetation left along the streambanks, and released by removal of the conifers, will soon shade the stream.

9.



Stream channel left in good condition after logging. Although there is a truck road on right slope and a tractor road on left slope, the stream-side vegetation is undamaged, and the overcast from the road (right foreground) has caught at a safe distance above the creek, leaving a clear undisturbed waterway. (Man in center stands on stream bank.)

10.

A small stream, choked with silt and logging debris, and with all riparian vegetation destroyed. Care in logging along the stream and on the watershed to reduce these damages would have entailed little additional expense.

B. The Cutting and Yarding Operation

The actual felling and removal of timber need result in only nominal disturbance of the soil and watershed. To achieve this requires exercising discretion and judgment, as well as observing certain practices and restraints in the cutting operation. The following procedures and practices are recommended in preparing specific guide lines for the project sale officer.

1. Selection of areas to be cut, marking, areas to be given special consideration or left uncut.

   (a) Examine critically cutting proposals on light erosible soils in heavy rainfall country especially where marking will remove more than 40 per cent of the volume or where slopes exceed 30 per cent.

   Burned areas to be salvage logged require special consideration. As the normal protective cover of undergrowth, litter and humus has been destroyed, a mechanical disturbance of the soil is likely to increase the erosion and downstream damage. There may be instances where the proper decision will be to refrain from logging rather than to attempt to salvage the fire-killed timber.

   (b) Adjust the marking to local conditions of soil, slope and precipitation so as to provide lighter cuts on steep slopes or light erosible soils and heavier cuts (where desirable) in flatter terrain or erosion resistant soils.

   (c) Leave an uncut protective strip along live streams and around the edge of meadows, or carefully remove only selected trees to attain the same objective.

   (d) Fell trees away from drainage channels, both live and dry, in order to keep slash out of water ways. (Note a commendable exception in picture number 4.) Fell trees toward skid roads to limit the haul distance and to minimize ground disturbance by tractors in assembling a load of logs.

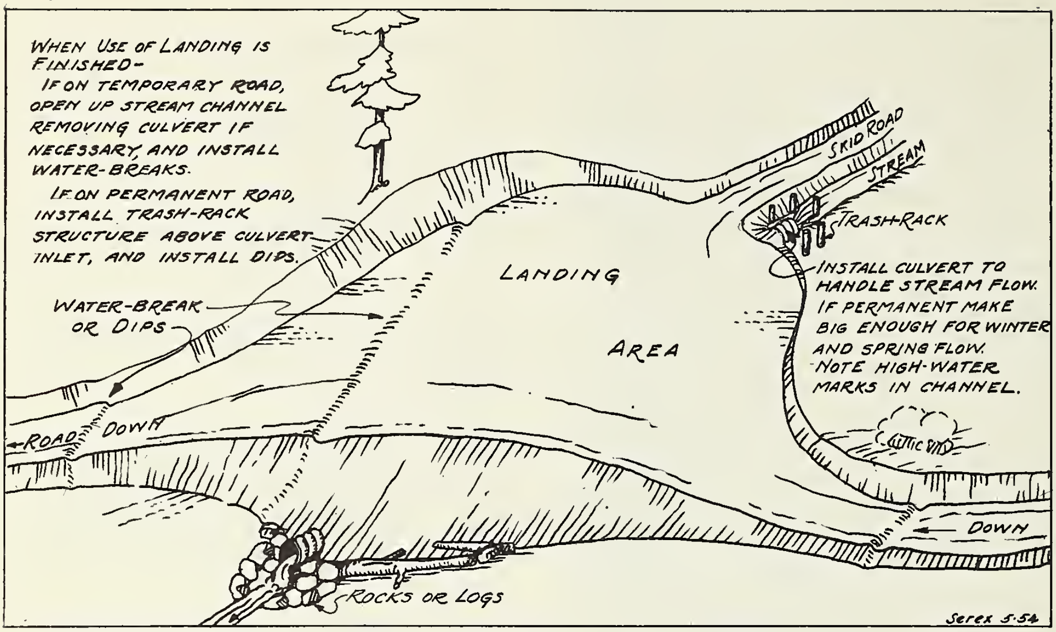


Fig.3 , Landing in Ravine near Flowing Stream — Plan.

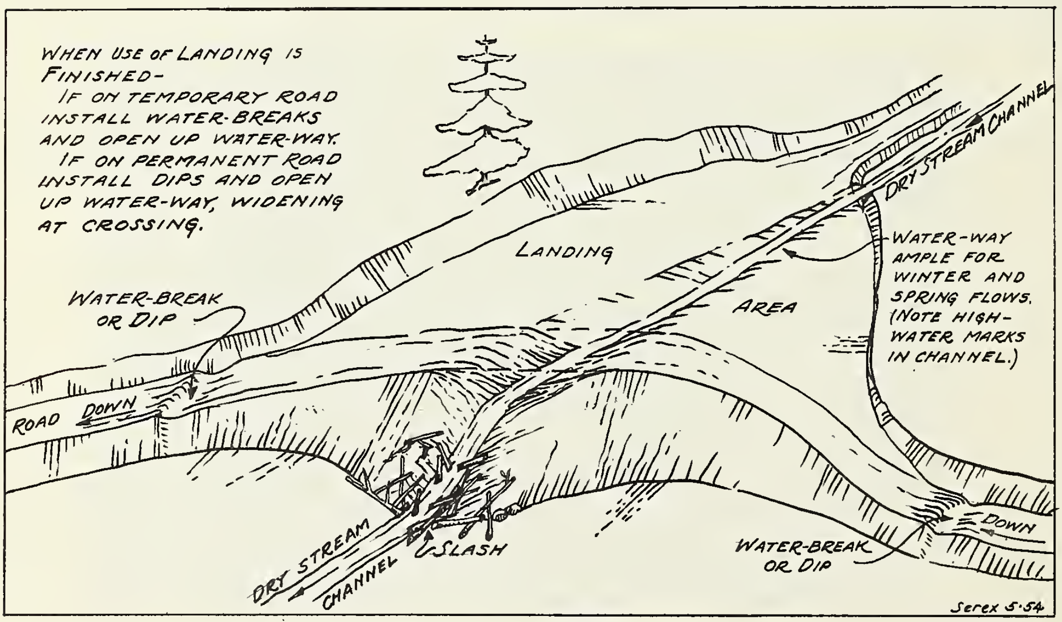


Fig.4 , Landing in Dry Ravine — Plan.

2. Selection of landing sites.

(a) Landings should be located on firm dry ground. In moderate terrain this is easily attained; in steep country careful reconnaissance of the sale area and designation of landing sites will minimize watershed damage.

Some of the best landings observed have been made by widening the haul roads at some distance from water courses. Material for the extra fill may be borrowed from a long stretch of road rather than a single spot, thus keeping the cut slope low throughout. Cribbing on the downhill side with cull or unmerchantable logs and chunks may also be used to support a landing fill and thus minimize excavation.

11.

Excellent example of large landing in dry ravine at end of road, made level from road excavation. The road slopes toward landing. Drainage dip on opposite side, at junction of landing and road, carries local runoff over edge into logging debris without erosion. The cull logs and organic matter at right have been well placed to prevent washout of the landing.

12.

Good small landing on road serving local area of dry ravine at right. Ditch across far side beyond the car carries winter runoff into debris below the road without erosion.

13. 

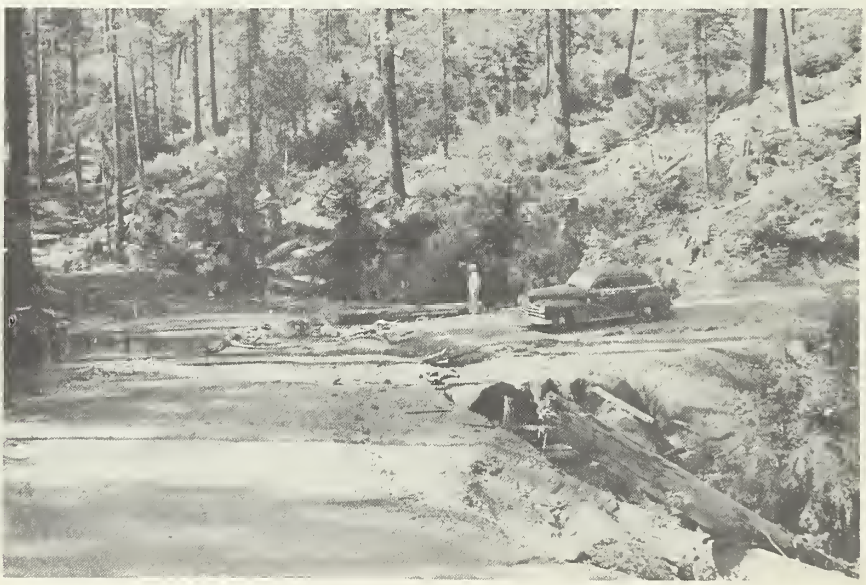
Combination of skid-road, landing, and temporary road in a stream channel. No treatment whatever was applied, the result being erosion of ravine bottom and diversion of winter runoff down road and over bank in the foreground. If this placement of landing was necessary, the skid-road should have been treated with slash after logging, and a sizeable channel constructed across landing with a levee at the road junction.

14. 

Combined landing and water-hole for trucks along secondary road, as left after logging. Overflow from pool has run down road softening and eroding it for a long distance. Pool should have been drained by dip or culvert across road and emptied harmlessly into slash below the road.

15. 

Landing in disintegrated granite soil below a steep slope that was heavily cut and tractor logged - with too many skid trails, poorly located, and not drained after logging. Uncontrolled runoff from trails gullied the landing, repeatedly blocked a forest highway, and carried much sediment into a popular fishing stream. With such site conditions, extraordinary precautions in logging should have been taken, or the slope left uncut.

16. 

Landing above a secondary road and beside a live stream. Logging slash in channel caused log fill to clog, and subsequent overflow to damage the road. Removal of the log fill and restoration of stream channel would have prevented the damage. Such simple precautions should always be taken where live streams are involved.

17.

Small landing along temporary road properly cleaned up, and an adequate drainage ditch constructed. Erosion is negligible and area is well established.

Where a landing must be made in the channel of an intermittent stream, adequate drainage should be provided for the period of use. Immediately on completion of logging the channel should be cleared to its full capacity and the fill material and debris spread along the road or slopes where it will remain stable.

Upon abandonment, all landings should be erosion-proofed by adequate ditching or mulching with forest litter, as needed, to prevent erosion. Where landings will be used again in repeated cutting cycles, seeding to grasses may be desirable if required for erosion control, otherwise restocking to coniferous species should be the objective.

3. Yarding and skidding

(a) Limb all logs before yarding to minimize the damage to reproduction and the soil disturbance incurred through movement of unlimbed logs.

(b) Consider restrictions or limits on type and size of equipment to be incorporated in the timber sale contract (this should be done before the sale is advertised) with a view to minimizing disturbance of soil and reproduction.

(c) Ground skidding may be required for sale areas with heavy reproduction and pole stands, with use of logging "arches" restricted to selective logging in more open stands or to patch clear-cutting operations.

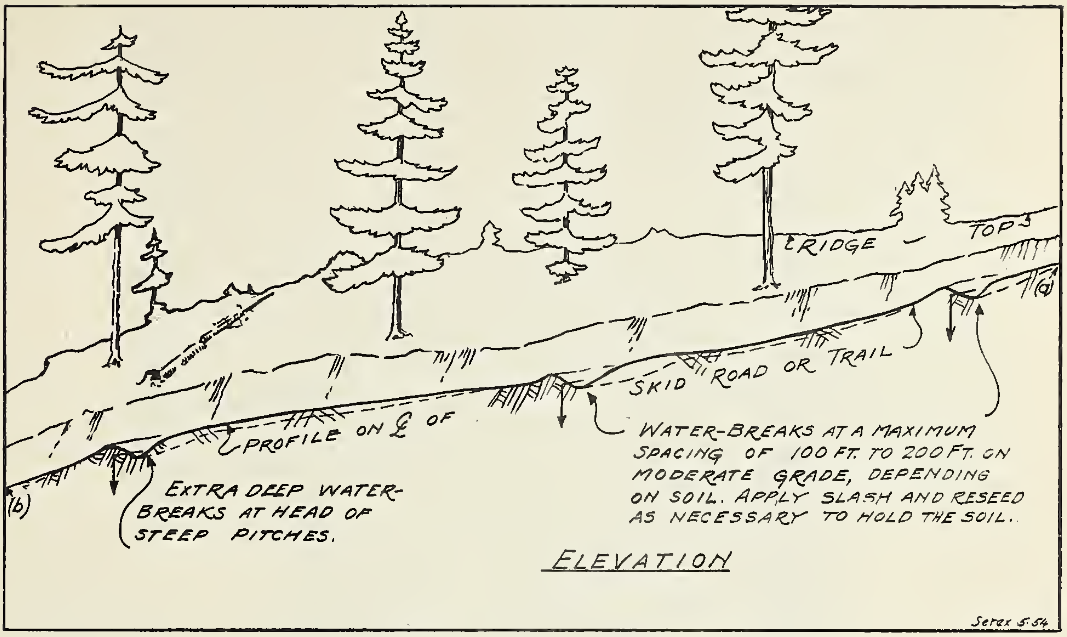


Fig. 5, Location of Skid Roads and Trails and Water-Breaks Along Hillside or Near Ridge Top to Obtain Moderate Grades.

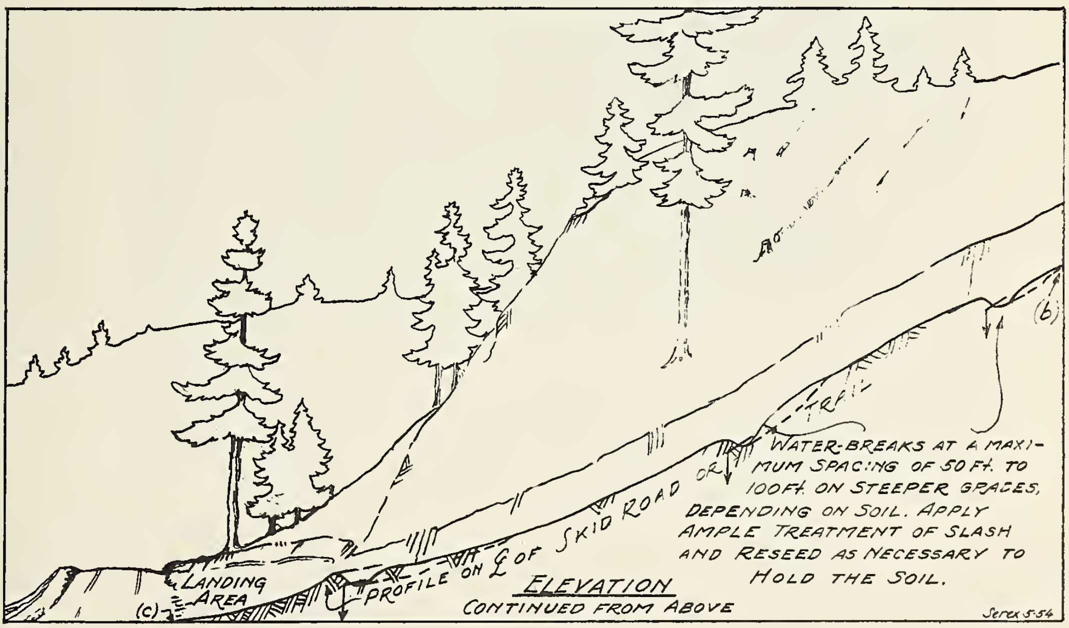
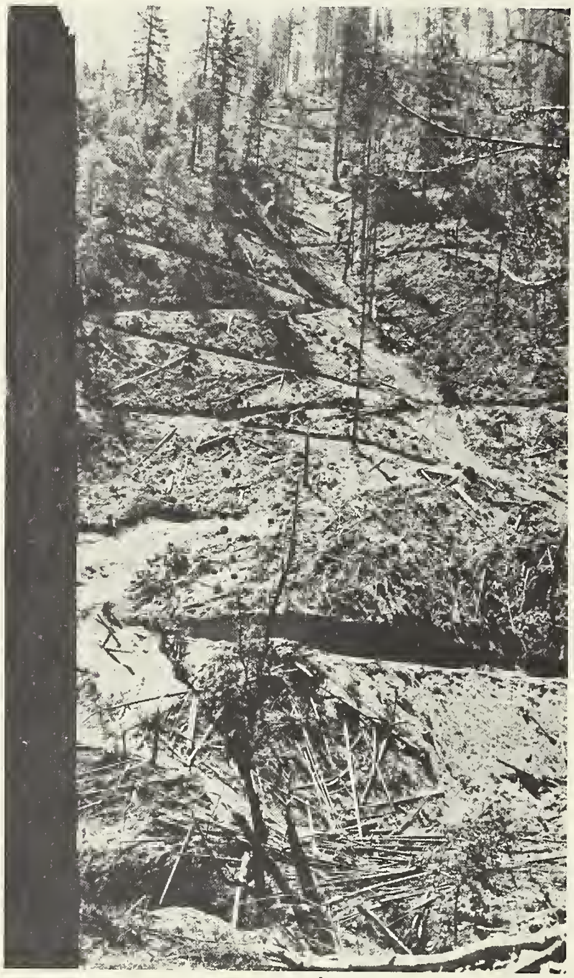


Fig. 6, Location of Skid Roads and Trails and Water-Breaks Around Ridge Top to Avoid Excessive Grades.

(d) On excessively steep slopes it may be desirable to preclude tractor logging and require cable logging. Cable yarding or ground skidding with tractors uphill will avoid the converging-trench pattern of downhill yarding which causes accumulation of water and concentration of run-off.



18.

In this canyon both soil and stream have taken a "beating" from the logging operation. This example is not unusual where steep topography and heavy rains aggravate watershed damages. Much of this damage could have been prevented by better planning and greater care in logging but the ultimate solution might lie in some adaptation of aerial yarding of logs by cableways.

19. 

Tractor road in very light (disintegrated granite) soil on 25 per cent slope. Shows erosion and accumulated sand at end of continuous one-fourth mile run. A water turn-out has since been constructed in the foreground, but additional water breaks with outlets should be installed at intervals of 100 feet, including one at the bend in the road. This skid road could and should have been constructed with several breaks in the grade.

20. 

Tractor road in light d. g. soil, constructed on long continuous grade (25 to 30 per cent) across several ravines in steep country. While general location is satisfactory, complete lack of drainage caused severe erosion during a very heavy rain. The grade should have been broken at each ravine crossing and all waterways properly opened up after logging. Also, water-breaks between ravines, slash in the road, and reseeding, should have been employed in this case because of the large amount of bare and highly erodible soil.

21. 

Tractor road along creek. Good location, well above high water level, with a fringe of streamside vegetation, and no unnecessary soil disturbance. All logs from a large area were arch-skidded over this road, and across the creek at a single crossing just below this spot. (See Photo 25.)

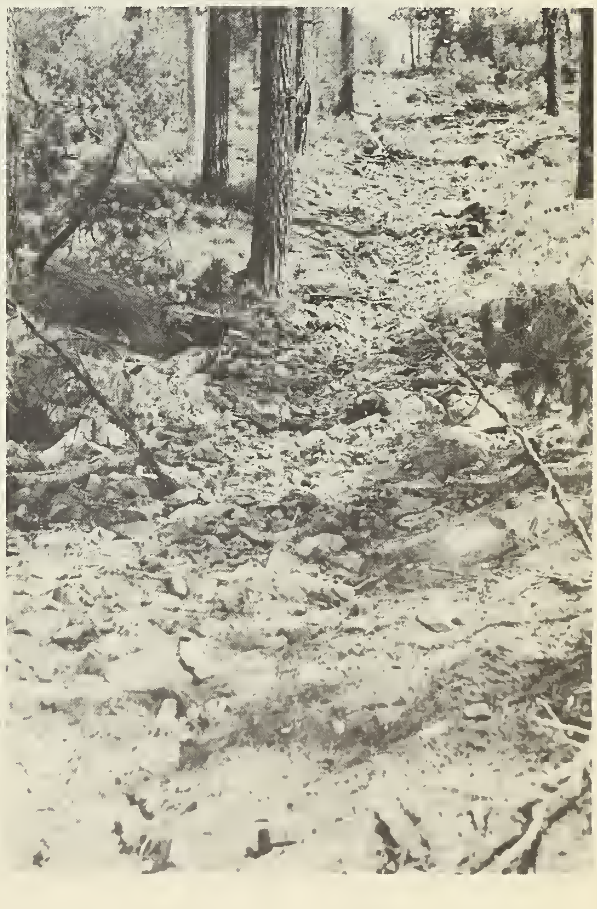
22. 

Tractor road in very steep country and light soil. Good location roughly on a contour with breaks in grade, localizes drainage and minimizes erosion. Low points on the grade should always be in the ravines to prevent diversion of stream flow down the road during high stages. Photo also illustrates use of cedar (or cull tree) for a bumper or rub tree where tractor road turns.

23.

Tractor road in a salvage logging area showing a well constructed water-break. This should have been augmented by placement of slash across the road in foreground to prevent rill erosion. In parts of this area grass seed was sown broadcast, and trees were planted. (Looking downhill)

24.



Tractor road on 35 per cent grade in very rocky soil. In spite of the rocky soil, erosion has been severe, owing to the accumulation of water from the roadway and adjacent ground. Most of this could have been prevented if water-breaks had been installed after logging. Due to the flatness of the terrain on both sides of the road, the breaks should extend well out into the adjacent slash.

TRACTOR ROADS

25. 

Excellent tractor road crossing of a perennial stream in good location with adequate slope on both banks. This prevents stream diversion into road. All the logs from about 100 acres came out over this crossing with little or no damage to the stream.

TRACTOR TRAILS

26. 

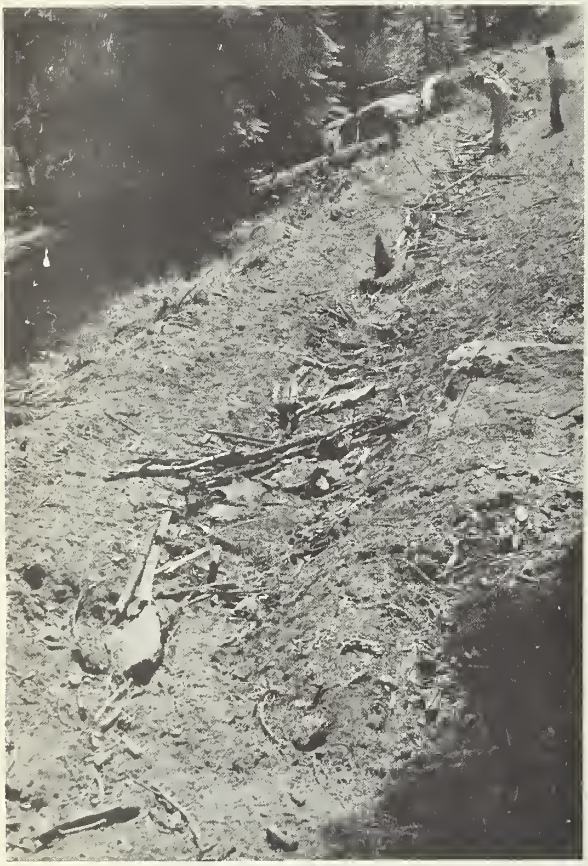
Tractor trail in bottom of a shallow ravine. Even though the watershed is small, there has been considerable erosion from one winter's runoff. Skidding down the intermittent waterway was easy and economical, but after it was done the channel should have been erosion-proofed by placement of heavy slash. Under good watershed management the logs from such a basin would have been skidded out over a tractor road on the slope, leaving the streambed undisturbed.

27.

Tractor trail on 30 per cent grade in light d. g. soil, completely stabilized with litter and slash placed by hand. Note the use of fine material and branches. Water break about 60 feet up slope turns water out into timber at right.

28.

Tractor trail on 20-25 per cent grade in light d. g. soil, well protected by a covering of fine litter about one inch deep, and waterbreaks about 100 feet apart, all done by hand. This road withstood a severe storm without perceptible erosion.



29.

Tractor trail in light d. g. soil, showing a stretch of 35 per cent grade treated by hand placement of light slash. With the water-break visible beyond the men, and one or two additional breaks farther up, this entire trail was effectively erosion-proofed.

30.

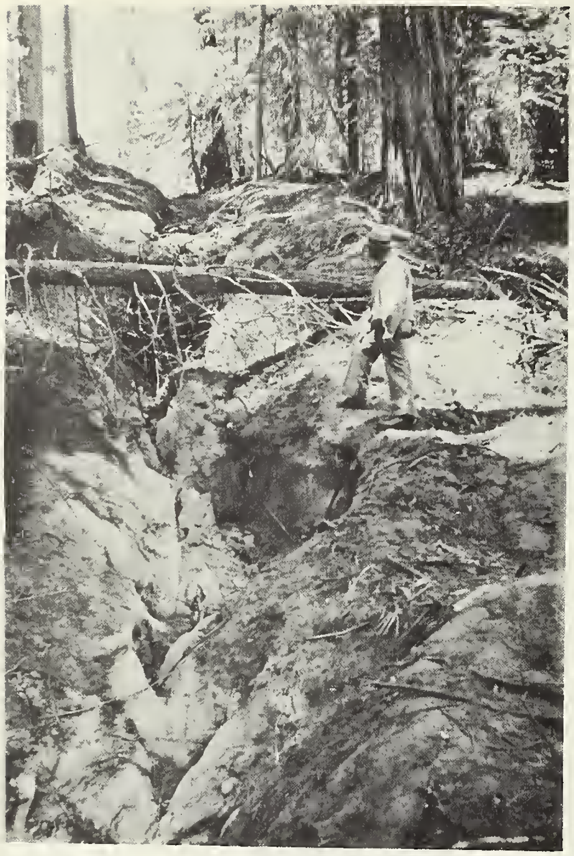
Tractor trail heavily treated with slash placed by hand and crushed into place by one pass of a tractor. Erosion control complete, despite steep grade of 50 per cent and light d. g. soil. Such dense placement of material is seldom necessary, but it may be the only practical treatment for short steep pitches or trough-shaped trails.

31.

Tractor trail in very light d. g. soil down a steep ravine and across a live stream, with no regard for soil conservation practices. Much material was excavated to make the fill across the creek in foreground and upstream, leaving unprotected slopes and banks. Erosion has been severe, is still active, and stream is heavily silted. This bad situation could have been prevented by proper planning, location, and construction.

32.

Tractor trail on a steep slope (55 per cent) in light soil, heavily eroded. Actually, this is a "bootleg" trail or shortcut from a well located tractor road around hill to right. Treatment now required consists of waterbreaks (one at top and another midway down slope), liberal application of slash, and possibly seeding to grass.



33.

Severe erosion of a short-cut tractor trail down a 50 per cent slope in very light d. g. soil. Erosion to bed-rock at lower end of trail was caused by water accumulated from one-fourth mile of undrained trail above. This trail needed water breaks at about 100 feet intervals, including one at head of this slope, and a good application of slash on the steeper pitches. Moreover, at this spot the trail should have angled down the hillside to the right on a gentler grade.

34.

Skid trail "trench" on a 30 per cent slope showing ineffective treatment. Erosion has continued because of poor placement of short pieces of branch wood without proper contact with the ground, and absence of water turn-outs. Large material like this should either be crushed down with tractors or mixed with finer material to create effective water-breaks.

35.

Skid trail beside a small water course. This trail is located well away from the water course and crosses it at a point (in foreground) where it will not divert stream flow. A light treatment with small slash and limbs has held erosion in check thus far, but a heavier application is needed because the light soil is easily eroded.

36.

Skid trail on a 30 per cent slope in compacted granitic soil, showing erosion which occurred prior to treatment. The water-break being dug in foreground will divert the water into litter above logs. The man above is placing slash in the gully, but another water-break farther up the slope at the turn might be needed.

(e) Tractor roads, tractor trails, and skid trails.

These terms refer to the various routes by which logs are tractor-skidded from stump to landing and differ only as to degree of advance preparation. Tractor roads, unlike trails, are graded in advance of use to facilitate the hauling of logs on very steep ground or other critical areas. Although the standards of alignment and gradient are much lower than for truck roads the same general principles of careful location and construction apply. As the chances for erosion are higher, the attention given to drainage and soil stabilization must not be minimized.

It has been found that some of the worst cases of skid trail erosion encountered could have been avoided if the trails had been scouted and flagged before use. Advance location is particularly needed in rough terrain: The flagging job must be done by a man on the ground, not by a tractor operator who cannot see well uphill.

Long steep grades should be avoided and maximum pitches should be based on local conditions of soil and rainfall. Grades above 30 per cent should be the exception rather than the rule. Use natural undulations in slope to facilitate drainage; on long grades where no natural undulations exist, introduce dips at suitable intervals as the major drainage features. Cross drainage placed just above a steep pitch or grade is more effective than if placed halfway down.

In general keep tractor roads out of streambeds, whether perennial or intermittent. Locate on slopes far enough above streams so that overcast material will not reach streams. In steep terrain, where use of a dry channel will result in less soil movement than grading a tractor road on the slopes, such channels may be used, provided the channel is properly regraded and cleared of slash after logging to permit full stream flow in the wet season. No logs or chunks should be left in a gulch bottom in such position that water will be diverted against either bank and erode the toe of the slope or cause waterfalls that will gouge out the channel bottom.

(f) Keep bulldozers and other heavy equipment out of live streams and off of meadows as much as possible.

Stream crossings for tractor skidding should be carefully selected in places where they will cause the least disturbance of streambed and streamside vegetation, such as at bedrock or gravel bottoms. Occasionally bedding a line of boulders or a log on the downstream side will support a tractor crossing for the duration of an operation. When skidding across a stream is completed, the channel should be promptly cleared of slash, and the streambed restored as nearly as possible to its natural shape and grade.

Where skidding across a channel is necessary, the crossing should be made with enough adverse grade on the downhill side to prevent any water from being diverted into the skid tracks from the streambed. The interception of even small lateral rivulets on slopes has often started skid trail rills which were harmless in summer but became large gullies during the subsequent rainy season. (Photos 31 and 33).

Short cuts between switchbacks on well located tractor trails have been another source of severe erosion. (Photo 32). Advance instructions to the cat skinners, and close supervision during skidding, can eliminate this trouble.

(g) Meadows: It should be emphasized that, by reason of their position in most watersheds, unbroken meadows perform an important function in storing water to supply summer flow for springs and streams. This may equal or exceed their value for grazing, and justifies the precautions suggested with regard to logging near them.

Meadow crossings by roads and skid trails have been responsible for gullying, draining and drying up meadows that were previously well watered and green. Tractor and skid trails should not ordinarily be permitted to cross meadows. It is usually possible to skirt meadows, but where this is not possible they should be crossed at a narrow point on fill material which has been hauled in. (Photos 52, 53, 54).

4. Treatment after Logging

This is largely a matter of providing drainage and some form of soil stabilization on the trails. The work should be done promptly after skidding is completed, and before the beginning of heavy precipitation. Several examples of bad erosion were observed which occurred because heavy autumn rain or snow stopped the logging operations, and the necessary equipment was moved out before any protective work could be done. In California logging areas, precipitation after October 1 is always probable, hence most of the watershed protective work must be completed by that date.

Slash disposal has generally been considered solely from a fire hazard reduction viewpoint. Lopping of tops and piling or bunching and burning are the most frequent methods of reduction of such hazard. The opportunity of utilizing slash from tops and other logging debris in positive measures to minimize or prevent erosion damage should not be overlooked.

In patch clear cutting on erosible soils, the windrowing of slash along contours may be more desirable than the usual scattering or piling and burning.

Slash and litter placement in skid trails properly done will prevent soil movement and divert excess water out of trails; improperly done it is ineffective, wasteful of effort and may even aggravate the erosion problem. The material must be in good contact with the soil and the larger pieces at such angles that they will lead water out of the skidway at many points.

Best results have been obtained by using a mixture of large and fine material, first placing the large pieces such as branch wood and small logs diagonally across the trail, then tossing twig and litter material between them, and finally passing a tractor down the trail to press the slash into contact with the soil (Photo 30). Where the tractor pass is not made greater care should be used in placing the slash, and more fine material should be placed between the large pieces.

Slash should be placed only where needed. Not all skid trails require it, and most trails need it only in spots. Mulching with slash is particularly adapted to trough-shaped trails in which it would be difficult and very costly to build water-breaks, to short trail-ends where slash mulch will do the necessary control more cheaply than dozer-built ditches, and to places where the maneuvering of a tractor would damage surrounding young trees.

In general, the combination of well-placed water-breaks, interspersed with slash placement in critical spots, will give the most effective protection to tractor and skid trails. How much of this to do by hand and how much by machine will be determined by conditions on each project.

Water-breaks or cross-ditches are most economically built by a bulldozer working down-slope. If the tractor passes over them after they are shaped they usually require some hand work to open the ditches and reshape the down-slope berms (Photo 23). Cases have been observed where the bulldozer work was wasted because the berms and ditches were not reshaped. The breaks should be spaced closely enough to prevent development of gullies between them. No fixed spacing will apply everywhere. On steep grades and very erodible soils they should be closer than on gentle slopes and rocky clay soils.

Thoughtful and timely application of preventive measures will minimize damage from timber harvesting. Each forest officer must be alert to develop and apply additional measures which will meet local needs. One measure that still needs serious attention is the safeguarding of streamside vegetation. This has been touched on in the discussion of cutting practices, but it needs emphasis. With care, mature trees can be cut from the very bank of a stream without excessive damage (Photo 8). But there is needed a determined effort to log more carefully in the vicinity of streams for the purpose of maintaining more natural streamside conditions, even though this will occasionally require leaving some merchantable trees uncut.

C. The Road System

The logical development of a road system in a working circle or operating area follows these steps in order:

1. Planning, Reconnaissance, and Location
2. Construction
3. Maintenance
4. Retirement or "putting to bed."

The first step is actually three important steps, but these are so closely related that for the purpose of this Guide they are treated as one.

To insure proper attention to watershed problems in planning logging road systems, and in the reconnaissance and location of roads, there can be no substitute for sound engineering procedures and methods carefully applied by skilled personnel. The details of these engineering procedures are beyond the scope of this Guide.

1. <u>Planning, Reconnaissance, and Location of Roads</u>

The following pictures (37-54) together with the related descriptions and text, illustrate some of the more troublesome points in connection with planning, reconnoitering and locating logging roads.

a. <u>Locate the roads to serve the type of logging planned, i.e., tractor, cable, etc.</u>

Picture 37 illustrates a typical satisfactory road system layout for a tractor logging job. In this case the terrain is somewhat broken but on the whole is not too steep for efficient tractor logging. The road system layout would work equally well for a timber sale in which the terrain was not so broken.

Picture 38 illustrates a marginal type country between that which should be tractor logged to contour roads, and that which can best be logged uphill by high-lead cable methods. The area was logged by tractor to three contour roads. With a high-lead system, one road--the lowest one, which involved the most excavation and erosion--would have been eliminated. The two upper roads would have been spaced farther apart, and the whole area logged with much less soil disturbance.

37. 

Aerial view of burned area on steep varied terrain showing road and tractor skid trail system used in timber salvage operation.

38. 

Aerial view of burned area in steep country, with roughly parallel ravines. Parallel contour roads are located to facilitate yarding of logs up or down tractor trails on ridges. This is a normal system layout for tractor logging.

39.

Secondary road on contour location in shale soil.

40.

Temporary road properly located along a creek.

Picture 39 illustrates a secondary road on a good contour location in typical tractor logging country. Alignment is good, cuts and fills well balanced and grades within desirable limits, as evidenced by the lack of roadbed erosion. It is possible in country of this type and on a road of this kind to locate landings and spur road take-offs so as to minimize erosion damage. A location of this kind with proper drainage provided will not create a watershed problem.

Picture 40 shows a good canyon bottom location for a temporary road in tractor logging country. Note that streamside conditions have been left largely undisturbed, overcast material caught well above water level, and screen of trees and shrubbery has been left between the road and the stream. Fill slopes have been protected by a raised shoulder. Spur or tractor road take-offs at intervals can be selected which will cross to the opposite slope with minimum streambed disturbance. Although this is a temporary road the location principle holds good for main or secondary locations as well.

b. Limit gradients on permanent system roads to non-eroding values for the soil type.

Picture 41 illustrates a secondary road built on a location which evidences consideration for the erosion values of the soil type - in this case a sandy soil. The grades were held to 6% and below, and ample drainage was provided. No erosion in evidence. Incidentally, other good features are illustrated by this picture: Machine shaped back slopes, ample inside ditch, raised shoulder (proper for this soil type), and clean roadside.

Picture 42 illustrates use of excessive grade (10% ±) for the soil type, a very light decomposed granite soil. Grades in this type soil should be held to 6% or below if possible. If absolutely necessary to use steeper grades, the erosion can be minimized by providing frequent and adequate cross drains (culverts or dips) to remove ditch water, paving ditches with hand laid rock riprap, and mulching fill slopes with forest litter. This picture illustrates another bad feature - undercut back slope - which results in bank sloughing, ditch plugging, and accelerated erosion of the road.

41.

Excellent stretch of secondary road on hillside location in sandy soil.

42.

Temporary road in very light d. g. soil showing deep ditch erosion.

43.

Main road on hillside location in rocky shale soil.

44.

Well constructed temporary road through rolling country.

45.

Abandoned temporary road showing severe erosion of the roadbed.

c. <u>Use undulating or broken grades where possible to reduce erosion control and drainage work.</u>

Picture 43 illustrates use of undulating grade in a main road. Although the undulations are long and rolling, they serve the purpose of providing low points where water can be taken across the road, thus reducing ditch and roadbed erosion.

Picture 44 illustrates correct use of undulating or broken grades on a temporary road. Roads located and constructed in this manner will require little in the way of permanent drainage structures - chiefly those at main stream crossings.

Picture 45 shows the bad results of locations using long sustained heavy grades unrelieved by grade breaks or other means of cross-drainage. Grade breaks at intervals of two to three hundred feet on this road would have helped to prevent much of this severe roadbed erosion which has washed away cushion material down to bedrock in many places.

d. Locate on solid ground above high water levels and, where possible, well back from natural water channels.

Picture 46 illustrates a temporary road location along a live stream. The roadbed is about 25' above streambed - in this case a sufficient distance for excavation overcast to catch above high water level. A screen of trees and reproduction has been left between the road and the stream. This location retains a good appearance of the scenery. It also avoids pollution of the stream by silt and debris and maintains shade on the stream, both of which are vital to fish life.

Picture 47 shows the results of a location too close to the stream channel. In the background the road is almost in the streambed. There is no apparent reason why this location had to be so close to the stream. The cross slopes are light and no rock is in evidence. A location above and away from the streambed, such as shown in the preceding picture would avoid this unsightly condition and maintain stream conditions largely undisturbed. The situation here could have been alleviated to some extent by clearing and slash disposal in advance of excavation.

46.

Temporary road in steep country and shale soil, showing location along live stream.

47.

A small creek polluted with silt and debris from a road constructed too close to the channel.

48.

Main road in difficult location across wet slide area in serpentine-shale formation.

49.

Main road constructed in a wet location at the crossing of three ravines.

e. Avoid wet areas or unstable ground.

Picture 48 shows some of the problems introduced by location through a wet slide area in serpentine. The outside shoulder has slumped and a slide has occurred in the cut slopes. The road location should avoid such areas if possible. Where they can not be avoided, it is essential to plan de-watering systems of perforated pipe, and careful placement, compaction, and stabilization of fill materials. In this instance a line of perforated pipe laid in a deep trench in the inside ditch line with coarse rock or gravel backfill would serve to intercept the ground water.

Picture 49 illustrates another type of undesirable location which introduces difficult drainage problems. The crossing should be made either above or below such wet areas if possible. If necessary to cross such areas, the location should include plans for a deep intercepting ditch, substantial raised shoulder berms with outlets and application of forest litter to the large fill slopes. Unless such areas are very large, usually some adjustment of grades in adjacent sections will make it possible to avoid them.

f. Avoid very steep slopes when possible.

While it is often necessary to cross steep mountain slopes with logging roads, such locations should be avoided whenever possible. Steep slopes introduce difficult construction and maintenance problems; roads built across them require heavy soil disturbance and result in aggravated watershed erosion problems.

Pictures 50 and 51 illustrate some of these problems. Excavation of roadbed on slopes above 65% results in long "sliver" fills which are very difficult to compact satisfactorily. This results in shoulder settlement, loss of shoulder berm, and serious fill slope erosion. The long cut slopes also increase the area exposed to erosion. Road construction on such locations frequently calls for special features such as retaining walls, intercepting ditches above cut banks, extra large raised shoulder berms, more frequent drainage structures, fill compaction and fill stabilization. Berm outlets require long down spouts or paved outlets. Special care is necessary in providing for drainage to insure that a minimum of water reaches the exposed surfaces. Heavy mulching of fill slopes with forest litter is also usually necessary to prevent erosion damage. All of these features add to the cost of the road and emphasize the desirability of avoiding such locations when possible.

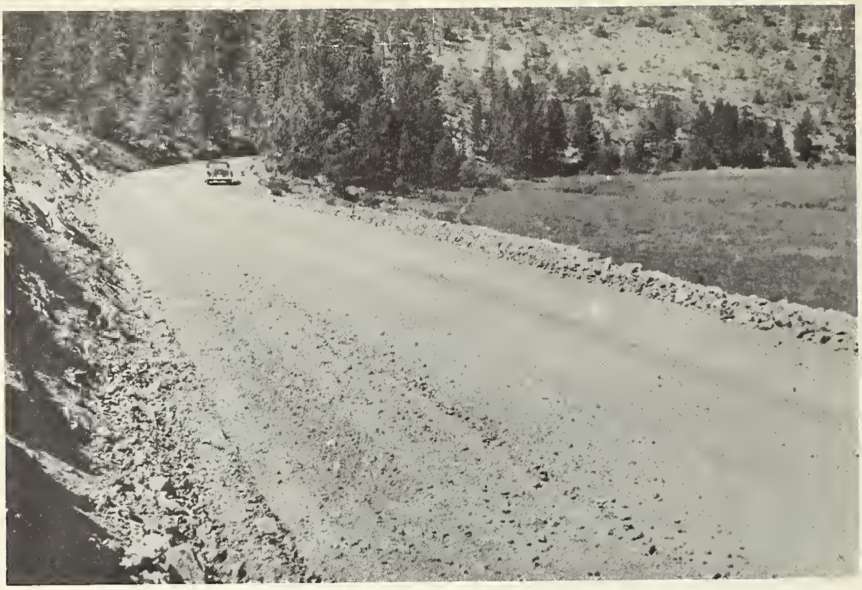
50.

Main road in difficult location, through decomposed granite in very steep terrain (over 80 per cent), resulting in sloughing and settlement of overcast fill.

51.

Main road in a problem location on a very steep mountain side (80-90 per cent) in light decomposed granite soil.

52.



Main road well located and constructed. Location around edge of meadow avoids damage to this important grazing resource.

53.

Secondary road, showing poor location and construction features; crossing through center of meadow instead of skirting its edge, and cutting through meadow sod to place the roadbed on mineral soil below the sod level. This is a certain way to start a gully across the meadow, by diversion of natural channels.

g. Keep stream and meadow crossings to a minimum.

Pictures 52, 53 and 54 illustrate good and bad road locations, and an example of meadow damage that resulted from improper road location and construction. It is usually possible to skirt a meadow by locating the road at the toe of the adjacent slope, as shown in picture 52. When a crossing through a meadow is necessary, it should be located at a narrow point in the meadow, and should be built as a low through-fill with borrow material from outside the meadow. Ample culverts should be provided for drainage through the fill.

54.

Example of meadow damaged by road construction. The roadside ditch, originally formed by excavation of material for the road, has eroded deeply and drained the meadow, thus favoring the spread of sagebrush at the expense of grass. Several check-dams have helped to stabilize the gully, but have not remedied the damage.

It is also bad location practice to follow a stream, crossing and recrossing frequently. Each crossing requires a structure, and maintenance of numerous structures adds much to total road costs.

h. Avoid successive switchbacks above each other.

The "Jacobs Ladder" type of location up the face of a mountain, with successive switchbacks above each other, is very undesirable and should be avoided if at all possible. Roads built on this kind of location cause more disturbance of soil in a given area than any other type of construction, and as a direct result cause excessive watershed damage. Maintenance of the road is much costlier than normal, drainage difficulties are multiplied, and the road is very unsatisfactory because of the severe alignment. Avoiding these switchback locations frequently introduces added construction costs. Considerable increased cost in construction, however, is usually justified in the long run by the lower maintenance and damage costs on the better location.

Every possible alternate location should be thoroughly explored and considered before resorting to switchback location. Money spent in reconnaissance and location study will more than pay off in ultimate savings.

2. Construction of Roads

If careful attention has been given to the planning, reconnaissance and location of a road project, the construction is made much easier. It is not within the scope of this guide to deal in detail with road construction methods. The Forest Road Handbook and other publications supply such details. The purpose here is to discuss some important features of road construction which have a direct bearing on watershed protection and management. In some cases these features are illustrated by pictures.

a. Clearing in advance of excavation.

Clearing and slash disposal should always be done in advance of excavation work. This holds true even though part or all of the clearing is done by bulldozer or other machine methods. When clearing is done concurrently with excavation, logs, slash and other debris are inevitably mixed in with fill material. This prevents proper compaction of the fill and often results in erosion of fill material.

Pictures 55 and 56 illustrate this point better than words.

55.

Main road through area with heavy cover constructed without advance clearing of construction zone. Much slash and logs are covered by excavation overcast and incorporated in the roadbed. As this material rots, the road shoulder settles, disrupting the drainage system, and resulting in serious erosion.

56.

Main road constructed with slash in fill has resulted in serious roadbed failure. This is the result of failure to clear the construction zone in advance. The damage is three-fold: road out of service, high cost of repair, and downstream siltation. All could have been prevented.

b. Excavation and fills.

Correct location in the first place will avoid any large volume of excess yardage, by careful balancing of cuts and fills. When excess yardage occurs, however, care should be exercised to place it where it will not erode into stream channels. Much waste yardage can be avoided during construction by moderately rolling the grade, or slightly shifting the center line to reduce the excavation needed.

Picture 57 illustrates a case in which poor road location resulted in badly unbalanced cuts and fills, and poor construction practice aggravated the situation by disposing of excess material downslope to constitute an erosion problem. Moderate adjustments to grade and center line during construction would have prevented much of this.

57.

Main road in very light decomposed granite soil and heavy terrain built under very poor construction standards. Excavation is excessive, with much waste into stream channel, large areas are exposed to erosion, and drainage control is wholly inadequate. Result is severe erosion, with damage to road and siltation of a reservoir just downstream.

Picture 58 illustrates an example of carefully balanced cuts and fills. There is no excess waste yardage spilled over into the stream channel. A careful location job followed by correct construction practice has resulted here in a well balanced stream crossing and no serious erosion problem. The logs and slash in the stream channel, however, should have been cleaned up.

58.

Main road along and across stream, representing good location and construction practice. Overcast and fill are retained well above high water level, and shoulder berm is ample.

c. Drainage for the road.

A properly planned and located road will have provision for drainage adequate to the rainfall and run-off conditions of the locality it serves. The drainage system may be of permanent or temporary type, depending upon the life of the road and economic factors affecting road construction. (See RHB R-5 Supplement, pages 108a and 108b of 9/10/53.)

Picture 59 shows a road which is otherwise well designed and constructed but, because the cross drainage culverts are too far apart (500 - 700 feet), the inside ditch is eroding. In this case culverts spaced at approximately 350 feet would have prevented the ditch erosion, and resulted in a thoroughly satisfactory road.

59.

Main road on hillside location in rocky soil. Good features are moderate grade (5 per cent), gravelled surface, and sloped cut-banks. Although ample in capacity, drainage ditch tends to erode due to excess distance between culverts (500 - 700 feet).

Picture 60 illustrates a more aggravated example of insufficient cross drainage culverts. In this case the culvert spacing was 700-800 feet on an 8% grade. Culvert spacing should not have exceeded 250-300 feet in this case. The excessive spacing has resulted in volumes of water beyond the culvert capacities. Culverts were by-passed and serious ditch erosion developed. Remedial measures for this situation will now require installation of properly spaced and installed culverts and filling of the eroded ditch with gravel or other erosion resistant material. Cut-off walls or dykes of impervious material will have to be provided immediately below each culvert intake to prevent further by-passing.

60.

Main road at crossing of shallow ravine, showing severe ditch erosion, drainage failure, and some road surface damage.

Picture 61 illustrates another type of road drainage fault frequently found on poorly located and constructed roads. The curve superelevation (not common on logging roads) results in an outsloped road surface. No raised shoulder berm and drainage outlets have been provided at the low inside edge of the curve. This has resulted in all roadbed water running down the erosible fill slope, with results shown in the picture. In this situation, with highly erodible decomposed granite soil, forest litter mulch and fill slope planting should have been installed in addition to raised shoulder berms and paved spillways. Forest litter mulch treatment is illustrated by Picture 62.

61.

Main road in highly erodible decomposed granite soil, showing severe erosion of the fill slope, the consequence of the lack of drainage control.

62.

A mulch of forest litter, in this case mostly pine needles, applied to a depth of 2 inches to this road fill slope has provided immediate protection against erosion. The seeds of trees and shrubs which such litter usually contains will provide permanent cover. This inexpensive treatment is suited to all classes of logging roads where erosion proofing is required.

It should be remembered that streams in logging areas frequently carry trash. The construction of strong and sufficient trash racks above culvert inlets should be given high priority to prevent clogging of culverts.

When temporary drainage structures are installed on a temporary road, the log bridges or culverts should have ample capacity to carry expected flood flows during the period of use. Removal of the temporary structures and restoration of the stream channels should always be required at the end of the term of use. Picture 63 shows a temporary log bridge on a temporary road.

Because green unpeeled logs were used, this bridge will have a short life. At the end of the period of log hauling this structure should be removed and the channel restored. Such structures should never be built on permanent roads except as an emergency measure.

63.

Log bridge on temporary road will accommodate high flows without damage. Where use of road is known to be for a limited period this type of structure is preferable to earth-fill crossings which will wash out every winter.

Picture 64 shows what happens when temporary fills at stream crossings are not removed and the stream channels restored over winter. When this type of construction is permitted on temporary roads, the fills across streams or dry watercourses should always be removed at the end of the logging season or period of use. (See Maintenance).

64. 

Through fill of a temporary road washed out and carried downstream during first winter after logging. This damage should have been prevented, the soil saved, and streambed restored by removing the fill and spreading it along road in each direction from stream.

Although seldom used during the period of log trucking, and especially on main roads, drainage dips are an excellent method of removing road-surface water and discharging it at points where the flow will not result in erosion. Frequently, at the end of the period of logging use, drainage dips are installed because they serve very satisfactorily for other types of traffic. In areas which receive considerable rainfall during logging season, properly constructed drainage dips can serve satisfactorily on secondary or temporary spur roads. One advantage of drainage dips is that they can be readily removed by a grader when not needed. Picture 65 and Figure No. 7 show examples of correct drainage dip construction.

65.

An excellent example of dip construction, showing long roll and outslope to culvert (at stick left). Drainage dips of this type kept several miles of road open under very severe rainfall and ground conditions. The shape of dip should be modified to suit vehicle, speed, and load.

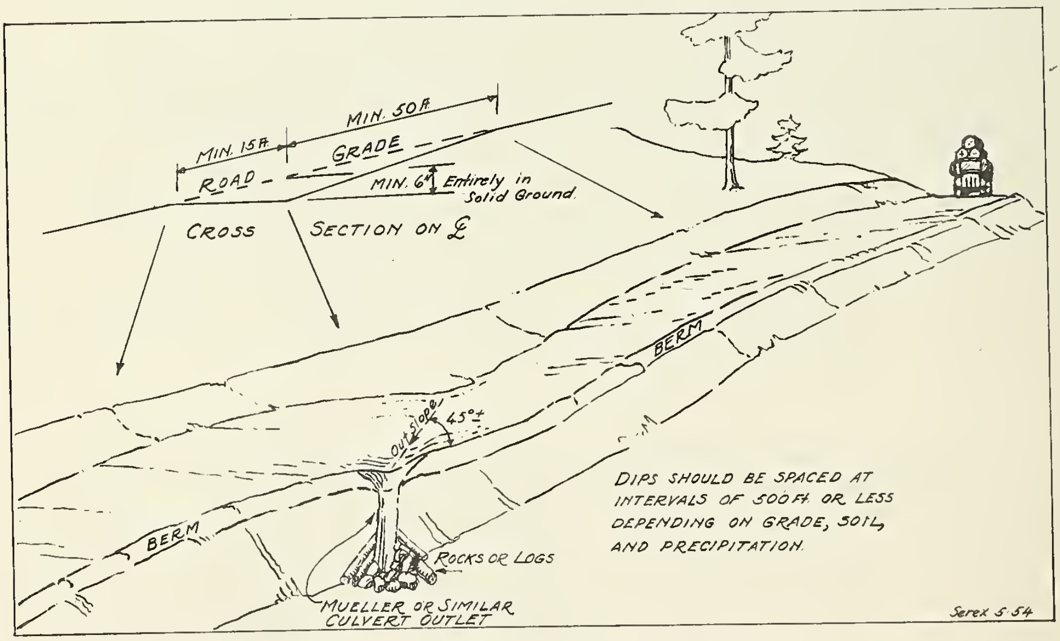


Fig. 7, Typical Drainage Dip Installation.

d. Meadow crossings.

When necessary to cross mountain meadows with logging roads considerable care is required in construction to avoid meadow damage. Crossings should be constructed as low through-fills with material borrowed from outside the meadows. Ample culverts should provide for drainage through the fills. Great care should be taken to avoid breaking the meadow sod. Picture 66 illustrates a good construction job in crossing a meadow, with the exception that clearing debris should not have been deposited on the meadow alongside the road.

66.

Good example of road crossing a meadow with minimum disturbance. Crossing is located at a narrow point of the meadow and has a metal culvert (hidden by log at far side) large enough to carry run-off from local watershed. Note that fill is raised above meadow level, the fill material having been hauled in, and that no excavation has been made in the meadow.

e. Back slopes

Avoid undercut back slopes during construction. Cut slopes should never be steeper than 1/4 horizontal to 1 vertical even in solid rock, 1/2 to 1 in stable mixed rock and earth, 3/4 to 1 in ordinary stable earth and 1 to 1 or even flatter in erosible type soils. Cut slopes should be entirely machine constructed with the bulldozer or grader. No hand polishing should be done beyond cutting off protruding large roots and prying loose rocks down off the slope. Hand polishing of cut slopes is usually a waste of time. Undercutting the cut slope causes slides which block drainage ditches and divert water onto the road surface with resulting erosion.

f. Fills

Fills over 10 feet in height in erosible soils usually require special treatment to secure good compaction. Before placing the fill all duff and slash should be removed down to firm mineral soil. The fill should be placed in successive layers not over 12 inches deep, and each layer compacted by passes of a bulldozer, carryall scraper or other equipment. In extreme cases rolling with sheepsfoot roller may be necessary. Rock and other coarse material should be placed on the edge of the fill to help protect the fill slope from eroding. Such careful construction, followed by mulching of the fill slopes, with forest litter, and in some cases planting of the fill slopes, will result in stable fills with little danger of erosion. Under no circumstances should end dumping of fills over 10 feet high, in erosible soils, be allowed.

g. Cushioning material

On permanent roads provide ample road cushioning material. Require that roadbeds be ripped, and rocks over 6 inches in diameter be removed from the top 10 inches of the roadbed. This is one of the most frequently neglected features of logging road construction and contributes heavily to equipment maintenance, damaged tires, etc. In case the roadbed material is predominantly rock and boulders, it may be necessary to import select borrow material to supply the cushioning surface to the required depth on the roadbed.

3. Maintenance

The maintenance of logging roads is usually performed by the timber purchaser under the terms of the timber sale contract. However, the purchaser can elect to deposit money in the Cooperative Work fund with which the Forest Service performs the road maintenance work. In either event the Forest Service has the responsibility of seeing that the maintenance work is properly performed.

Regular maintenance as a watershed and road protection measure cannot be over-emphasized. It should be regular and thorough. For permanent and secondary roads the following items deserve special attention:

a. Repair and clear out all drainage ditches, dips, culverts, and bridges, etc., in the fall and as necessary again in the spring.

b. Keep damaging traffic off soft roads in the fall and spring.

c. See that the road surface is in good condition as the winter season approaches.

d. During the hauling season the roads should be bladed frequently enough to maintain a reasonably smooth driving surface.

e. Earth and gravel surface roads should be sprinkled frequently enough to keep the roadbed firm and avoid "dust" erosion of the surface.

In the case of temporary roads that are to be eventually abandoned, the following work should be done before winter sets in to prevent erosion and encourage stabilization:

a. Install waterbreaks with outlets through the berm, if any, at 50 to 200 feet intervals, depending on the steepness of grade, soil type, and precipitation. Such waterbreaks are readily removed by a grader at the beginning of the next season's logging.

b. Locate water outlets where growing vegetation, rocks, or tangles of slash will break the force of the water and thus prevent the formation of gullies.

Figure 8 and Picture 67 illustrate the proper method of installing waterbreaks for winter when some traffic is expected to use the road in the "off" season.

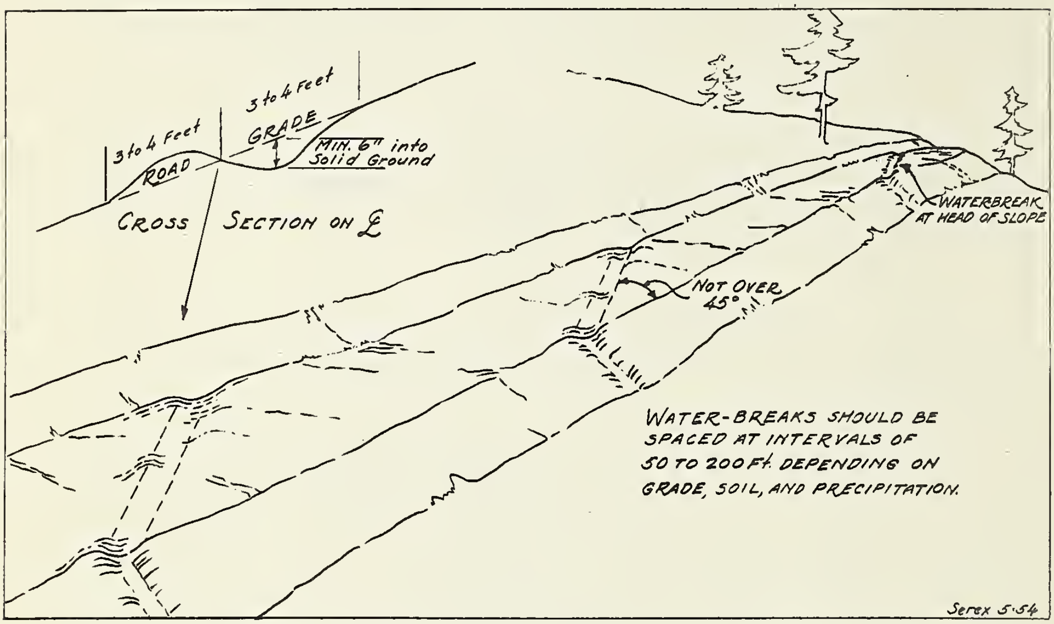


Fig. 8, Typical Water-break Installation for Temporary Road or Skid Road, etc.

67.

Secondary road in decomposed granite, with good surface drainage for the winter season provided by numerous rolling dips about one foot deep, at 45° angle, and with a slight outslope.

Picture 68 shows a waterbreak built at right angles to the road. Such a waterbreak is not self-cleaning; it tends to fill up and become ineffective.

68.

Temporary road in very light decomposed granite soil showing improperly built waterbreak, with obstructed outlet and a berm that is too high and is placed squarely across the road instead of at an angle of 40 or 45 degrees.

c. Remove temporary fills and culverts at stream crossings, making sufficient channel to carry high water.

Picture 69 illustrates the correct fill removal treatment at the end of the logging season or at final termination of use.

69.

Temporary road crossing of a small stream showing the channel properly cleared out after logging. Both fill and logging debris were removed. Erosion on road beyond car should be stopped by water breaks to drain off surface water.

4. Retirement or "putting the road to bed."

Putting the temporary roads to bed is one of the most important erosion prevention measures in a timber sale operation. If correctly done, very little, if any, damage to the watershed will result. If incorrectly done or neglected, serious erosion scars, polluted streams, and silted reservoirs will result.

The methods used will depend upon the soil type, steepness of terrain, grade of road, precipitation (especially whether it is mostly rain or mostly snow), road exposure, and other factors.

Following are some very important points to observe in putting roads to bed:

a. Remove temporary fills and drainage structures in water channels and clear the channels to allow full flow of water without erosion.

   Picture 69 illustrates the proper method of removing temporary fills from a stream channel.

b. In porous soils such as volcanic cinders, rocky shale, etc., removing the berm and giving the roadbed an outslope will serve the purpose.

   Picture 70 shows a retired road treated in this manner.

70.

Temporary road, on steep hillside (about 60%) in porous rocky shale soil, "put to bed" after completion of logging. Constructed on variable grade, with sloped cut-banks and slight outslope, this proved a very satisfactory road and required little treatment after use. The break in grade near car, and outslope, together prevent serious erosion in this soil type, thus maintaining the roadbed for possible future use.

c. In more erosible soils, install water breaks at 50- to 200-foot intervals, depending upon soil type and steepness of road grade, to intercept water running down the roadbed. Breaks should be placed so as to discharge on rock outcrops, in natural water channels or in heavy brush.

Pictures 71 and 72 show examples of water break construction in temporary roads.

71.

Secondary road with well built water break, installed at a good angle and of sufficient size to provide effective protection for winter conditions. However, if road is to be traveled during the winter, the break is too abrupt. Both ditch and berm should be broadened into a dip-and-mound profile so that vehicles will roll rather than bounce over them.

72. 

Drainage ditch and water break in abandoned temporary road functioning effectively after one winter. It would be more dependable if both ditch and cross ditch were somewhat deeper. Another water break exists just beyond trees. There is no erosion, and vegetation is becoming established in the road.

Pictures 73, 74 and 75 illustrate what happens when badly needed water breaks are not installed.

73. 

Abandoned logging road in decomposed granite soil severly eroded as the result of inadequate drainage. Upon abandonment water-breaks, at least, should have been constructed. Preferably the roadbed should have been scarified and planted, since this is site lA sugar pine land. The gully should now be checked, because the eroded material is being deposited in an irrigation reservoir downstream.

74

Abandoned temporary road in rocky soil showing severe erosion of outside shoulder and berm by accumulated water from one-eighth mile of road. Heavy bank slough forced water over against the outside berm, causing the washout. In this case, the treatment after logging should have included removal of the berm and installation of frequent water breaks.

75.

Diversion of winter flow of an intermittent stream down this abandoned temporary road cut out much of the road and deposited the debris on a small meadow. The direct cause was the excavation of the stream bank in foreground and failure to replace it, and failure to clean out and deepen the stream channel after logging. Heavy water-breaks at close intervals would also have helped the situation.

d. Where natural revegetation of an abandoned road will be slow, it is sometimes advisable to scarify the roadbed and seed or plant with trees. When vegetation is firmly established in the roadbed the erosion problem will be largely cured. Frequently scarifying the roadbed will give enough aid to natural regeneration to complete the job without seeding or planting.

e. Placing slash or other debris in close contact with the abandoned roadbed will impede the flow of water and reduce erosion. This treatment is especially good when, because of road location, it is difficult to construct water-breaks as frequently as desirable to prevent erosion. Picture 76 shows an example of this treatment.

76.

Temporary road protected from erosion after logging by felling a partly rotted snag, and placing slash in the roadway. Good contact with ground was obtained by passing tractor over the fallen snag and slash after placement.

CONCLUSION

When the foregoing methods of logging and road construction are neglected, the results to watersheds are frequently disastrous and long lasting. Pictures 77 and 78 illustrate some of these unfortunate results.

77.

Slash barriers in this stream have stopped the circulation of fish; erosion deposits have killed their food and covered their gravel spawning beds; removal of streamside shade trees has admitted full sun to warm the shoaled water above optimum temperatures for trout. Result: a nearly dead trout stream.

Spring floods may open some of the barriers, or pile them into fewer and higher "dams," and streamside trees will grow again. But, unless the barriers are removed by man, it will be many years before this stream becomes once more a suitable environment for trout.

78.

This large stream, once deep and clear, is now heavily choked with sediments and debris from improperly logged areas. Each year during high water much of this material moves down into an irrigation reservoir, a case in which the watershed damages extend far beyond their source.

SUGGESTIONS FOR FURTHER READING

Forest Service Manual References

TIMBER MANAGEMENT - TITLE 7.
Sets forth official policy and standards for Forest Management and Utilization. Sections specifically relevant to watershed protection are:

102.8	Prohibition of Destructive Methods of Logging
106.6	Timber Management and Protection of Water Resource
203.11	Transportation Plan
203.16	Restoration, Repair, or Protection Work by Purchasers
203.17) 203.18)	Road Maintenance
212.53	Requirements to Reduce Erosion

ROAD AND TRAIL SYSTEM - CHAPTER 1 OF TITLE 13.
Presents general policies concerning roads and trails. Of special interest are the sections dealing with Timber Haul Roads: 106.21 through 106.27, and the R-5 Supplement to Section 106.24.

WATER MANAGEMENT - R-5 SUPPLEMENT IN VOLUME III.
Sets forth the objectives and policies of Region 5 concerning the water resource, its management, utilization, and protection.

Handbooks and Directives

FOREST ROAD HANDBOOK, By Division of Engineering, Forest Service, Washington, D.C. Presents forest road design standards, surveys, plans, construction, maintenance, structures, transportation system planning, records and reports, construction contracts and specifications.

DRAINAGE PRACTICE, REGION 5, By Division of Engineering, Forest Service, San Francisco. Compiled in 1940 as a supplement to the 1940 Truck Trail Handbook. Revision expected within next few months but old edition has much good material in it.

TIMBER SALE CONTRACT FORM
Contains standard contract terms, including provisions relating to watershed protection. (Although the contract form does not appear in the Manual, it is referred to in Sections 203.58 and 203.59).

SPECIAL INSTRUCTIONS FOR THE GUIDANCE OF THE FOREST OFFICER ON THE TEN MILE UNIT SALE, KINGS RIVER WORKING CIRCLE, SEQUOIA NATIONAL FOREST, CALIFORNIA. Contained in Memorandum to Supervisors (R-5) from Regional Forester P. A. Thompson (S-SALES-General) Nov. 12, 1947. (Mimeo.)

THE DESIGN OF MOUNTAIN ROADS AS INFLUENCED BY SOIL TYPES. By C. L. Young. U. S. Forest Service, Region 5. December, 1953. (Mimeo.) This paper contains an evaluation of soil series classifications as they pertain to road location and construction.

Logging Plans and Methods

REDUCING LOGGING DAMAGE. By R. D. Cosens. California Forest and Range Experiment Station. Research Note No. 82. February 21, 1952. Describes measures taken to reduce logging damage on an experimental logging project in sugar pine-fir type in California.

SKID ROAD EROSION CAN BE REDUCED. By S. E. Weitzman and G. R. Trimble, Jr. Jour. Soil and Water Conservation. July, 1952. Presents results of a study of the effects of location, grades, and drainage of skid roads on an experimental logging operation in the Appalachian Mountains.

SOME WATERSHED ASPECTS OF LOGGING ON NATIONAL FOREST LANDS IN REGION ONE (WITH SPECIAL REFERENCE TO THE SPRUCE PROGRAM). By C. A. Friedrich. U. S. Forest Service Region 1. December, 1953. An illustrated booklet dealing with the effects of "highball" operations on watersheds and stream conditions. Copy obtainable on request from Regional Forester, Missoula, Montana.

APPLIED FOREST MANAGEMENT IN THE DOUGLAS-FIR REGION. By Philip A. Briegleb. Pacific Northwest Forest and Range Experiment Station. Research Note No. 71. December, 1950. Describes specific measures necessary to avoid excessive erosion and to maintain watershed conditions.

SUGGESTIONS FOR GETTING MORE FORESTRY IN THE LOGGING PLAN. By R. H. Ruth and R. R. Silen. Pacific Northwest Forest and Range Experiment Station. Research Note No. 72. December, 1950. A detailed study of the factors involved in making a logging plan.

PRACTICAL GUIDES FOR SEEDING GRASS ON SKID ROADS, TRAILS, AND LANDINGS FOLLOWING LOGGING ON EAST-SIDE FORESTS OF WASHINGTON AND OREGON. By J. O. Gjertson. Pacific Northwest Experiment Station. Research Note No. 49. January, 1949.

General References

THE FRASER EXPERIMENTAL FOREST. Rocky Mountain Forest and Range Experiment Station. Station Paper No. 8. May, 1952. Includes results of studies of the effects of logging on runoff and erosion.

RELATION OF RUNOFF AND WATER QUALITY TO LAND AND FOREST USE IN THE GREEN RIVER WATERSHED. By W. A. Kunigk. Jour. Amer. Water Works Assn. 37:21. January, 1945. This article reflects the growing concern of water works administrators in the condition of water source areas.

WATER AND TIMBER MANAGEMENT. By M. D. Hoover. Jour. Soil and Water Conservation. April, 1952. Explains why our steadily growing water needs require special care in logging and other activities in mountain watersheds.

VEGETATION AND WATERSHED MANAGEMENT. By E. A. Colman. Ronald Press, N. Y. 1953. 412 pp. An appraisal of vegetation management in relation to water supply, flood control, and soil erosion.

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