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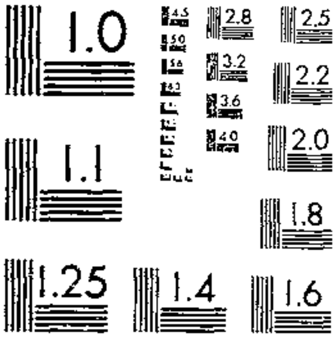

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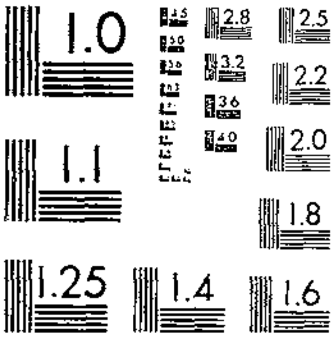

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The Application of Unit Area Control

in the management of

Ponderosa-Jeffrey Pine

at Blacks Mountain
Experimental Forest

by William E. Hallin

Technical Bulletin No. 1191

United States Department of Agriculture
Washington, D. C.

ACKNOWLEDGMENT

Many people have participated in one way or another on the Blacks Mountain project. Without their efforts, this report would not have been possible.

Special recognition is given to:

Duncan Dunning (retired), formerly in charge of forest management research at the station, for the development of unit area control and for guidance, training, and inspiration given to the author.

Past members of the staff of the Blacks Mountain Experimental Forest for planning supervision and operation of the project during its early years—in particular, A. A. Hasel, Reginald Drew, and V. A. Clements. A. A. Hasel is recognized for designing and supervision of installation of the cutting plot study in addition to his major efforts in early planning and supervision.

Russell K. LeBarron for his helpful suggestions, guidance, and critical review of the manuscript.

The present staff of the Blacks Mountain Experimental Forest—Donald T. Gordon, resident manager; Oscar E. Stark, logging superintendent; Joe Perini, logging foreman; and Davis S. Carleton, former logging superintendent; for insuring the practical success of the project.

The present and past members of the staff of the Division of Forest Insect Research of the California Forest and Range Experiment Station (formerly the Berkeley Forest Insect Laboratory of the Bureau of Entomology and Plant Quarantine) for their cooperation in the entomological phases. Of this group, Jack Bongberg is given special mention.

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For sale by the Superintendent of Documents, Washington 25, D. C. Price 35 cents

The Application of Unit Area Control in the Management of Ponderosa-Jeffrey Pine at Blacks Mountain Experimental Forest

By **William E. Hallin**, California Forest and Range Experiment Station,[1] Forest Service, U. S. Department of Agriculture

INTRODUCTION

Throughout northeastern California and extending southward in a narrow band along the east slope of the Sierra Nevada in California and Nevada, the most widespread commercially important timber type is ponderosa-Jeffrey pine.[2] Locally known as "eastside pine," the type covers 1.8 million acres of the 4 million acres in the Eastside Sierra subregion of the Forest Survey, and these two pines are important components of another 1.6 million acres in the subregion (*3*, p. 22).[3] In 1953, the subregion was estimated to contain 41 billion board-feet, International ¼-inch rule.

Large-scale lumber production began in northeastern California in the early 1900's. Since then the annual cut has varied greatly from time to time, but lumber production has been the chief industry of most of the major communities in the district. The cut in 1952 was about 760 million board-feet (*3, p. 41*). Continued harvest of timber in the ponderosa-Jeffrey pine type at a level equal to or greater than past cutting is clearly a desirable objective for the economic welfare of northeastern California.

Methods of timber harvesting in eastside pine have been governed by several considerations and have followed many patterns. At first, many loggers simply extracted whatever timber they wanted by whatever method they considered to be cheapest. They gave little thought to silvicultural requirements such as protection of residual trees, prevention of logging slash fires, or encouragement of natural regeneration. Felling and skidding often caused excessive damage to residual trees.

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[1] Maintained at Berkeley, Calif., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California.

[2] The type varies from pure ponderosa pine through different degrees of mixture to pure Jeffrey pine. Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) also occurs in southwestern Oregon, the Coast Range of California, the west slope of the Sierra Nevada, southern California and northern Lower California; ponderosa pine (*P. ponderosa* Laws.) occurs throughout western North America from British Columbia, Canada, southward to Sonora and Chihuahua, Mexico.

[3] Numbers in parentheses refer to Literature Cited, p. 60.

Much of the earlier timber harvesting amounted practically to clear cutting of the better merchantable trees. Because of differences in logging and stand conditions, the end result was variable. Sometimes many undersize or low-quality trees were left. Sometimes advance stocking of reproduction was present. Some areas reseeded after cutting. But slash fires killed much of the reproduction and advance growth, and then many areas were invaded by brush species such as snowbrush ceanothus (*Ceanothus velutinus*) and greenleaf manzanita (*Arctostaphylos patula*).

Timber owners have become increasingly aware of the desirability of prolonging or perpetuating timber supplies through forest management. Today, the principal private timberland owners are quite willing to undertake forest practices which they deem to be financially profitable.

On the national forests sustained timber production was a definite objective from the very beginning of timber harvesting. But to maintain high-level production, foresters needed answers to many practical questions. What annual growth would the forest land sustain, and what was the allowable annual cut? What pattern of regulating the cut should be adopted to convert the wild forest into an evenly distributed arrangement of age classes? What kinds of cultural treatment do young stands need for maximum growth in quality and quantity to be ready for harvesting when needed? Should the stands of the future be planned for management on an even-aged basis or should an effort be made to create uneven-aged stands?

One of the more critically important problems that faced forest managers was how to insure prompt and adequate regeneration. Obviously, high, sustained production requires that the land be stocked continuously without a long wait between harvesting and re-establishment of the next crop. Although many of the stands in the eastside pine type were abundantly stocked, productivity was relatively low because of climate. All in all, comparatively inexpensive methods of management were needed.

Then too, bark beetle outbreaks periodically killed large amounts of timber. Beginning about 1921, both private timber owners and public forest managers in northeastern California recognized the unusually difficult problem created by bark beetles. During the period 1925 to 1937, bark beetles killed nearly 11 billion board-feet of pine in California (*11*). At the peak of the epidemic, average annual losses in typical overmature eastside pine stands amounted to more than 200 board-feet an acre. In some tracts losses ran far higher and many stands were seriously depleted. Could these losses be prevented, or were they uncontrollable? Would silvicultural measures reduce losses? Was salvage of the dead and dying trees feasible?

The technical forest management problems that have been briefly outlined—determination of growth, regulation of the cut, selection of harvest cutting methods, cultural treatment of young stands, and protection of the stand against excessive insect-caused loss—are the subject of this publication. Its purpose is to tell what has been learned about the solution of these problems during two decades of operating the Blacks Mountain Experimental Forest. The conclusions and methods developed in managing the ponderosa-Jeffrey pine type can be adapted and applied to other pine types.

THE BLACKS MOUNTAIN EXPERIMENTAL FOREST

The Blacks Mountain Experimental Forest was established as the principal site for management investigations in the eastside pine type. It was set aside from land in the Lassen National Forest in 1934, the year after preliminary work started. Studies going back as far as 1910 had resulted in new theories of management, silviculture, and insect control *(10)*. A primary objective of the Blacks Mountain project was to develop these theories into a system of management and to test, demonstrate and improve the system through continuous operation of a timber tract on a commercial scale. Each year since 1937, except in 1948 and 1949 when logging crew and equipment were used on another project, timber harvesting operations have been conducted as a part of the planned management of the area.

The experimental forest is well suited for conducting investigations in the east side pine type. Geographically, it is near the center of the type (fig. 1). Site, climate, topography, and vegetation are representative of the conditions found over most of the type.

In terms of the interregional ponderosa pine site classification *(23)*, the site index at age 100 years varies from 60 to 80 feet and averages 72. These indices correspond to 100, 125, and 114 feet at age 300 in Dunning's California site classification *(9)*. Low annual precipitation is the chief reason for the relatively low site quality. During the period 1935–53, the mean annual precipitation varied from 9.09 inches to 29.24 inches and averaged 18.17 inches. About 90 percent of the precipitation fell in the months of October through May.

Rock outcrops are common, and the soil is shallow and stony. Soil conditions, then, are partly responsible for the poorer sites.

Approximately half of the experimental forest lies in a gently rolling basin; the rest extends up the moderate slopes of Blacks Mountain to the north and of Patterson and Cone Mountains to the east. Elevations range from 5,600 to 6,900 feet.

Government-owned land in the experimental forest totals 10,252 acres. At the time of the first inventory in 1933 and 1934, the average stand per acre was 18,400 board-feet. Of this volume, 90 percent was ponderosa and Jeffrey pine, 7 percent white fir, and 3 percent incense-cedar.

The forest is even-aged by small groups. The overstory in ponderosa and Jeffrey pine stands is predominantly overmature, but it is broken by small groups of immature and mature-age classes and by openings. The total area of these intermediate age classes is small, and this complicates stand regulation. Seedlings, saplings, and poles are represented in much of the forest as advance growth, both as an understory and in openings caused by losses in the old stand. Scattered older residuals may be present in young stands. The age classes are not evenly distributed. Instead they form a mosaic of small homogeneous units (fig. 2)—a variable pattern of many even-aged groups.

Some groups are differentiated not so much by age as by other stand condition—density, thrift, or the amount of undergrowth or advance reproduction. They vary in size from a fraction of an acre up to 5 or 10 acres. Despite its variability, then, the forest is composed of small units, even-aged and with distinct differences in stand condition.

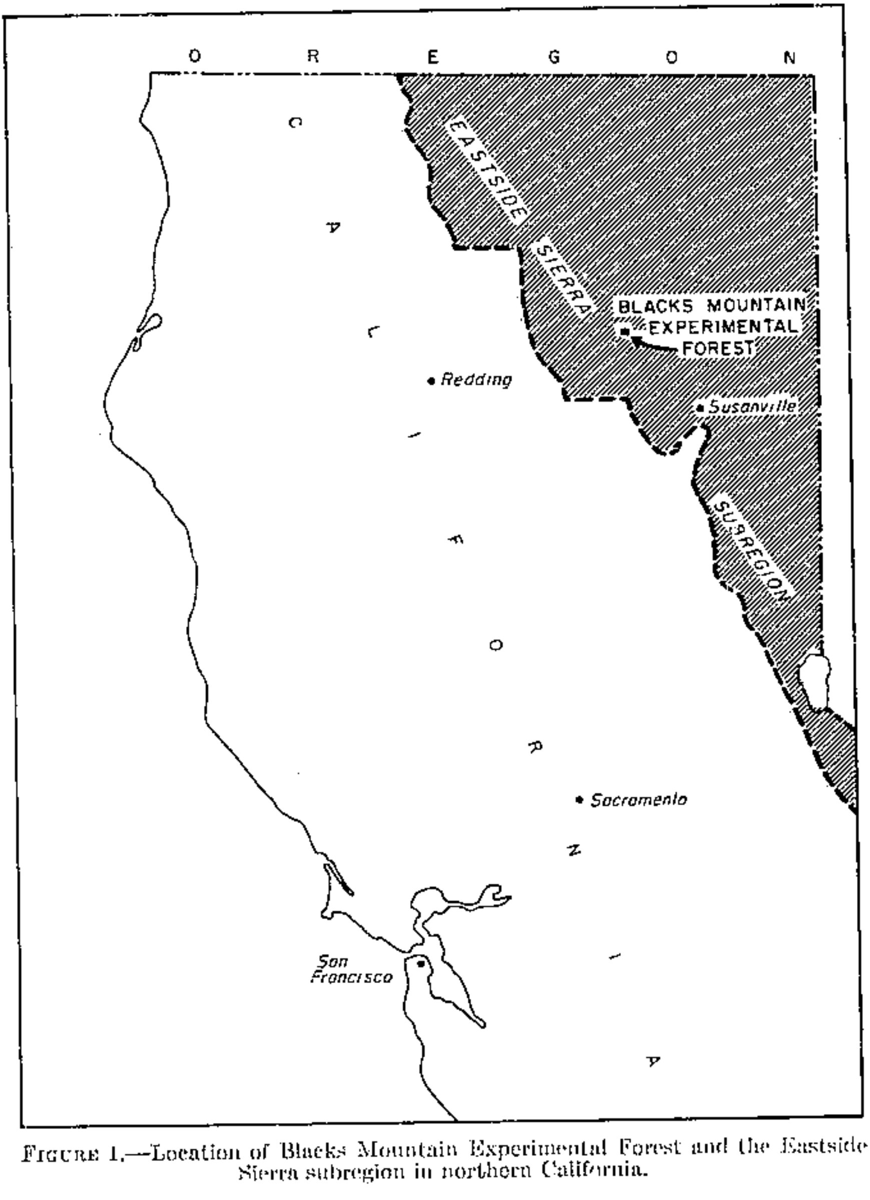

FIGURE 1.—Location of Blacks Mountain Experimental Forest and the Eastside Sierra subregion in northern California.

When activities began on the experimental forest, insect-caused mortality was severe. Average annual mortality in pine was 202 board-feet an acre (fig. 3). This high mortality was typical of that prevalent in the eastside pine type. In the first 10 years of experimental work in the type, emphasis was on cutting for insect control. Also, methods of cutting were compared on plots, and work was started on regeneration, stand improvement, and other silivicultural problems (*17*).

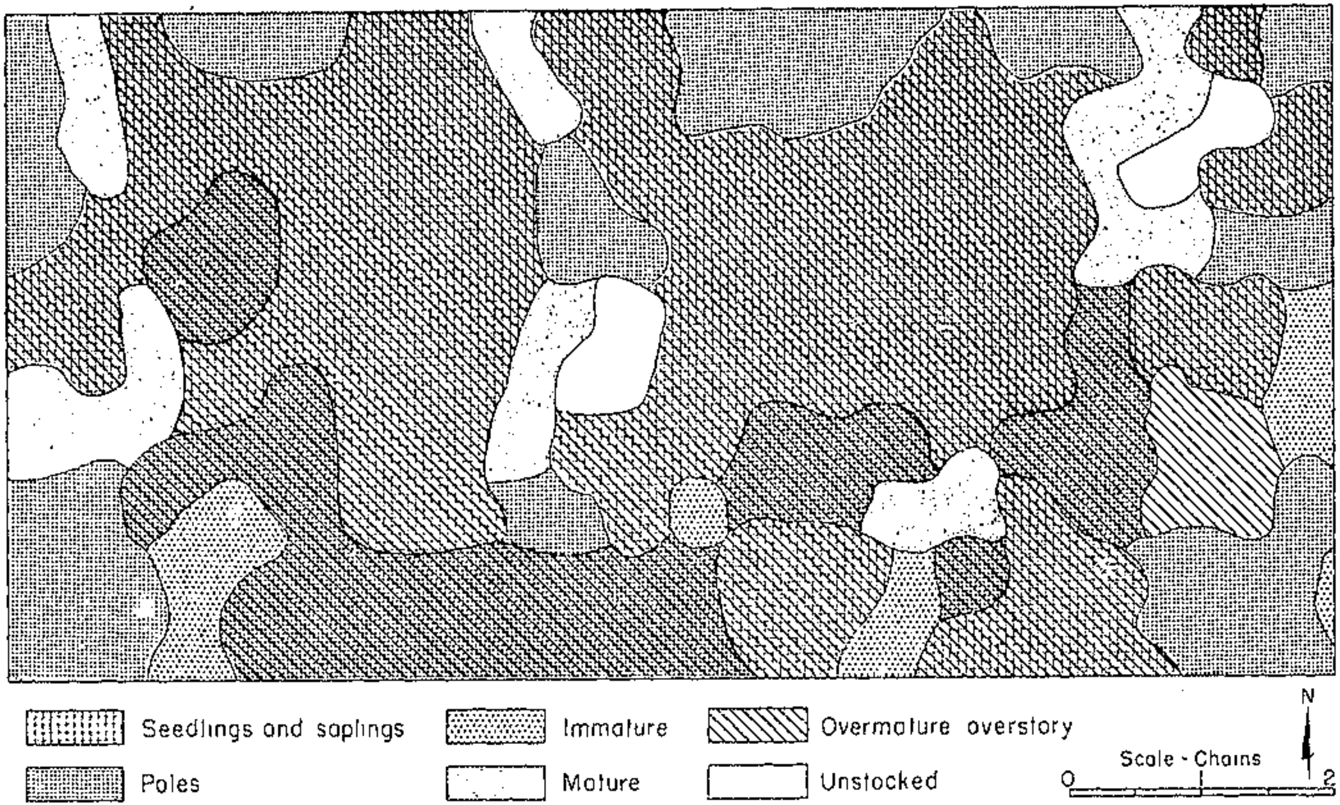

FIGURE 2. Mosaic pattern of condition classes on a 20-acre unit plot, ponderosa pine, Blacks Mountain Experimental Forest.

F-[illegible]

FIGURE 6.—Heavy tree mortality caused by bark beetles on the Blacks Mountain Experimental Forest, 1939. (Compare with [illegible].)

As work progressed, the research staff saw that each small uniform group of trees had different silvicultural requirements. They were convinced that the cutting methods being used did not recognize this pattern of growth and therefore would answer few of the questions plaguing forest managers.

Duncan Dunning conceived the idea of making homogeneous units or groups of trees rather than individual trees the subjects for management (8). Although the idea of "detailed control of stocking on small areas" was not new, the idea of applying such a system to stands rendered highly variable in condition by natural factors was. Dunning chose the term "unit area control" because it is descriptive of the system.

A "unit area" is a single natural stand unit, one of the homogeneous parts making up the mosaic pattern of the forest. Although the units vary in size from a fraction of an acre to many acres, each has a particular combination of such characteristics as age, species, composition, and stocking. It follows that different combinations require different silvicultural treatment.

The word "control" describes the aims of management. Of first importance is control of the ground by desirable trees rather than by brush or inferior trees. Control also means regulating the distribution of age classes and maintaining a growth rate of desirable species commensurate with site and age class on each unit area. The forester exercises control by preparing and executing a plan of regulations and by applying silvicultural treatments at the proper time.

SILVICULTURAL STUDIES

Silvicultural studies laid the foundation for unit area control in the east-side pine type and will continue to be a part of the operation of the experimental forest. Small studies of pruning and thinning were the basis for stand-improvement practices. Other studies resulted in a method for reducing insect-caused losses, showed the requirements for regeneration, and provided information on growth after cutting.

Sanitation-Salvage Cutting

Silviculturists and entomologists have studied host selection, tree susceptibility, and bark beetle attack in eastside ponderosa and Jeffrey pines for a long time. Dunning (*8*) conducted the first studies in the early 1920's, and before long much basic information was available from the work by Craighead and others (*6*) and Person (*24*). By the time cutting started at Blacks Mountain, Salman and Bongberg (*27*) had shown that the risk of bark beetle attack in individual trees could be determined from crown characteristics indicative of current tree health. They identified four degrees of risk based on gradations in crown characters, needle length, needle complement, needle color, degree of twig and branch killing, and other conditions (appendix, p. 62). Bongberg later developed a penalty system to improve the accuracy of risk classification (appendix, p. 62).

Salman and Bongberg showed that high-risk trees (risk classes III and IV) made up only 15 percent of the stand volume. But 84 percent of the annual bettle-caused losses occurred in these high-risk trees. They reasoned therefore that the selective removal of the high-risk trees would prevent 84 percent of the loss. Also, the light cut would permit rapid coverage of the area so that most of the potential losses could be salvaged.

The first trial of this means for control of bark bettles in eastside ponderosa and Jeffrey pine stands was on the Blacks Mountain Experimental Forest. As soon as it was demonstrated that the average cut of 2,547 board-feet per acre could be logged economically, and that the cutting reduced the annual rate of tree killing, sanitation-salvage was adopted as the principal type of first cut in the eastside pine type on national forests. It was also adopted by private operators and put into use extensively on private lands.

EFFECTIVENESS IN REDUCING MORTALITY

On the compartments where sanitation-salvage cuttings were first made in 1937, Bongberg found that the cumulative reduction in loss for the first 10 years was 71 percent (*2*). The reduction was even greater on plots established to study the effects of cutting methods on growth. Records for 10-year periods on four 20-acre uncut plots show an average annual pine loss of 98 board-feet per acre, whereas similar sanitation-salvage cut plots had an annual loss of 18 board-feet per acre—an 82-percent reduction.

Losses were lower on sanitation-salvage cut compartments each year from 1938 to 1952 (fig. 4), and analysis of the data shows that the effect of cutting lasted longer than 10 years. During the first 3 years of cutting, high-risk pines were harvested from 481 acres. In 1951, 12 to 14 years after cutting, mortality on these areas was 29 board-feet per acre, 81 percent less than on uncut compartments. One year later they lost only 3 board-feet per acre—a reduction of 97 percent.

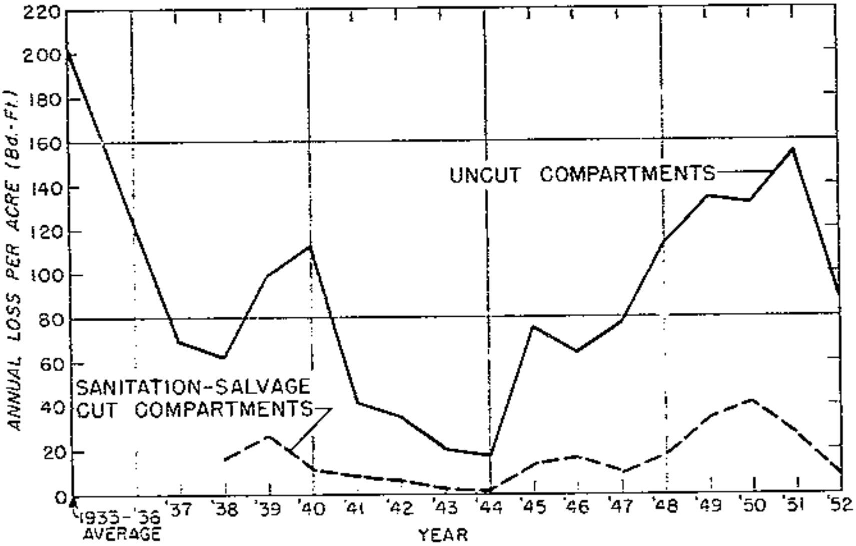

FIGURE 4. Annual insect-caused losses, Blacks Mountain Experimental Forest, 1933-52.

CURRENT TEST UNDER EPIDEMIC CONDITIONS

The bark beetle epidemic of the early 1930's began to subside around 1937. Consequently, until recent years, tests of sanitation-salvage cutting were under conditions of moderate to low bark beetle populations. In 1951 beetle populations again developed to near epidemic size. Losses averaged 155 board-feet per acre on uncut compartments. In 1952 the high-risk pine trees were logged on three compartments that had been kept uncut in order to have an area for testing the effectiveness of sanitation-salvage.

Too little time has passed to measure the effectiveness of this cutting. Losses will need to be recorded for 10 years or more, but preliminary results are encouraging. Good reasons exist for supposing that longer period reactions will be favorable.

FUTURE APPLICATION OF SANITATION-SALVAGE CUTTING

The principal sanitation-salvage cutting at Blacks Mountain has been completed. In the future, such cutting will be confined to units on which the final harvest is being deferred until a later cutting cycle.

Sanitation-salvage cutting is recommended for general application in overmature, virgin ponderosa pine forests. A light cut—2,000 to 3,000 board-feet per acre of high-risk trees—permits rapid coverage of uncut areas; losses can be reduced quickly. However, sanitation-salvage cutting is only the first step in management. It should be followed by cuts with other silvicultural objectives. High-risk trees that develop in units to be reserved should, of course, be removed in these subsequent cuts.

Regeneration

In most of the eastside pine type, overmature timber stands are well stocked with advance reproduction. On the experimental forest, for example, only about one-fifth of the area will need to be regenerated after the removal of the overstory. During the early years of operation, sanitation-salvage cuttings seldom create a need to regenerate. When final harvesting of overmature timber by group clear cutting starts, regeneration becomes important.

NATURAL REGENERATION

Several conditions are essential for abundant reproduction of ponderosa and Jeffrey pine: (1) A good seed crop followed immediately by one or more favorable growing seasons; (2) a seedbed of mineral soil; (3) no competing vegetation; and (4) few seed-eating rodents. These favorable conditions seldom occur together in the eastside pine type, but one of the chief reasons for lack of reproduction is irregular seed crops. Between 1942 and 1953 the pines on the experimental forest bore four light to good seed crops:

	Seed fall per acre through October [1] (thousands)
1942	42
1945	4
1948	77
1952	33

[1] From seed-trap records (54 or more seed traps each year). Records taken in late October and the next spring for 2 of these years indicate that 65 to 75 percent of the year's seed crop falls before the first of November. The remainder falls during the winter.

In the other 7 years they bore few or no seed. Insect damage to seeds and seedlings may partly account for regeneration failures.

Even the rare good seed crops produced few established seedlings unless other conditions were suitable. Before the heavy 1948 seed crop, for example, 6 cut-over openings in need of regeneration were scarified with an offset disk-harrow 2 weeks before seed fall *(30)*. The aim was to simulate freshly disturbed ground that results from logging, slash disposal, and removal of vegetation. Seed-eating rodents were poisoned on each opening and on a buffer strip one-fourth mile wide. The openings were one-fifth acre or larger and had a border of cone-bearing trees. Seed traps on nearby plots with similar reserve stands caught seed at the rate of 130,000 per acre during the fall and winter.

Seedbed preparation greatly aided regeneration. Few seedlings survived after 4 years where competing vegetation was moderate or heavy:

	Seeds germinated per acre	*Seedlings established per acre at 4 years*	
Competing vegetation:	*(number)*	*(number)*	*(percent)*
None	33, 329	11, 017	33
Light	11, 420	1, 277	11
Medium	3, 816	139	4
Heavy	2, 914	127	4

Source: Tackle and Roy *(30)*.

On bared soil, seedlings were abundant (fig. 5) and growth was better. At the end of the fourth growing season, average heights of the tallest seedling on each milacre quadrat in the sample were as follows: No ground cover, 6.7 inches; light, 3.0; medium, 3.1; heavy, 2.4.

Even with only light ground cover, germination, survival, and growth were much lower than on bare ground. Possibly the 1,277 4-year-old seedlings per acre on areas with light ground cover are adequate. But they were the result of an exceptionally good seed crop. The better growth on bare soil means that removal of all competing vegetation is usually desirable.

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FIGURE 5.—Natural regeneration 5 years after establishment in 1949 on bare soil. Area scarified and rodents poisoned in 1948 prior to seed fall.

Yet forest managers may have difficulty in achieving favorable conditions for natural regeneration. This was shown by an attempt to capitalize on a moderate seed crop in prospect for 1952. About 11 acres in units varying from ¼ to 2½ acres were clear cut. Borders of cone-bearing trees were left around each unit. These trees were estimated in the spring of 1952 to have a prospective production of at least 600 cones per acre for the units to be regenerated. A crop of 600 cones is the equivalent of roughly 43,000 seeds (*12*). After the units were logged, slash and vegetation were removed and rodents were poisoned before seed fall started in mid-September. At best, the results were only moderately successful (table 1). Lack of success was attributed chiefly to ineffective rodent control. The areas on which natural regeneration was inadequate were planted in the spring of 1954.

What do the greatly different results of these two experimental attempts to assist natural regeneration add up to? Reduction of competing vegetation and preparation of seedbeds can be accomplished by well-known methods. Elimination of animal-caused losses is much less certain. Favorable weather for initial establishment and early survival cannot be controlled. Therefore, planting is regarded as the surer method for promptly reforesting most unstocked units, at least until more certain methods for natural regeneration can be worked out.

TABLE 1.—*Results of 1952 regeneration cutting, Blacks Mountain Experimental Forest* [1]

Sample area	Seed production per acre		Seedlings per acre, 1953 [2]		Survival	Seedlings germinating per seed
	Fall [3]	Total [4]	June	October		
	Number	*Number*	*Number*	*Number*	*Percent*	*Number*
1	24, 336	40, 265	375	42	11	0. 009
2	32, 153	41, 003	790	274	35	. 019
3	38, 053	51, 019	1, 095	679	62	. 021
Average	33, 038	[5] 45, 183	820	392	48	. 018

[1] Data compiled by D. F. Roy.
[2] Basis, 194 milacre quadrats.
[3] Through October 17, 1952.
[4] Through May 1953.
[5] Basis, 54 seed traps.

ARTIFICIAL REGENERATION

The main requirements for successful planting of nursery propagated trees at Blacks Mountain have been determined. In an experiment started in 1951, 1–1 stock was shown to be superior to 1–0 stock for both ponderosa pine and Jeffrey pine (*25*). The principal specification for 1–1 stock in the California Region is a minimum diameter of 0.11 inch at the root collar. However, ground cover conditions were more important than class of stock. Two years after planting, survival was best on bare ground and poorest where vegetation was heavy; logging slash and stony ground also reduced survival.

Ground cover:	*Seedling survival (percent)*
Bare ground	56
Light nonliving cover or stoniness	50
Heavy nonliving cover or stoniness	35
Light living cover	25
Heavy living cover	2

Routine planting has also indicated the necessity for removal of competing vegetation. Survival has been good on all but the few small units not cleared of slash and vegetation. For example, plantings in the spring of 1953 averaged 71 percent survival at the end of of the first season. Without site preparation, however, some plantings were almost complete failures even where the competing vegetation appeared to be relatively light. One reason is that roots fully occupy the soil even though the soil surface between competing plants is bare.

Routine planting was started in the spring of 1952 on 14 acres cut in 1951 (fig. 6). In the next 4 years 50 acres were planted. Survival at the end of the first season averaged 70 percent.

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FIGURE 6.—Ponderosa pine 1-1 stock 2 years after planting in the spring of 1952. Before logging in 1951, the planting site was an overmature unit without advance growth.

The side hole method and a long-handled mattock are used (4), and 1,000 trees per acre are planted at 6.6- by 6.6-foot spacing. In some places, however, fewer trees are planted because of stumps, small patches of slash, rocks, and existing trees. For example, in 1952 only 650 per acre were planted.

Costs have been high—$45 per acre at best, in 1952. Nursery stock and labor are expensive. Also, stocking standards required planting of many fifth- to half-acre units; as a result, transporting and handling small lots of stock boosted costs. In the future, a less exacting standard of stocking for units smaller than one-half acre will reduce the number of small units to be planted. Fortunately, only a small fraction of the experimental forest requires artificial reforestation.

What planting costs are justified? To help answer this question, present values of estimated future intermediate and final harvests were calculated for ponderosa pine plantations (16). After subtracting the discounted cost of pruning selected crop trees, these values at selected compound interest rates are as follows:

Site index 60 feet (Dunning's site Class IV 100)	$65	$35		
Site index 70 feet	114	67	$16	
Site index 80 feet (Dunning's site Class III 125)	177	113	75	$31

Because only a small part of the tract needs planting, the existing growing stock can carry the normal costs of management and protection. Only planting and pruning costs and their interest charges need to be assessed against the plantation yields.

A reasonable return at Blacks Mountain would be 2 percent, an interest rate at which the Federal Government has borrowed money. If half of the site preparation cost is credited to hazard reduction for fire protection, site preparation and planting costs at Blacks Mountain amount to about $70 per acre. Yields from plantations on site index 70 feet and better have a present value well above $70 at 2-percent interest. Therefore, on areas poorer than site index 70, planting would be deferred until planting costs are lower or until better knowledge of growth and future prices indicates higher dollar yields can be expected.

Direct seeding has been tried as a means of reducing regeneration costs but has not proved worthwhile for general use. The trouble lies in protecting seed from rodents. Without protection, few seeds germinated. With wire screens protecting the seed, 40 to 50 percent of the seed spots generally were stocked after 1 growing season. But seed spots protected with dome or cone screens cost as much as or more than planting nursery stock. Expense mounts because the screens are costly and must be picked up to let the seedlings grow properly.

Small, inexpensive cylindrical screens were tested (*26*) but did not work out. They protected the seed from rodents, but only 12 to 21 percent of the screens were stocked at the end of the first season. Failures were due to such causes as frost heaving, cutworms, trampling, and desiccation.

Limited experiments with rodent repellents and poisons had varying results, generally not good enough to warrant wide application.

Despite the failures, efforts to develop successful methods of direct seeding will be continued on a limited scale because of the possibilities for reducing regeneration costs.

RODENT CONTROL

Keeping rodents from eating too much seed is essential for either natural or artificial regeneration. Trials of poison bait met with varying success at Blacks Mountain in 1948 and 1952. Even though poisoning cut the rodent population in 1952 (table 2), regeneration was poor.

Rodents are difficult to control because they may quickly migrate into treated areas. Furthermore, most rodents multiply rapidly. If only a few escape poisoning, they can quickly re-populate an area. For best results poisoning must be timed closely in advance of seed fall and re-poisoning may often be necessary.

Both the 1948 and 1952 poisonings used oat groats treated with "1080" (sodium fluoroacetate) as bait.[4] It was distributed in pinches of 15 to 30 kernels every 15 feet along lines about 50 feet apart. Where possible the bait was placed under or around logs, stumps, slash, or near other places that rodents are likely to frequent.

The cost of baiting 810 acres in 1948 (*5*) was 26 cents per acre. In 1952, September rains and wet conditions caused considerable lost

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[4] *Caution:* "1080" and most other poisons are highly toxic to humans. Laws govern their use. Local personnel of the U. S. Fish and Wildlife Service or County Farm Advisors should be asked for help or advice before any forest rodent poisoning is undertaken.

TABLE 2.—*Rodent census in poisoned and unpoisoned areas, Blacks Mountain Experimental Forest, September 1952* [1]

Species	Rodents trapped in—		
	Unpoisoned area 1	Unpoisoned area 2	Poisoned area
	Number	*Number*	*Number*
Yellow pine chipmunk (*Eutamias amoenus*)	16	13	3
Tahoe chipmunk (*E. speciosus*)	11	13	7
Towusend chipmunk (*E. townsendii*)	5	6	0
Golden mantle squirrel (*Citellus lateralis*)	17	7	0
White-footed mouse (*Peromyscus maniculatus*)	5	10	2
Trowbridge shrew (*Sorex trowbridgeii*)	1	5	0
Chickaree (*Tamiasciurus douglasii*)	1	0	0
Snowshoe rabbit (*Lepus americanus*)	1	1	0
Total	57	55	12

[1] Data from 100 traps for 3 nights at each area.

Source: Lloyd Tevis, Jr., Dept. Zoology, Univ. Calif., Davis.

time and made some re-poisoning necessary; baiting 420 acres cost 72 cents per acre. That year natural regeneration was sought on a net area of only 10.7 acres scattered about in several small units, but the cost was $28.26 per acre.

Both the high cost for the area protected and the uncertainty of success leave much to be desired in baiting as a method of rodent control on small scattered clear cuttings. Therefore, when only a light seed crop is in sight on such cuttings, baiting cannot be recommended. If regeneration areas can be so arranged that the net area to be protected is a relatively large fraction of the total area that must be baited, or if more efficient methods are discovered, rodent control will become much more practicable.

SITE PREPARATION AND SLASH DISPOSAL

Both bulldozer blades and brush rakes on crawler tractors have been used to clear the ground and pile slash in preparing the site for regeneration (fig. 7). Brush rakes are preferred because they push less topsoil into the slash piles. The cost has varied from $7.91 to $50.58 per acre (table 3). Some reasons for the low cost in 1951 were an exceptionally skillful tractor operator, a relatively low volume of slash, and light or no coverage of areas with small amounts of slash and vegetation.

The tractor often skips narrow strips of slash and vegetation in preparing a site. Complete clearing has proved unnecessary. After 1951 the operator was instructed to leave strips of slash a few feet wide rather than go back to clean them up. He was not to skip whole areas that seemed to have little competing vegetation. As experience with this procedure grew, costs declined and it was apparent that the strips of slash have a beneficial shading effect. It should be possible to reduce costs still more by further training of the crew and by learn-

FIGURE 7.—Slash and vegetation piled by tractor with bulldozer blade on area to be regenerated.

ing how much slash can be left without unduly retarding seedling germination and survival.

TABLE 3.—*Cost of site preparation and slash disposal, Blacks Mountain Experimental Forest, 1951–55* [1]

Year	Prepared units		Cost per acre [1] prorated over gross area logged	Cost per M feet total volume cut
	Average area	Cost per acre		
	Acres	*Dollars*	*Dollars*	*Dollars*
1951	19.3	7.91	0.33	0.04
1952	15.8	15.71	2.70	.34
1953	22.2	50.58	2.27	.44
1954	11.5	19.50	2.56	.19
1955	15.2	36.91	1.20	.24

[1] Site prepared and slash disposed of only on areas to be regenerated.

Source: Gordon (*16*).

SUMMARY OF RECOMMENDATIONS FOR REGENERATION

Unstocked areas should be regenerated by natural seed fall when practical. Because good seed crops are infrequent, however, areas in need of reproduction will usually have to be planted. Insects are one cause of poor regeneration; they destroy cones, seeds, and seedlings, but the extent of their damage is not known. If investigations prove these insect attacks to be serious and adequate control measures are devised, natural regeneration can be relied on to a greater extent.

Ponderosa and Jeffrey pine cones mature in 2 years. Consequently the prospects for a seed crop can be detected a year in advance. Because one-year-old cones of these pines are quite small, tops of freshly cut timber should be checked each year to determine prospects for a seed crop before it is too late to plan the necessary measures for regeneration.

Protecting seed from rodents is essential for successful establishment of natural reproduction. Current methods of rodent control require that poison bait be placed in a buffer zone one-fourth mile wide around the regeneration area. Therefore, the cost of rodent control is high if the area to be regenerated is small. Since the success of known control methods varies, an attempt to obtain natural regeneration is a questionable venture unless a bumper seed crop is in sight or a large area in the aggregate is to be regenerated.

If natural regeneration fails, the area should be planted promptly so that reproduction is established before competing vegetation takes over the ground.

Whether regeneration is natural or artificial, competing vegetation and slash must be removed. In either case, mechanical removal is essential in order to provide a mineral soil seedbed for seeds or space to plant. Tractors with brush rakes have proved the best equipment. Adequate planning of the work and training of equipment operators are essential to keep costs low. Complete coverage of the ground can be avoided by leaving narrow stringers of slash.

Natural regeneration can be depended upon if (1) cutting is deferred until a good seed year or (2) site preparation of areas cut during poor seed years is deferred until a good seed year. Either deferment, however, will result in an excessively heavy workload for the good seed years and a regeneration program that is extremely difficult to carry out. In addition, deferring site preparation loses the advantage of optimum release of ground for any new seedlings that do result from cutting and logging. If several years elapse after cutting, the ground will be taken over by shrubs, grass, and other vegetation.

Planting with nursery stock is still the cheapest and surest method for successfully establishing artificial regeneration. At Blacks Mountain spring planting with 1–1 ponderosa or Jeffrey pine stock has been most successful. Direct seeding cannot be recommended until effective rodent repellents or other cheap means to protect seed are found.

Growth After Harvest Cutting

A study of growth after cutting was started in 1938 to compare several methods of harvest cutting. It was designed as a randomized-block experiment that included four plots per block: (1) control—no cutting; (2) heavy selection (approximately 75 percent of volume cut)—as then used on national forests in California; (3) moderate selection (approximately 55 percent of volume cut)—similar to, but not identical with, so-called "standard marking" in national forests of California; (4) unit area control—originally called silvicultural selection.

The fourth method is representative of the treatment applied to the experimental forest as a whole. Unit area control plots were given a sanitation-salvage cut at the time of establishment. The first recut was not made on most plots until the time of the latest (10-year) measurement. Consequently these plots are used primarily for showing growth following a sanitation-salvage cut. One replication of each method was established every year for 10 years. In certain years clear-cut plots were added to the study.

Plots in the harvest-cutting series are 20 acres in area. Each was divided into one-tenth-acre squares at the time of establishment. All trees 11.6 inches d. b. h. were tagged, measured to the nearest tenth inch, and their locations mapped. At the time of the 10-year remeasurement, the original stand and cover conditions for each tenth-acre subplot were described and recorded by a system of condition classification (p. 74) adopted for unit area control. The 10-year data from the first four blocks of plots were the basis for the analyses of growth and mortality that follow. These plots include four each for uncut, heavy selection, moderate selection, and sanitation-salvage, and two for clear cutting.

GROWTH BY INTENSITY OF CUT

The greatest actual growth per acre, both gross and net, occurred on the sanitation-salvage cut plots (table 4). However, much less growing stock on the heavy-cut and clear-cut plots produced about the same growth as the heavier growing stock volume on the moderate-cut plots. Growth by 5-year periods emphasized the advantages of heavy cutting. In the second 5-year period, clear-cut plots grew as much as those given heavy selection and more than those given sanitation-salvage or moderate selection cutting:

	Average annual growth per acre, all species	
Type of cutting:	*First 5 years (board-feet)*	*Second 5 years (board-feet)*
Sanitation-salvage	137	77
Moderate	80	64
Heavy	68	88
Clear	48	88

As the cut increased, young trees furnished an increasing share of net growth. In both table 4 and the tabulation, net growth includes ingrowth and growth of residuals minus losses through death. On all but the clear-cut plots, the cutting was in older trees. Therefore, on all but clear-cut plots, volumes in the younger age classes were relatively similar after cutting. Also, number of poles, which supply the ingrowth, was approximately the same on all types of plots.

Briefly, analysis showed that the young age classes grew faster after heavy cutting than after moderate or light cutting. When a sustained cut and short cutting cycles are desired, however, heavy cutting over the entire working circle or property is not possible. Nevertheless, forest managers can capitalize on the growth potential after heavy cutting. By taking advantage of variation in stand structure, they can clear-cut overmature groups and subject other groups to a light improvement cut.

TABLE 4.—*Annual growth and loss per acre*[1] *by method of cutting, Blacks Mountain Experimental Forest, first 10 years after cutting*

Item	Uncut	Sanitation-salvage cut	Moderate cut	Heavy cut	Clear cut
	Board-feet	*Board-feet*	*Board-feet*	*Board-feet*	*Board-feet*
Volume after cutting	18, 465	15, 808	8, 326	5, 092	598
	[2] **17, 559**	**14, 295**	**7, 753**	**4, 977**	**402**
Gross growth	73	97	65	64	18
	64	**79**	**59**	**61**	**11**
Ingrowth	20	30	23	21	51
	15	**22**	**19**	**19**	**29**
Mortality	101	20	16	7	1
	98	**18**	**15**	**7**	**1**
Net growth	−8	107	72	78	68
	−19	**83**	**63**	**73**	**39**
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Pine in volume after cutting	95	90	93	98	67

Basis: Four 20-acre plots for each method except clear-cut, which had two 20-acre plots.

[1] Trees 11.6 inches and larger.

[2] Figures in bold type are for pine only; figures in roman, all species including white fir and incense-cedar.

GROWTH BY AGE CLASSES

To determine how the grouped arrangement of age classes affects management, an analysis was made of growth in relation to age-class groups on the harvest-cutting plots (appendix, p. 65). The plots were divided into tenth-acre subplots, and the reserve stand on each subplot was classified by broad age classes as overmature (300 years or more), mature (150 to 300 years), or immature (less than 150 years) (fig. 8). As would be expected, overmature groups grew slowest, and immature fastest (table 5).

The periodic growth of immature age classes[5] was still more striking than shown in table 5 on subplots with a reserve volume equal to the average volume for overmature age classes (18,755 board-feet). Under these circumstances, trees less than 150 years old grew at the rate of 269 board-feet per acre (fig. 9). The annual ingrowth of 86 board-feet brought the total to 355 board-feet per acre. These data bear out the obvious conclusion that maximum growth will be produced when old-growth stands are converted into young, fast-growing stands.

Young stands progressed more rapidly toward harvestable size when the competition from older trees—as an overstory or as scattered individuals—was removed. For example, on all plots, ingrowth was greater where the overstory was removed. On all except clear-cut plots, the adequately stocked pole stands without an overstory occurred as small scattered groups, usually surrounded by older trees.

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[5] Periodic growth for stands of this age is higher than mean annual growth.

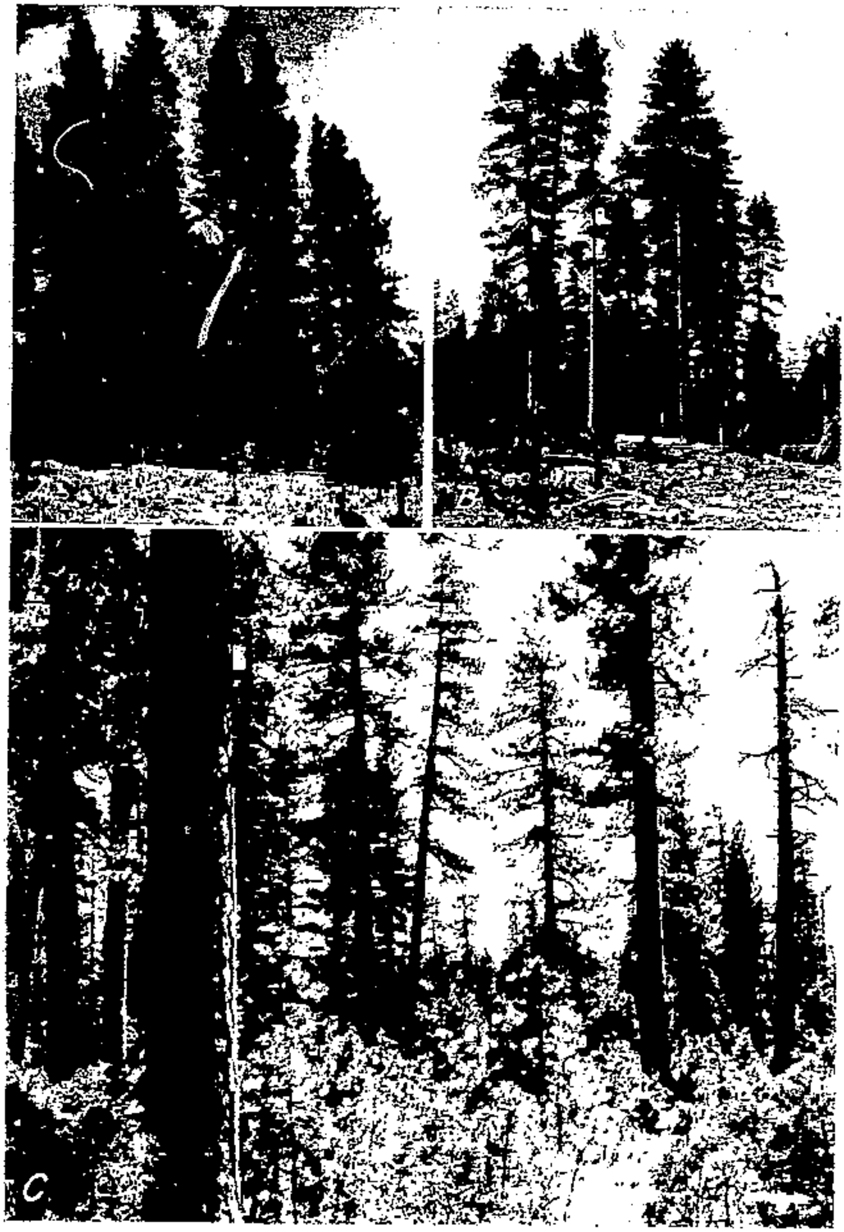

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FIGURE 8.—Age classes at Blacks Mountain Experimental Forest: *A*, Immature; *B*, mature (at edge of area clear cut for regeneration); *C*, overmature with seedling understory.

Where the overstory was removed and the border effects from adjoining older trees were reduced or eliminated, the annual ingrowth was as much as 70 board-feet per acre on clear-cut subplots adequately stocked with pole stands, compared with 37 board-feet where the overstory was cut in small groups.

TABLE 5.—*Periodic annual growth and reserve volume per acre on cut plots by age class, Blacks Mountain Experimental Forest, first 10 years after cutting*

Age class	Reserve volume	Total net growth	Ingrowth	Net growth, excluding ingrowth	
	Board-feet	*Board-feet*	*Board-feet*	*Board-feet*	*Percent*
Overmature (300 years)	18,755	92	14	78	0.42
Mature (150 to 300 years)	15,278	127	12	115	.75
Immature (less than 150 years)	[1] 7,755	202	86	116	1.50

[1] Naturally occurring immature age classes have a low volume of growing stock in comparison with overmature age classes because (a) some of them are just reaching merchantable age and (b) older residual trees have precluded full use of the ground by young ones.

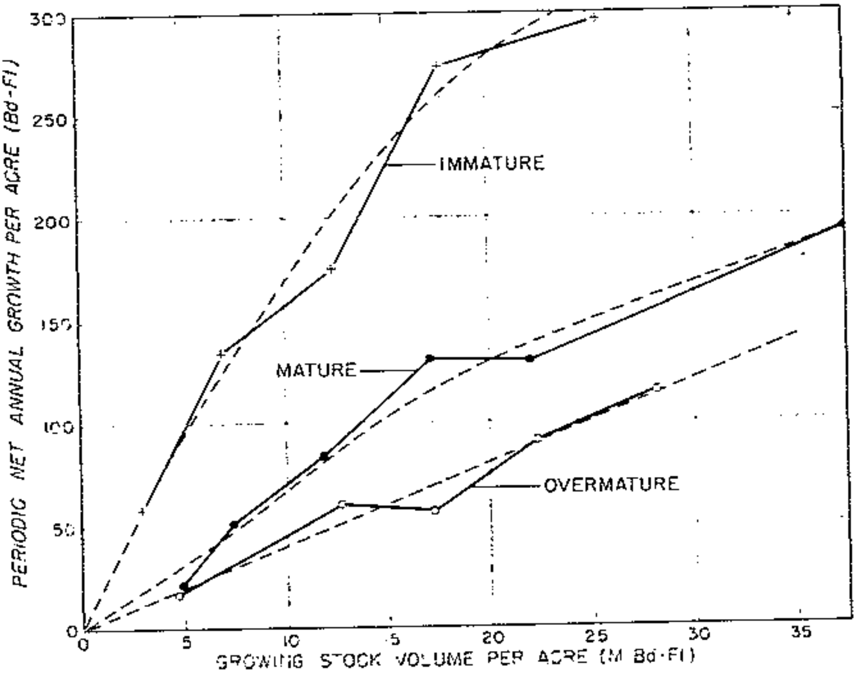

FIGURE 9.—Periodic net annual growth by age class and growing stock volumes, all species (ingrowth excluded), Blacks Mountain Experimental Forest.

Immature stands also grew faster without older scattered trees. For example, the annual net growth of immature age classes on heavily cut plots was 264 board-feet, whereas on sanitation-salvage cut plots it was 182 board-feet. Immature age classes included only 448 board-feet in trees older than 150 years on heavily cut plots, but 3,989 board-feet of older trees on the sanitation-salvage cut plots (table 6).

Maximum production per acre, then, is reached most quickly if overmature stand units are harvested and the ground given over to younger age classes or new reproduction. Yet intermediate age classes cover too little of the area to permit rapid removal of the overmature timber—for example, only 14 percent of the management unit in 1949. Consequently, the forest manager must carry part of the overmature timber as a reserve for a long time if he desires a sustained cut at a uniform rate.

Table 6.—*Annual growth of immature trees in relation to volume of older trees on plots, Blacks Mountain Experimental Forest, first 10 years after cutting immature subplots*

Volume per acre in trees over 150 years	Volume per acre in trees under 150	Net growth per acre of trees under 150 years		
		Total	Without ingrowth	
Board-feet	*Board-feet*	*Board-feet*	*Board-feet*	*Percent*
3,888 (uncut plots)	6, 834	151	99	1. 45
3,989 (sanitation-salvage cut)	5, 458	182	97	1. 78
1,808 (moderate cut)	5, 336	152	98	1. 84
448 (heavy cut)	6, 556	264	135	2. 06
46 (clear cut)	3, 063	182	88	2. 87

Which overmature group should be cut and which carried as a reserve? One important consideration is whether the group contains trees under 300 years of age. Plot records at Blacks Mountain show that on overmature subplots on the sanitation-salvage cut plots, pines under 300 years old made up only 34 percent of the total volume (all species) but produced 76 percent of the net growth (excluding ingrowth). Although the plot records probably show too high a share of the volume in younger age classes, they indicate the desirability of choosing for reserve overmature groups that have a high proportion of trees under 300 years old.

Age of overmature unit areas had little effect on growth rate when no trees under 300 years were present. This was shown by analysis of growth in relation to average volume per tree on overmature subplots. (It was recognized that average volume per tree gives only a rough approximation of relative age.) For overmature age classes as a whole, both growth percent and growth in board-feet per acre decreased as the average volume per tree increased (fig. 10). However, when only pine trees over 300 years of age were considered, the decrease in growth was very small. This analysis, too, showed the desirability of reserving overmature groups with younger trees and higher growth rates.

Overmature unit areas with the larger trees have a high priority for early harvesting for several reasons. The potential value loss is greatest in large trees; they produce more high-quality lumber and are more likely to die soon. Also, narrowing the size range of trees may help reduce the size of logging equipment in future cuts and therefore the skidding damage to reserve trees.

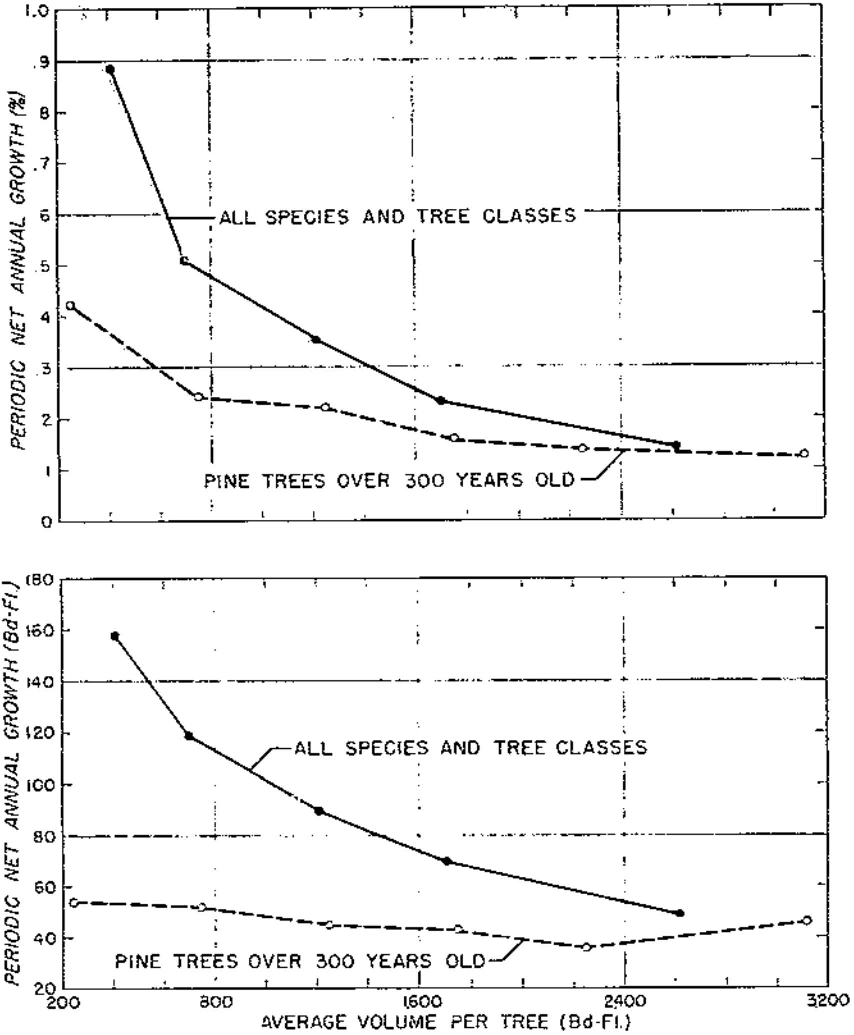

FIGURE 10.—Periodic net annual growth percent and board-foot growth by average volume per tree, overmature condition classes, 1/10-acre subplots with 10,000 board-feet per acre or more (uncut areas and ingrowth not included).

Results of the analysis of growth in relation to age classes on the harvest-cutting plots may be summarized as follows:

1. Conversion of virgin forests to young age classes is essential for rapid growth.
2. Removal of the overstory is essential for rapid growth of pole stands.
3. Growth of poles is further stimulated by removal of borders of older trees surrounding groups of poles.
4. Immature age classes (saw-log timber under 150 years of age) grow more rapidly without older residuals.
5. Heavy cutting stimulates growth of the residual trees more than light cutting.

6. Overmature stand units grow very slowly without admixtures of younger trees.

7. Average size of trees in overmature stand units has little effect on growth rate unless younger trees are present.

LOGGING COSTS

One of the important purposes of the Blacks Mountain project was to determine whether logging at a profit was possible where trees were removed in widely varying and frequently very low average volumes per acre for silvicultural reasons rather than for the greatest immediate profit at the mill. As a result, cost records have been studied closely, and special cost studies have been made. Although the Blacks Mountain studies cannot completely answer the question, they have thrown much light on it. The striking fact is that logs have been delivered to a competitive market under the prescribed silvicultural methods. The payments for logs have been sufficient to allow a reasonable stumpage value, pay all logging costs, and leave a margin for profit.

Roads

The road network was designed to permit as much flexibility as possible in timing the area and volume of cut. It was completed, except for a 2-mile spur, in 1938, providing a permanent system to meet all future needs in the main topographic unit of the experimental forest.

Roads were located to fit the topography and to keep skidding distances short, 2,000 feet or less for most compartments. They were located on the ground from map locations, with minor adjustments to avoid construction difficulties. Finally, compartment boundaries were located so as to conform with the road system and permit downhill yarding without going through adjoining compartments.

Three standards of roads, totaling 46 miles, were built (fig. 11). The main utilization or primary road extends from the county road and the common carrier railroad through the center of the experimental forest. Although many loggers thought the road system had unreasonably high standards when it was built, many private timber operators now build their roads to a much higher standard.

Because the roads were constructed by the Civilian Conservation Corps, costs were not the same as for builders employing experienced road construction workers. After the roads were built, engineers estimated that the cost with experienced road crews would have totaled $80,600.

Road costs per thousand board-feet will amount to $1.20 over the first 20 years of operation. This figure is for an estimated cut of 67 million board-feet to be hauled over the 46-mile system by 1957. (Another 2½ million board-feet logged in 1954 were taken out by way of 1¼ miles of road built that year.) The system serves 9,126 timbered acres. Consequently the cost per acre was $8.83. There is one mile of road for each 198 timbered acres, or 3.2 miles of road per section.

The network of roads constructed in advance has been an important factor in the success of the Blacks Mountain operation. It made

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FIGURE 11.—Three classes of roads at Blacks Mountain Experimental Forest: *A*, Primary; *B*, secondary; *C*, tertiary.

possible sanitation-salvage cutting as planned. Areas most in need of cutting could be cut first. When seed crops were good, cutting was shifted to other areas that needed regeneration. Other shifts were possible to adjust the species cut to market conditions and to harvest timber where insect attacks flared up unexpectedly.

Logging Methods

Since the start of cutting in 1937, the experiment station, rather than the timber purchaser, has logged the timber. The experiment station undertook logging so that the method could be tested, not to intimate that Government agencies should log as a normal procedure in disposal of Government-owned timber.

The proposed sanitation-salvage cutting raised two questions. One concerned technical soundness. Would the removal of high-risk trees by a light cutting be effective in reducing insect-caused losses? To get a reliable answer to this question, the cutting needed to be tested on a reasonably large scale.

Another was the question of whether this novel method of logging would pay. When work started, loggers in northeastern California were cutting 10 to 20 thousand board-feet per acre. They were unwilling to cut as little as 2,500 board-feet per acre because they did not believe it would return a profit. Costs and returns had to be determined by testing the method on a practical scale.

Other important reasons why the station conducted the logging were to insure that all of the details of harvesting would be performed according to the requirements of the experiments, to obtain full records of the operations—costs, manpower, and equipment, and to gain on-the-ground experience in the practical problems of timber harvesting.

From 1937 through 1941, a crew of Civilian Conservation Corps enrollees (fig. 12) logged the timber. A competent logger was hired

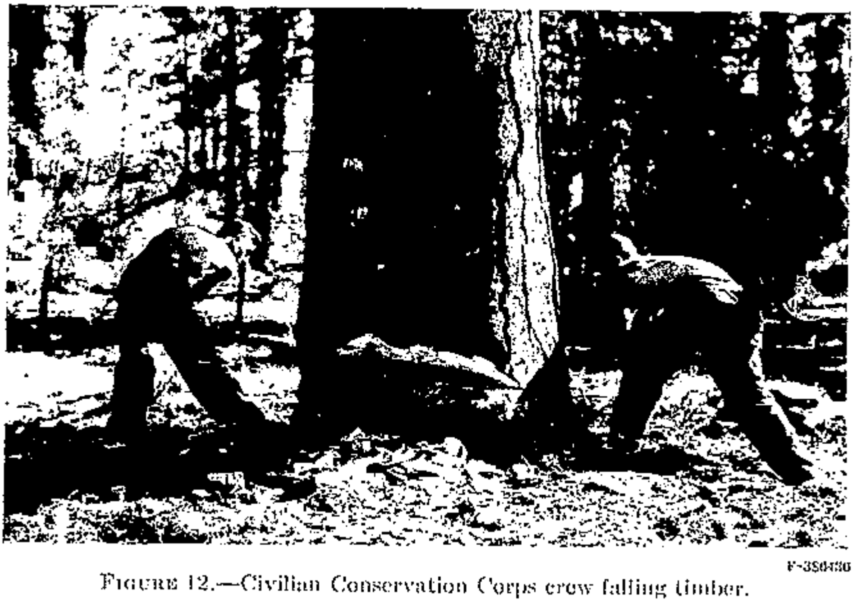

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Figure 12.—Civilian Conservation Corps crew falling timber.

as superintendent and experienced men were hired for key positions such as loaders, mechanics, and bull buck. After the CCC program ended, local loggers were hired for all logging activities.

From 1937 through 1946, the experiment station's logging activities included trucking. Since 1947, the station has loaded the logs on the purchaser's trucks at landings in the experimental forest.

Large equipment is needed to handle the timber on the forest. Trees over 50 inches in diameter are common. Trees cut on some compartments average more than 3,000 board-feet, and those commonly cut scale between 1,500 and 2,000 board-feet. Some logs scaled more than 4,000 board-feet and weighed between 18 and 20 tons.

Logs were skidded primarily with crawler tractors and arches until 1950. (The tractors weigh about 11 to 17 tons and have 80- to 130-drawbar horsepower.) But arches damage a great deal of the reserve stand and advance growth because of their width and the space they need for maneuvering. As release cuts increased, injury to advance growth became more serious. After 1949, arches were used less and less, and since 1952, practically all skidding has been done without an arch (fig. 13). In the future, an arch will be used only in the few places where an unavoidable uphill grade is too steep for ground

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Figure 13.—Skidding logs without an arch at Blacks Mountain Experimental Forest.

skidding or on relatively open areas when skidding distances are long.

A portable loader designed at the experimental forest has been one of the principal keys to the success of the logging operation. The light initial cut required frequent landing changes and threatened to increase logging costs seriously. This threat, in fact, was one of the major reasons why loggers shied away from the job. A log-loading machine that could be easily and quickly moved was a necessity. Logging Superintendent D. S. Carleton, with the assistance of other experiment station personnel, designed a portable log loader (fig. 14) and built a working model (*21*). This loader solved the problem of moving quickly and cheaply between landings.

Later, the logging industry recognized and adjusted to the need for frequent moves between landings where sanitation-salvage or other types of light cutting are desirable. Many other portable loaders have been designed, manufactured, and used throughout the West in response to this demand.

Motor-powered chain saws have replaced handtools for all cutting activities—bucking, limbing, and felling (fig. 15), and pay for timber cutting was changed from day rates to contract. Contract cutting has several advantages. More skillful fallers are obtained; labor turnover has ceased to be a problem; and an adequate supply of logs is always ready for skidding. Daily output is 40 to 50 thousand board-feet, and one set of fallers is adequate for the size of operation.

Effect of Volume and Size of Timber on Costs

In a logging cost and time analysis made in 1943, light cuts were found to be entirely practicable in the eastside pine type if a road system had been built (*22*). A sanitation-salvage cut of 2,835 board-feet per acre required a total of 118.97 man-minutes per thousand board-feet, whereas heavy selection cutting, with a cut of 13,022 feet per acre, required nearly as much time—118.29 man-minutes per thousand (table 7). The success of sanitation-salvage logging during the first 6 years of the operation demonstrated the feasibility of light cuts. Sanitation-salvage logging on three compartments in 1952 again demonstrated the practicability of light cuts. The average daily production from these three compartments was the same as from much more heavily cut compartments logged that year. The conclusion is that volume cut per acre had little effect on direct logging costs.

Size of tree or log was the more important factor. Usually, time per unit decreased when size increased. This relation has been found elsewhere under widely differing conditions (*14*, *15*, *32*). Actually, the increased cost for small logs results from a reduction in daily output rather than from the increased logging time per log, and the increased cost may not be as great as time studies indicate.

Many operations are geared to a fixed number of truck trips per day because of hauling distance. If the number of small logs is not too great, a skillful loader can distribute them so that the daily production is reduced little, if any, by handling them. When a load approaches maximum size one or more small logs can readily be loaded, but a medium-sized one cannot. Usually the yarding crews have enough slack time so that the daily quota can be brought to the

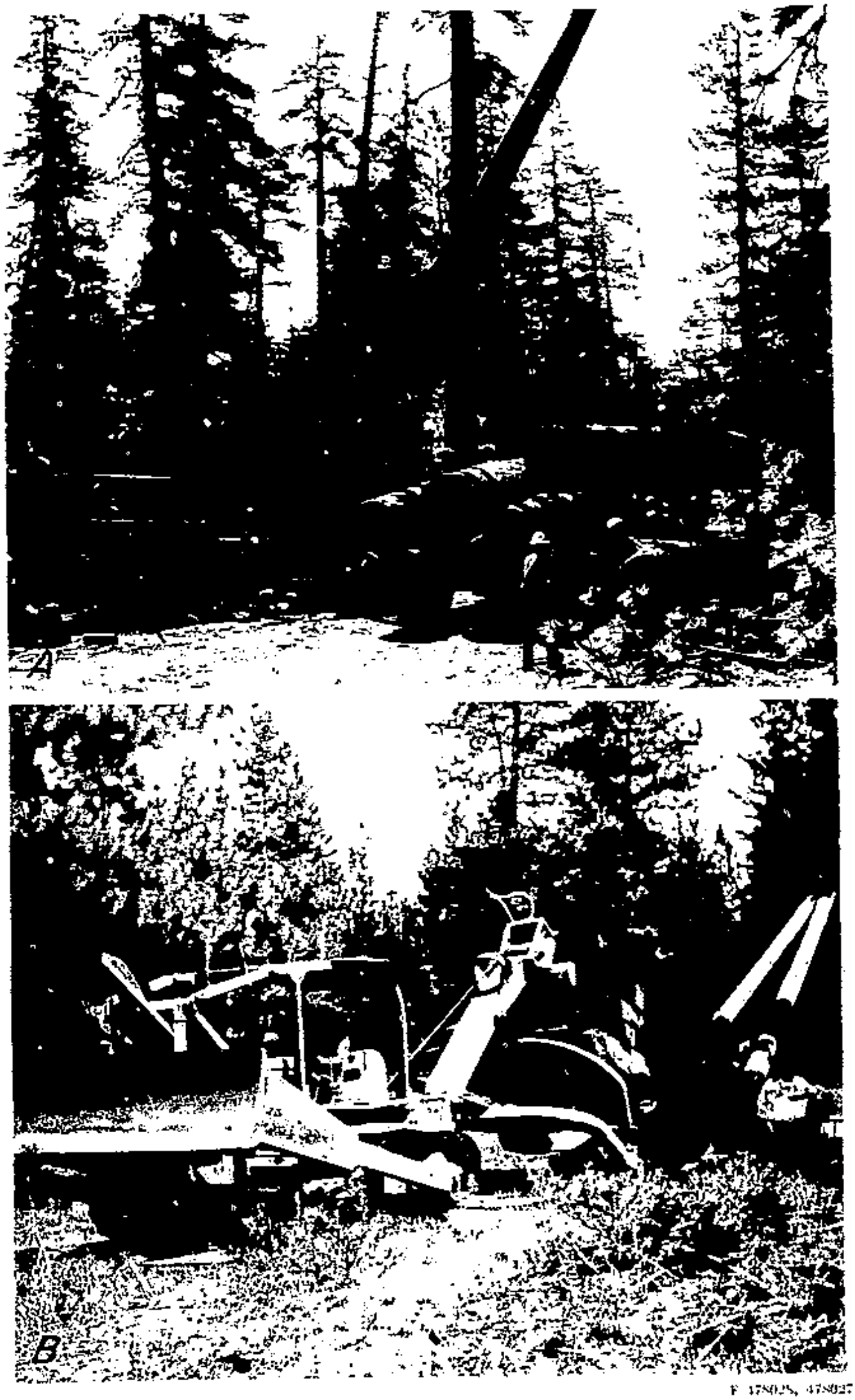

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FIGURE 11.—Blacks Mountain portable log loader: *A*, Loading logs; *B*, being moved with tractor and arch.

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FIGURE 15.—Falling timber with power saw at Blacks Mountain Experimental Forest.

landing even if a good many of the logs are small. Thus, logging of small logs may be economically justified. The economic removal of small logs is important to the forest manager because the cutting of small trees is frequently essential to accomplish silvicultural objectives.

Total Operating Cost

Costs of the Blacks Mountain operation, excluding camp costs, rose from $7.96 to $11.32 between 1947 and 1952 (table 8). Production per man-day, however, was fairly uniform—about 4 thousand board-feet in 3 of 4 years (table 9). Prices of labor, supplies, and equipment generally increased during the period, but yearly variations in cost were also affected by operational changes.

In 1947 trees were felled with power saws but bucked and limbed by hand. In 1950 timber cutters used only power saws. This change accounted for most of the increased production per man-day in 1950. Changing payment for cutting from a day rate to a contract rate in 1951 resulted in increased production per man-day. In 1952 annual cut was reduced according to plan. Even though production per man-day was slightly higher than in 1950, charges per thousand board-feet for overhead and camp operation were the chief factors in the increased cost.

TABLE 7.—*Logging time and volume cut under different marking systems, 51¼ acres, Blacks Mountain Experimental forest*

TIME PER THOUSAND BOARD-FEET

Item	Marking system			
	Clear cut	Heavy selection [1]	Moderate selection	Sanitation salvage
	Man-minutes	*Man-minutes*	*Man-minutes*	*Man-minutes*
Falling	35. 23	30. 98	29. 60	30. 79
Limbing	17. 62	15. 49	14. 80	15. 40
Bucking	32. 77	28. 93	27. 68	28. 76
Yarding	20. 40	18. 80	18. 24	20. 06
Loading: [2]				
Truck	12. 96	11. 67	11. 23	11. 61
Railroad	13. 98	12. 42	11. 89	12. 35
Total	132. 96	118. 29	113. 44	118. 97

VOLUME

Item	Clear cut	Heavy selection [1]	Moderate selection	Sanitation salvage
	Board-feet	*Board-feet*	*Board-feet*	*Board-feet*
Cut per acre	17, 315	13, 022	9, 174	2, 835
Cut per tree	957	1, 332	1, 513	1, 350

[1] Representative of marking on Forest Service timber sales before 1938.

[2] Assumes logs and trucks or railroad cars continuously available at the landing.

Source: (*22*, p. 559)

TABLE 8.—*Logging costs per thousand board-feet, Blacks Mountain Experimental Forest, 1947 and 1950–52* [1]

Item	1947	1950	1951	1952
	Dollars	*Dollars*	*Dollars*	*Dollars*
Fall, limb, and buck	2. 707	2. 669	2. 677	3. 119
Yarding	2. 083	2. 398	2. 398	1. 962
Loading	1. 168	1. 352	1. 500	1. 446
Overhead	1. 383	1. 121	1. 536	2. 730
Rigging	. 044	. 030	. 060	. 068
Transportation (crew, etc.)	. 349	. 420	. 495	. 466
Logging supplies	. 224	. 395	. 336	. 247
Miscellaneous		. 026	. 044	1. 280
Total	7. 958	8. 411	9. 046	11. 318
Camp cost	. 976	2. 326	1. 694	2. 654
Grand total	8. 934	10. 737	10. 740	13. 972

[1] Data compiled by D. T. Gordon.

TABLE 9.—*Log production, net scale, Blacks Mountain Experimental Forest, 1947 and 1950–52* [1]

Item	1947	1950	1951	1952
	Thousand board-feet	*Thousand board-feet*	*Thousand board-feet*	*Thousand board-feet*
Production per man-day [2]	2.961	3.964	4.422	3.968
Cut per acre	3.930	4.407	9.010	5.574
Daily output	50.842	54.423	60.179	40.539
Seasonal output	4,675.82	5,442.33	5,175.37	2,878.28

[1] Data compiled by D. T. Gordon.

[2] Equipment maintenance and camp activities not included.

Application of unit area control was not responsible for the upward trend of costs at Blacks Mountain. Each year the Forest Service collects cost data from representative logging operations for use in stumpage appraisals. Including the same items, costs per thousand board-feet at Blacks Mountain and on representative operations in the California Region were as follows:

Year:	*Blacks Mountain*	*Regional average*
1947	$8.94	$9.77
1950	10.74	11.62
1951	10.74	12.68
1952	13.97	13.62

The two sets of figures show a similar trend. Admittedly, costs at Blacks Mountain are not wholly comparable to those of private operators. Freedom from direct tax charges gives the experiment station an advantage. Yet several disadvantages probably more than offset the advantage. The station works under special restrictions on hiring, procurement, and accumulating reserves to cover reverses. Because of its isolation, the experimental forest must operate a logging camp; many private operators no longer find a camp necessary. All in all, the cost records are reasonably comparable. They show that a timber property can be managed by advanced silvicultural methods at about the same cost as by other methods of timber harvesting.

APPLICATION OF UNIT AREA CONTROL

Application of unit area control involves, as does any system of management, (1) the objectives of the landowner, (2) the silvical requirements of the principal tree species, (3) condition of the forest, and (4) the treatments required to integrate the first three items. Foresters must critically review these four points for each property or working circle in order to adapt unit area control to them.

Objectives of Management

Lumber and plywood are the principal and more valuable end products of ponderosa-Jeffrey pine timber. Hence, the production of saw logs and veneer bolts is a primary objective. For maximum returns large high-grade logs are essential. The pine trees now being harvested in the eastside pine commonly vary in diameter from 30 to 50 inches. Because of the length of time required to grow trees to these sizes, forest managers undoubtedly will be satisfied with much smaller trees in the future. On the medium sites (site index 70), 20 to 24 inches is probably a reasonable objective for future final harvest.

There is good evidence that this objective is realistic. In natural mixed stands the average diameter of dominants is about 21 inches at 140 years of age for site index 70 (site 112, fig. 16). On methods-of-

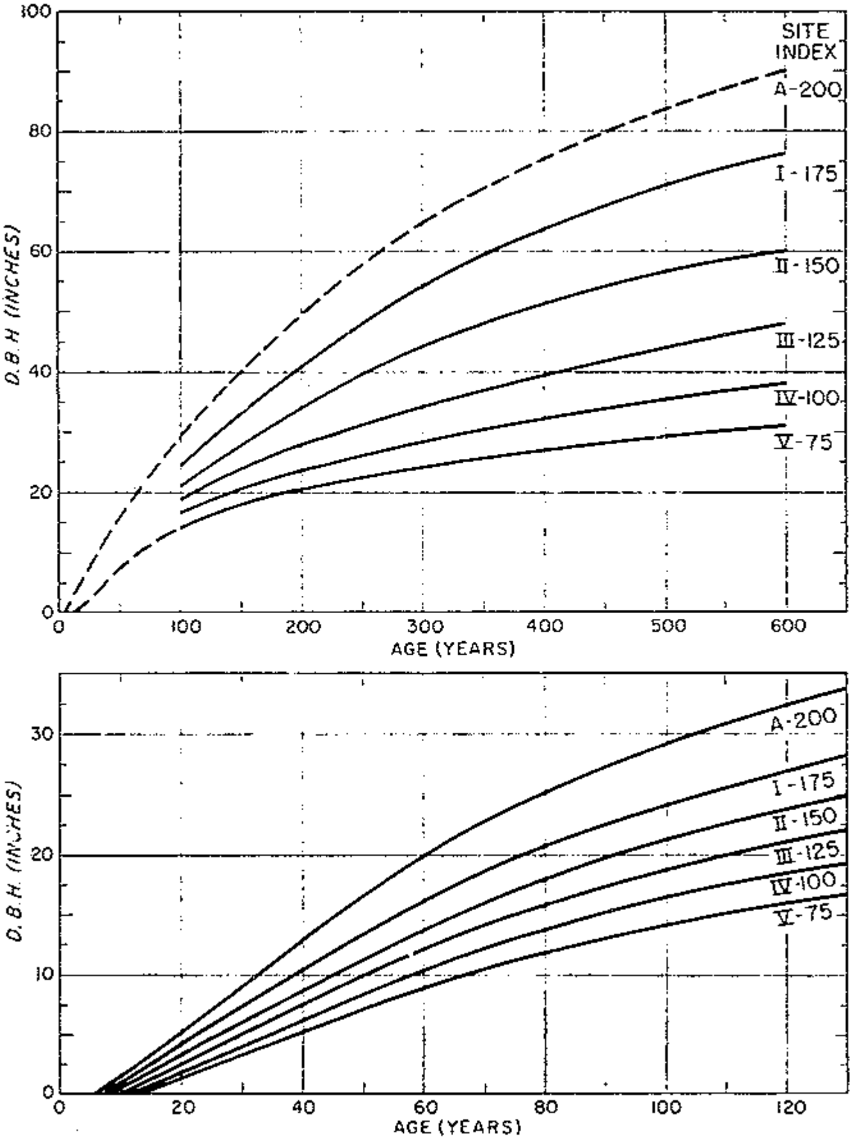

FIGURE 16.—Diameter of average dominant, ponderosa pine, sugar pine, and white fir in mixed stands, by site index. Source: Dunning (*9*).

cutting plots at Blacks Mountain, dominant trees under 150 years old grew at the average rate of 0.8 inch each 5 years. Allowing 10 years for seedlings to reach breast height, they would attain 20.8 inches at 140 years. Other studies with young trees indicate that by proper selection of crop trees and moderately intensive stand management, growth rates greater than 0.9 inch per 5 years may be expected. Thus careful stand management can produce crop trees averaging as much as 24 inches at 140 years.

At the higher elevations and on north slopes in the eastside pine type, white fir is a common associate of the pines, and the forest manager may have to decide on the desired species. In such locations white fir grows as fast or faster than pine and its relative value is increasing. But in this type white fir is subject to heavier periodic losses from insects and disease than is pine. Even though conversion to pine would seem desirable, such practice is not recommended unless the fir now growing can be harvested as Christmas trees, logs, or other salable products. Pine regeneration is costly and not always successful.

To make his management program effective, the forest manager must decide upon acceptable minimum levels of stocking. During early cutting periods, he will have to set up standards for new regeneration and advance growth. Acceptable stocking for immature and mature units can be decided later because harvest of these units will be deferred while the overmature units are being converted to young fast-growing stands.

The main purpose of stocking standards for young stands is to determine whether fill-in planting will be required. Because poles would compete strongly with seedlings, fill-in planting in pole stands is not practical unless the stocking is so low that openings are present. At Blacks Mountain, for example, two crop trees per square chain are rated as the minimum acceptable stocking of poles.

The number of seedlings per acre required to produce adequate stocking at older ages is subject to considerable speculation. The large number of young trees that yield tables quote for so-called normal stands is certainly much greater than needed. One set of ponderosa pine yield tables, for example, shows 3,000 trees per acre at 20 years for site index 70 (*23*). These tables also show 490 trees and an average diameter of 8.3 inches at 80 years for site index 70. The first intermediate harvest in the future probably will occur when the average diameter is about 8 inches. Judging from early survival in plantations, a stand of 500 trees at an average diameter of 8 inches would result from planting 1,000 trees per acre. Therefore, 1,000 trees per acre is a reasonable standard.

Although this is a reasonable standard, it should not be confused with minimum acceptable stocking as a guide to fill-in planting. Such plantings on small areas are costly, and the moderate to low growth rates over much of the eastside pine type are not likely to return the cost. Because of this, acceptable stocking must be low. On the experimental forest 25-percent stocking, or 250 trees per acre, of seedlings and saplings has been set as the acceptable minimum. Furthermore, minimum stocking must be related to size of opening. Ground in relatively small openings is utilized by border trees. The smallest opening that is planted or otherwise regenerated is one-fifth acre, but regardless of size the opening must be at least 1 chain wide.

However, areas up to one-half acre in size ordinarily are considered to have acceptable stocking if the central fourth of the opening meets the minimum standard.

Finally, if a continuous, reasonably regular harvest of certain products is desired, the forest manager must keep in mind the need for a regulated forest. This objective is easily overlooked, for good silviculture does not automatically insure both sustained yield and regular production. The means to these ends is conversion of the unmanaged forest to one in which each age class is present through rotation or harvesting age on equal areas but not necessarily uniformly distributed.

Some Silvical Requirements of Ponderosa and Jeffrey Pine That Affect Management

Ponderosa and Jeffrey pine have been widely recognized as intolerant (*1, p. 67*). The significance of this characteristic as it affects management has not been recognized until recent years. Intolerant species are generally best suited to even-age management. Illustrations of the desirability of even-age management of these pines can readily be found. Seedlings and saplings only a few feet tall but 40 or more years old are common under an overmature overstory. The rapid increase in height growth of seedlings and saplings after the overstory has been removed can be seen on most heavily cut areas. Then too, ponderosa and Jeffrey pine commonly grow in even-aged groups. When the group occurs as an understory, growth is extremely slow. On cutting plots at Blacks Mountain, ingrowth from pole stands without an overstory was nearly twice that with an overstory.

Other important silvical characteristics that affect management of these pines are as follows:

1. Seedlings and saplings stagnate and grow very slowly when they occur in overdense thickets. The development of vigorous dominants is slow and irregular. Thinning is necessary to promote early development of vigorous potential crop trees. The release given by removal of an overstory and the incidental thinning resulting from logging usually increase growth substantially. For maximum growth, however, overdense thickets should be thinned.
2. Ponderosa and Jeffrey pines shed their branches very slowly. If production of clear lumber is desired in rotations commonly planned, artificial pruning is necessary.
3. These species are long lived. In virgin forests, trees older than 400 years are common. They die as individuals or small groups. Consequently, young age classes commonly occur in small groups.
4. Good cone crops occur at irregular and relatively infrequent intervals. In most years regeneration can be obtained only by artificial means.
5. Pine seeds are preferred food of several indigenous rodents. Thus, if natural regeneration is to be successful, the rodent population must be reduced to a low level before seed fall. Rodent depredations still prevent successful large-scale establishment of regeneration by direct seeding.
6. Pine seeds germinate best on bare mineral soil. If seedlings start free of competition, they grow rapidly and are usually able to

keep ahead of subsequently established fir, brush, or other competition. Intensive site preparation is necessary for successful establishment of both natural and artificial regeneration.

Condition of the Stand

The mosaic pattern of ponderosa-Jeffrey pine forests gives rise to stand conditions that have a highly important effect on management (fig. 17). The units in this pattern of even-aged groups of trees—homogeneous in stocking and species composition—have been called condition classes by Dunning. The first step in management is to identify the condition classes on the property.

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FIGURE 17.—Pattern of age classes in east-side pine type—mature at left, seedlings in foreground, and large poles in background. Overmature overstory has been harvested.

Classifying the forest into its parts serves several purposes:

1. To subdivide the forest or working circle into natural units sufficiently small and homogeneous for practical, uniform treatments such as harvest cutting, regeneration, and stand improvement.
2. To determine which unit areas have stands adequate to carry as growing stock and which should be harvested to release advance growth or to free ground for new regeneration.
3. To provide the basis for a cutting plan, cutting budgets, allowable cut, and other steps in a management plan that is most likely to accomplish stand regulation in the conversion period.

The attributes present in the various stand units must, of necessity, form the basis for a condition classification. The attributes and their classification may not necessarily be the same in all regions and types.

At Blacks Mountain a system recognizing five basic criteria has proved successful (appendix, p. 74). The criteria are age, species composition, degree of stocking, presence or absence of seed trees, and presence or absence of competing vegetation. Dominant trees are used as indicators in condition classification. They make up more than 90 percent of the board-foot volumes but only about 40 percent of the stand in numbers of trees; therefore their use as indicators simplifies the work.

For other forest properties, some changes may be appropriate. No matter what factors are used, though, an inventory of the forest by condition classes is an essential step in management. Recognition of the homogeneous units does much to clarify silvicultural methods and objectives. It provides an orderly system for regulation of the cut. It is of great assistance in making logging plans.

It is possible to start application of unit area control without prior inventories and maps if a simple plan outlining objectives for harvesting is made. This can be used by the timber marker as a guide in deciding what to cut now and what to cut later. However, some form of inventory by age classes will soon be required to accomplish stand regulation. Maps showing age classes are not essential.

The conventional methods of obtaining inventory data by sampling can be used to obtain adequate estimates. Volumes may be estimated by means of sample plots. Areas can be estimated by the line transect method. If large-scale aerial photos are available, condition class may be mapped on the photographs and acreages determined either on a sampling basis or for the entire area.

Before starting the inventory, the forest manager should prepare a brief outline of how the inventory data are to be used. This will insure that no essential data are omitted and avoid the extra work of collecting and analyzing unneeded data. Usually several condition classes can be combined for volume estimates and summaries. Estimates of volume for the different overstory age classes and species combinations usually are adequate. However, a more detailed classification is necessary for area estimates. It is desirable to have acreage estimates of all the age classes that are to be used in planning for regulation.

At Blacks Mountain, volume summaries by three overstory age classes (overmature, mature, and immature) and one additional class (scattered trees over advance growth) were adequate. Area estimates were needed for the three overstory age classes and also for four other conditions: (1) seedlings and saplings, (2) small poles, (3) large poles, and (4) unstocked areas each with and without an overmature overstory.

Treatments and Procedures

SANITATION-SALVAGE CUT

Reducing insect-caused losses is the first step in converting a virgin ponderosa-Jeffrey pine forest to a managed state. The first cut should come from the 15 percent or so of the volume made up of high-risk trees *(27)*—risk groups III and IV. Because sanitation-salvage cutting is most effective when the management unit is covered rapidly, it may be desirable to step up the allowable cut during the first cutting period. On the cutting plots at Blacks Mountain, for example, the average 2,547 board-feet per acre of high-risk trees can be cut in 11 years under an allowable annual cut of 237 board-feet (see p. 57) per acre. The remaining overmature timber can be harvested in 60 years at the same rate. A 50-percent increase in allowable cut for the first period would complete the risk cutting in 7 years. Whether this practice is desirable depends largely on the capacity of established mills and the effect of later reductions on the local economy.

Where there are few high-risk trees on a unit area, sanitation-salvage sometimes may be deferred until the second cutting period. On extensive areas with few high-risk trees, sanitation-salvage may be omitted and final harvest may be started with the first cut. Where high-risk trees are many, it may be desirable to harvest all overmature trees so that younger trees can be pruned or the area regenerated without hindrance from scattered old trees.

HARVESTING SUBSEQUENT TO THE SANITATION-SALVAGE CUT

After the property has had a sanitation-salvage cut, other steps in the conversion from wild to managed forest should follow. This means that each unit area of a specific condition class is given the appropriate treatment at the proper time. It is as vital for the forester to apply all essential treatments as for a farmer to plow, seed, cultivate, weed, and spray to grow a crop.

Many combinations of criteria are possible for classifying condition classes, but when the classes are grouped for initial treatment, the number is not formidable. Condition classes can be grouped into (1) overmature overstory with advance growth as an understory; (2) overmature overstory without advance growth; (3) mature and immature overstory suitable to carry as a reserve; and (4) occasional scattered older trees with seedling, sapling, or pole understory. The advance growth may be subdivided into two categories for treatment after the overstory has been removed: (1) seedlings and saplings in which cleanings and thinnings are possible, and (2) pole stands in which pruning and thinning can be conducted.

Overmature unit areas ready for harvest and having adequate advance growth are clear cut to release the understory. In pole understories, cutting is followed by pruning of selected crop trees, and thinning if markets for pole-size timber permit economic thinnings. In seedlings and saplings, overdense thickets are thinned if economical methods are available.

Overmature unit areas ready for harvest but with inadequate advance growth are clear cut for regeneration (fig. 18). If the harvest comes in a good seed year, seed trees suitable for reserve are left around the perimeter of the unit area. Enough border trees should be left to provide 800 to 1,000 cones per acre. Then the rodent population must be reduced to a low level. Slash and competing vegetation are removed, piled, and burned; this treatment exposes a bare mineral soil for a seedbed. If natural regeneration fails, the unit area should be planted at once before brush and other vegetation become reestablished. If an adequate seed source is not available because of too few seed trees or lack of a seed crop, rodent control should be omitted and the area planted the following spring.

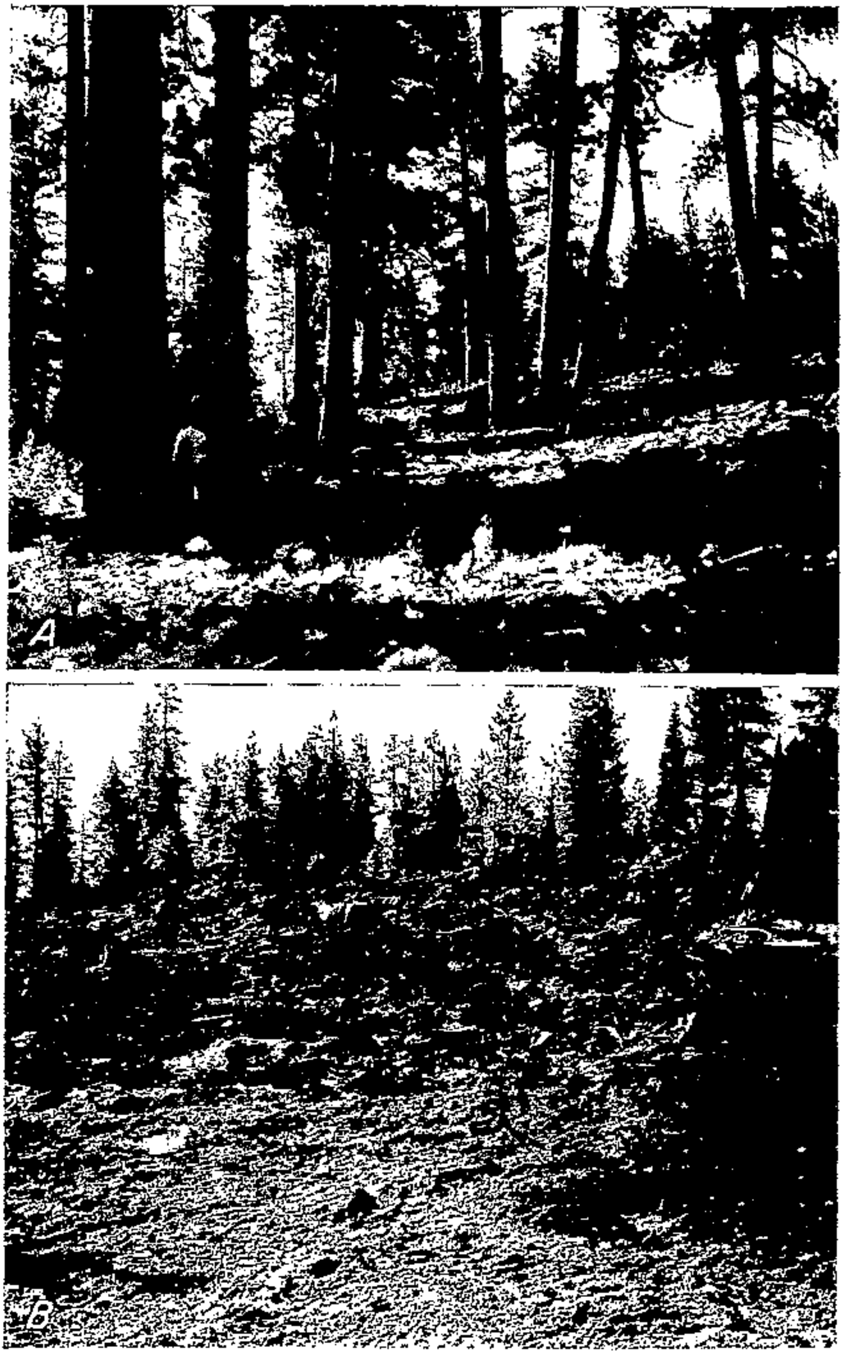

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FIGURE 18.—Cutting for artificial regeneration. *A*, Marking overmature unit area for cutting. *B*, Same area after logging, site preparation, and slash disposal in 1953. The area was planted in 1954.

Mature or immature condition classes that are to be carried as a reserve receive improvement cuts. This treatment removes the occasional wolf tree, scattered older trees, malformed or defective trees, and high-risk trees. If the property has a large volume of timber in overmature condition classes to be harvested, improvement cuts should be held to a minimum. A sharp distinction exists between final harvest cutting and intermediate harvesting in the form of improvement cuts. Even though even-aged management is the objective, improvement cuts must of necessity be made by individual tree selection.

Occasionally, poorly stocked mature and immature stand units may be harvested to prevent leaving a few isolated merchantable trees. Or by combining such groups with adjoining overmature units, more desirable-sized regeneration areas can be made.

Unit areas of seedlings, saplings, and poles without a complete overstory usually contain scattered merchantable trees. Some are thrifty young trees; others are very old decadent ones. Many of the thrifty young trees can be expected to put on enough growth to compensate for their retarding effect on the younger stand. They should be left until the first improvement cut in the younger stand. Other scattered trees should be harvested to release the young trees and to confine logging damage to as young an age as possible. If a good vigorous tree is destined to be destroyed in logging, the next best tree can take its place more effectively at a young age than later when growth has slowed.

Selection of Areas for Harvesting

Until the overmature timber has been harvested, final harvest of younger age classes should be deferred. On most areas in which cutting has been under way for a short time, overmature timber must be carried for a long time if a continuous cut is planned. On the management unit of the experimental forest, 80 years will be required (including previous cutting) to harvest the overmature unit areas. Obviously, if short cutting periods are used, an appreciable amount of overmature timber must be carried as a reserve. To maintain the planned cutting pattern, overmature timber should be reserved by deferring the final harvest on certain unit areas, rather than by leaving individual overmature trees scattered over the property.

Three considerations govern the selection of overmature unit areas to be carried as a reserve. First, young stands grow much faster than old stands. Second, growth of overmature stand units changes very little as the average size of tree changes except when there are admixtures of younger trees. Third, the growth rate of advance reproduction increases much faster when advance growth is released in substantial blocks rather than in small scattered patches.

For these reasons, it is proposed to harvest all overmature units in blocks of 5 to 50 acres or occasionally larger. Unit areas are seldom more than a few acres in size. Commonly, however, several adjoining units may have an overmature overstory yet be recognized as distinct units because they have different kinds of understory. These overmature units, but not mature and immature ones within the block, will be clear cut. The maximum size of continuous clearcuts, then, will depend on the proportion of mature and immature units within the block.

In adjacent blocks of similar size the overmature units will not be clear cut, but will be carried as reserve. Here a light cut would be made, removing only high-risk trees and an occasional tree cut for stand improvement. In exceptional cases an occasional extremely decadent overmature unit area might be harvested within the reserve block.

Overmature unit areas with a high priority for early harvest are those with—

1. Advance growth of the age most in need of release.
2. A high proportion of high-risk trees.
3. A high proportion of white fir.
4. Relatively large sized trees.

Blocks of timber most suitable for light cutting often are those that contain many unit areas of mature and immature age classes usually not cut until later cutting periods. These younger units reduce the acreage on which all of the overstory can be harvested. Also, overmature unit areas with appreciable admixtures of younger trees should ordinarily have a high priority for deferment of final harvest. If artificial regeneration must be delayed for administrative or financial reasons, overmature unit areas that would require planting can logically be added to areas on which the final harvest is to be deferred.

The acreage devoted to each type of cut can be determined from knowledge of the volume to be harvested. The sanitation-salvage cutting plots at Blacks Mountain are used in the following example. The average volume per acre for all except mature and immature unit areas was 15,954 board-feet immediately after the sanitation-salvage cut. The net growth (excluding ingrowth) of this timber for 10 years, or half the cutting period, is 612 board-feet. A complete harvest, then, would average 15,954 + 612, or 16.566 board-feet per acre. The light cuts would include mainly high-risk trees.

On sanitation-salvage compartments 1,110 board-feet per acre of high-risk trees developed 16 to 17 years after logging (*13*). Areas to receive a light cut should have a good deal less than the average volume of high-risk trees because most units with many high-risk trees probably would be selected for a complete harvest. Therefore, it is reasonable to assume that the cut on the reserve areas would be about 1,000 board-feet per acre. Under an annual allowable cut of 237 board-feet per acre (see p. 57) and 20-year cutting periods, the total cut per acre would be 4.740 board-feet.

The relative area in each type of cut is computed as follows:

X=percent of area on which complete harvest is made

$$16{,}566\,\frac{X}{100}+\left(\frac{1-X}{100}\right)1{,}000=4{,}740$$

$$X=24$$

Thus, a complete harvest of all the overstory can be made on 24 percent of the area cut in any one year. This example assumes that a uniform cut will be maintained while the overmature timber is harvested. When a larger annual cut is desirable in early cutting periods than in later ones, the area devoted to a heavy cut would of course need to be adjusted.

The size of the completely harvested blocks must be a compromise of what is ideal for logging, administration, and silviculture. Loggers frequently will want the blocks of such a size that both heavy and light cuts are tributary to each landing. This distribution simplifies the task of maintaining uniform daily production. And if short skidding distances are desired, the heavily cut blocks ought to be small. For ease of administration and efficiency of planting-site preparation, regeneration, and timber stand improvement, the ideal size would be large.

Silviculturally, the size of the blocks on which all overmature unit areas are harvested would depend entirely on stand conditions. If natural regeneration is planned for a particular unit area, adjoining unit areas must be left as a seed source. Areas clear cut for natural regeneration should not be larger than 6 or 7 acres. Sometimes, the age classes are so distributed that large continuous areas on which all the overstory is harvested are not possible. The experience at Blacks Mountain is that blocks having a continuous complete harvesting will vary in size from a few acres to about 50.

Cutting Control

Marking rules and guides alone will not always adequately control the cut with a pattern of heavy cut alternating with light cut. Control can be obtained by allotting specific volumes to specific areas. In order to allow flexibility in marking to fit stand conditions, either the specific volume of cut should be allotted to a large area or a specified percentage deviation in volume cut should be allowed. However, the sum of the volume cut on all areas should not exceed the limitations established for the annual cut. Sometimes the marker may need to go over an area, or parts of it, twice to mark the desired volume and make the best selection of unit areas for harvesting.

When timber is to be sold on the stump, areas in the appraisal sample should be divided into three categories: (1) areas of heavy cut; (2) areas of light cut; (3) areas that may be cut either way. The trees in the third category should be tallied separately according to method of cutting. When the data are analyzed, adjustments can be made in the third category in order to achieve the desired cut. Usually the final selection of areas for heavy cutting will be made at the time of marking although large-scale aerial photographs may permit selecting areas for heavy and light cuts before the appraisal survey. In this advance mapping, areas that may be cut either way should be indicated so that adjustments to reach the planned cut can be made in the appraisal analysis.

Unit area control allows a great deal of flexibility in planning and conducting the timber harvest because unit areas can be harvested at once or during a later cutting cycle. Safe storage on the stump of overmature timber is possible because sanitation-salvage cutting has proved effective in preventing excessive insect-caused losses in ponderosa and Jeffrey pine eastside stands.

Prevention of Logging Damage

Prevention of logging damage to the reserve stand and advance growth is a vital part of forest management whenever release or improvement cuts are made. Because of the prevalence of advance growth in the ponderosa-Jeffrey pine type saving, it is an especially critical problem.

Logs are skidded primarily with crawler tractors with or without arches. Arches damage much of the reserve stand and advance growth because of the width and space they need for maneuvering. Bunching logs with a skid cat and then hauling them to the landing with a cat and an arch is not always satisfactory because a large area is needed for logs and maneuvering at each bunching point. Logging damage can be kept to acceptable levels when skidding without arches.

Three essentials in preventing logging damage are the preparation of a logging plan, carrying out the plan, and training and supervision of the crew. Logging plans can and should be simple and informal. The forester and logging foreman should work the plan out together and have the details thoroughly in mind before logging starts. The plan for each compartment or logging unit should include a large-scale sketch map showing landings, skid roads, trees to be cut, and areas to be regenerated. Tree locations and areas to be regenerated can best be mapped when the timber is marked. Experienced 2-man crews consistently mark 300,000 board-feet per day and do the related mapping.

On areas previously logged, tractor roads can be mapped either on the ground during marking or in advance from aerial photos. Before timber is felled, the forester and the logging foreman select the tractor roads, flag them on the ground, and mark them on the map. Tractor roads through advance growth obviously will be kept to a minimum. The foreman decides the sequence of logging by compartments and within each compartment so that felling will progress in an orderly manner.

Keeping felling, bucking, and limbing well ahead of skidding is very important in carrying out the plan. If timber is not felled in the desired sequence, the logging plan may have to be changed. Then extra skid roads are usually needed to keep logging on schedule. Unnecessary damage to advance growth invariably results from the extra skid roads.

Fallers and choker setters both should use the logging plan maps. The maps will help them find the marked trees and plan the order of cutting or skidding. It is essential that they use only the planned skid roads and prevent needless damage to advance growth. When logging is started at a new landing, it is desirable that the skid roads be opened at once to the far end of the logging area. Long hauls can then be balanced with short ones to keep truck loading on schedule without deviation from the original plan. Fallers should cut the trees with a favorable angle for skidding to tractor roads whenever possible to minimize damage to advance growth.

Training and supervision of the yarding crew are highly important steps in holding logging damage to a minimum. The two can be combined and continued through the season to prevent the loggers from acquiring careless habits or adopting undesirable practices that may contribute to logging damage.

TIMBER STAND IMPROVEMENT

The forester must tend his stand from establishment to final harvest if he wishes to obtain maximum high-quality yield. Pruning and thinning are the principal stand-improvement measures. Ponderosa and Jeffrey pine shed their lower limbs too slowly in the eastside pine type to produce much clear lumber in 140- to 160-year rotations. In comparatively short rotations, branches must be removed artificially if clear lumber or veneers are desired. Also, slow-growing overdense seedling, sapling, and pole stands are common in the type. Thinning of these stands is essential for maximum board-foot growth rates.

Pruning and thinning for selected crop trees is recommended. Pruning all trees in the stand is not desirable because only a small fraction of the trees in young stands live until rotation age. Thinning of the complete stand is usually undesirable because of the high cost and slow growth rates. However when crop trees are selected for early intermediate as well as final harvest, thinning may remove all but the crop trees.

Crop trees may be harvested in either the final or intermediate harvests. They can be selected before the harvest for pruning or release by thinning. Those selected for the final harvest may be pruned and released. On sites commonly prevailing in the eastside pine type, crop trees for intermediate harvests may be released but should not be pruned.

Pruning

Crop trees that are to be pruned must contain enough extra clear wood when harvested to pay the initial pruning costs and carrying charges on this investment. Therefore the pruned crop tree must (1) live until the final harvest, (2) grow rapidly, (3) be of such form and condition that it is capable of growing an adequate amount of sound clear wood,[6] and (4) be subject to pruning at a reasonable cost.

To satisfy the first two requirements, crop trees should be vigorous dominants or vigorous codominants that have been made dominant by release. Also, the overstory should be removed. If it is not removed, growth will be retarded and the crop trees may be damaged or destroyed in later logging. At Blacks Mountain no trees are pruned within 30 feet of mature or overmature trees nor under the lean of a mature or overmature tree. To qualify as crop trees, they must be capable of growing three-fourths inch in diameter per 5 years (13 rings per inch) or faster for the remainder of the rotation, and at least 0.4 of the total height of the tree must remain in crown after pruning. A pruning study showed that up to half of the live crown could be removed without seriously reducing the growth rate if at least 0.4 of the total tree height remained in live crown *(20)*.

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[6] The following defects disqualify trees for pruning: Crook; rot; large scars; bayonet tops; mistletoe in trunk, on branches above pruning, or within 1 foot of the trunk in branches that would be removed in pruning.

The number of crop trees also affects growth rate. Trees require more growing space as they become larger. Obviously, the maximum number selected should be the number that the ground can be expected to support at the final harvest. An ideal stand structure will have 30 to 50 dominant trees per acre at a rotation age of 140 years. In order to allow for stand and site variation, mortality, and errors in selection, 70 crop trees per acre appear to be a reasonable maximum number for pruning. The maximum number of crop trees applies to the net stocked area.

The amount of clear wood that must be grown is subject to speculation. On the experimental forest at least 12 inches of diameter growth is considered essential on pruned trees. This provides for 6 inches of radial growth: 1 inch to cover knot scars; 1 inch for taper in a 16-foot log; and 4 inches of clear wood. Taper sawing or sawing boards shorter than 16 feet will increase the effective widths of this collar of clear wood.

An upper size or age limit for pruned trees must be established to allow enough time to grow the clear wood. This limit will depend on the time when the present age classes will be harvested and may change with future utilization standards. Final harvesting is planned in present immature age classes in about 70 years. The present average growth rate of immature dominants would amount to less than 12 inches in 70 years. Consequently, pruning is not done in any group of trees if the dominants average more than 12 inches (fig. 19).

To keep pruning costs reasonable and to permit rapid healing, trees with branches larger than 2½ inches in diameter should not be pruned. On the experimental forest, trees with many branches larger than 1½ inches in diameter are rarely pruned unless they are fast-growing isolated trees.

Pruning work should start when the trees are small so that it can be done in stages. Since the basic harvesting length for saw or peeler logs is 4 feet, the tree can be pruned in multiples of 4. Stump height and trim allowance must be included; thus, if four basic units are desired the total height pruned should be 18½ feet.

Thinning

Because crop trees released by thinning can be cut in an intermediate harvest, requirements for their selection are not as exacting as for crop trees to be pruned. Crop trees for the final harvest are the first choice for release and should meet the requirements for those to be pruned. Crop trees that are to be removed in an intermediate harvest should (1) have a good straight terminal leader, (2) be relatively straight and perpendicular, and (3) be reasonably vigorous. Differentiation of crown classes in seedling and sapling stands is not as pronounced as in older stands; consequently uniform spacing can be emphasized. Forked trees, bayonet-topped trees, and badly barked or bent trees will usually be removed in thinning operations.

Thinning in pole size (4- to 12-inch d. b. h.) or larger timber is not recommended unless a salable product can be harvested. The number of trees to select will hinge on utilization standards. At present, 8 inches d. b. h. seems to be the smallest size from which future sizable intermediate harvest might be obtained. Stand density curves

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FIGURE 19.—Pruning selected crop trees at Blacks Mountain Experimental Forest.

for mixed stands indicate 290 dominant trees and a total of 660 trees per acre when the dominants average 8 inches d. b. h. (fig. 20). In a fully stocked stand with 8-inch dominants, then, 250 to 300 crop trees is a reasonable number to leave for intermediate and final harvest.

Overdense seedling and sapling stands usually contain more trees than can be carried to the first intermediate harvest. Furthermore, stagnation is more common in seedling and sapling stands than in pole stands. They should only be thinned, however, when thinning can be done at a reasonable cost. Several new power-driven chain or circular saws appear suitable. In brief preliminary tests, one chain saw has shown promise for economical thinning of saplings from 1 inch to 4 inches in diameter at stump level (fig. 21).

Spacing may control the number of seedlings and saplings to select in a thinning operation. At the present time a 9-foot average spacing is being tested at Blacks Mountain, and it has resulted in fastest

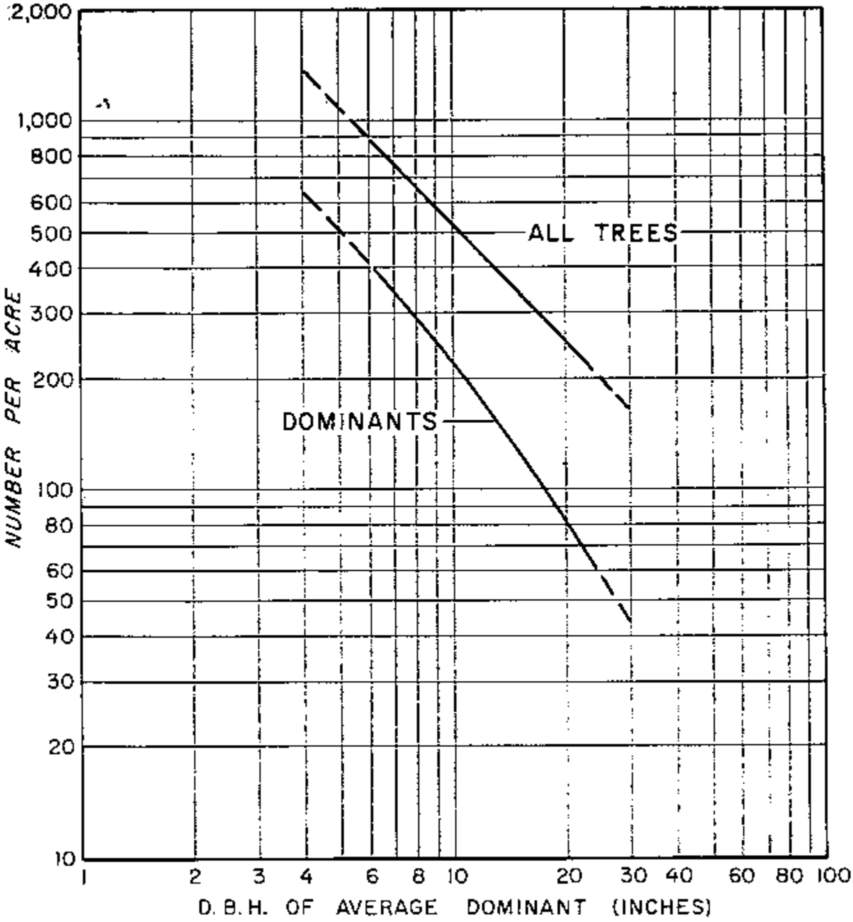

FIGURE 20.—Number of dominants and all trees per acre, by d. b. h. of average dominant, mixed stands. Compiled by Duncan Dunning.

growth for 3-inch trees. If the power-driven chain saw proves to be economical, overdense seedling and sapling stands will be thinned extensively. The intention is to continue thinning to an approximate spacing of 9 feet—a maximum of about 500 trees per acre. Only stands that have no overstory will be thinned.

REGULATION OF THE CUT

Regulation of the cut is essential if a continuous forestry enterprise is desired. An even distribution of age classes is necessary to maintain a sustained annual cut reasonably uniform in amount and kind of product. Obviously, however, in the transition from a preponderantly overmature ponderosa-Jeffrey pine virgin forest to a managed forest, the size and quality of the product harvested will change.

Three common characteristics of the eastside pine type affect regulation significantly: (1) the mosaic pattern of small even-aged groups, (2) the excess of overmature age classes and deficit of inter-

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FIGURE 21.—Thinning overdense sapling thickets at Blacks Mountain Experimental Forest: *A*, Operation of chain saw; *B*, sapling thicket after thinning.

mediate classes, and (3) the generally high share of the ground covered with advance growth of seedlings, saplings, and poles with or without an overstory.

Since even-aged management of ponderosa-Jeffrey pine stands is proposed, methods of regulation that will provide and maintain a uniform distribution of age classes in even-aged units should be used.

The deficit of intermediate age classes forces managers to store overmature timber on the stump for long periods of time. This is the only way to bridge the gap between the harvesting of overmature timber and the harvesting of what is now advance growth. The procedure can be overworked. Some old timber may be lost, and attainment of ultimate growth goals delayed by postponing the time when the ground is controlled by young fast-growing stands. Yet the effectiveness of sanitation-salvage cutting in reducing insect-caused losses makes on-the-stump storage reasonably safe.

The large amount of advance growth postpones the time when regularity of age classes and improvement in size of stand units can be accomplished. The age-class pattern of stands below rotation age is largely set until the advance growth is harvested and the stands regenerated. Cutting can improve the overall distribution of age classes, however, by reducing the excess volume in the old age classes and releasing young age classes. The kind of distribution desired is one in which the trees are of the size expected at the given age rather than merely being the actual age of the indicated class. This size-age relationship is important in ponderosa pine stands because advance growth commonly remains stagnant until the overstory is removed.

The irregular, complex age-class pattern of the eastside pine type can be brought into an orderly arrangement by using a combination of area and volume regulation. The seedlings, saplings, and poles can be allotted to cutting periods in the later years of the rotation on an area basis. The periods to which they are assigned depends, of course, on the time the oldest of the advance growth will reach rotation age. The immature and mature age classes can be allotted on an area basis to the cutting period or periods just before harvesting of the advance growth begins. The overmature timber can then be allotted on a volume basis to the remaining years in the first part of the rotation.

Rotation

Length of the rotation selected is dependent on a number of factors; most of them are related to future events and hence can only be estimated—for example, stumpage prices or costs. Therefore, lengthy calculations for determining rotation age are of questionable value. One thing is fairly certain: because site quality is usually medium, the rotation will be relatively long.

The kind of product the manager is to produce, and the minimum acceptable levels of return on capital invested, are the underlying factors controlling determination of the rotation. Obviously the rotation must be long enough to permit trees to grow to sufficient size so that the desired products can be produced. The products must also be produced at a profit.

Studies in many areas have shown that both logging and milling costs, as well as yield, vary with size of trees harvested. Ordinarily there is an optimum size for maximum profit margin. This cost-size relationship is not constant for all types of equipment. Maximum efficiency of operation occurs when the range in log sizes handled is not too great. Equipment and machinery used 100 years from now in all probability will be vastly different from that used now, because of changes in average size of the timber handled and because of technological development. Consequently, it is not likely that any accurate estimates of cost and value in relation to tree size can be made for periods as long as a rotation in the future. However, experience and logical reasoning point to somewhat shortened rotations.

The culmination of mean annual growth as determined from normal yield tables indicates the desirable rotation for maximum volume production. Mean annual growth varies only slightly for many years on either side of the age of culmination. For example, in the interregional ponderosa pine yield table (*23*) for site index 70, the mean annual board-foot growth for the stand 6.6 inches and over in d. b. h. varies only 3 board-feet for ages 120 to 160 years. Consequently there is considerable latitude in selecting a rotation without materially changing the mean annual yield.

Investment factors in the ponderosa pine type indicate the desirability of a rotation shorter than for culmination of mean annual yield. As the rotation is lengthened, the capital investment rises. For example, for site index 70, nearly 30 percent more growing stock is needed for a 160-year rotation than for a 140-year rotation. Carrying charges for regeneration and timber stand improvement also favor shorter rotations. But increasing unit values as trees become larger indicates a rotation longer than for maximum volume production. Therefore culmination of mean annual uield is a reasonable compromise if trees at rotation age are of a size that can be efficiently harvested and converted into the desired product.

As a guide to rotation age in the ponderosa pine type, yield table data for the stand 6.6 inches d. b. h. and larger, or for the stand 11.6 inches d. b. h. and larger, can be used. Within 50 years, utilization standards very likely will equal or surpass those used in the table for the stand 6.6 inches and larger. Mean annual growth in this size of stand culminates at 135 years. Therefore, the rotation selected for the experimental forest is 140 years.

The average size of dominant trees at 140 years for site index 70 will be 21 to 24 inches, according to growth data from the experimental forest and other areas in the ponderosa pine type. Trees much smaller than this are efficiently logged and sawn into lumber in other parts of the country. For example, in a mill study of second-growth Douglas-fir in Washington, 49 percent of the logs were 10 inches or less in diameter and 6 percent were 7 inches or less (*31*). It is not unreasonable to assume that small logs also will be efficiently logged and milled in northeastern California.

Cutting Periods

When even-aged management is applied by small areas the term cutting cycle may be confusing because it commonly refers to the interval between tree selection cuts. Cutting period is a more appropriate term. As used here, cutting period refers to the interval between cuts in a general area such as a compartment or other management subdivision. Only for the part of the stand in which intermediate harvest cuts are being made does cutting period indicate the interval between cuts on a specific spot of ground or stand unit.

The length of cutting period for even-aged management by small groups is dependent on the desirable interval between intermediate harvest cuts on the reserved unit areas and on efficiency of operations. Sometimes the optimum size of unit areas may also have a bearing. Short periods are desirable to keep losses at a minimum and to maintain an adequate growth rate. However, running a profitable enterprise requires that efficiency of operations be considered first.

Logging efficiency is affected primarily by the average cut per acre. At Blacks Mountain and elsewhere in the eastside pine type cuts as low as 2,500 to 3,000 feet per acre can be made efficiently. Although lighter cuts have been made, they cost appreciably more and were justifiable only for special purposes such as salvage or insect control. It has been estimated from the interregional yield table that the average annual yield from a stand 12 inches and larger on site index 72 (average for the experimental forest) will be 144 board-feet per acre. With a 20-year cutting period the average cut per acre will be 2,880 board-feet. From the standpoint of logging efficiency, therefore, 20 years is satisfactory.

Efficiency of administration, marking, and regeneration activities may be more important than logging efficiency. The length of cutting period determines the area in the regulated forest that will be cut each year. The working circle must be divided into as many parts (each part not necessarily a solid block) as there are years in the cutting period. All of the part assigned to a particular year must be considered for final harvest and regeneration, intermediate harvest, or stand improvement.

The shorter the cutting period the greater is the gross area cut. Consequently, more area must be covered in marking for cutting and in carrying on regeneration and timber stand improvement activities. For example, if a 140-year rotation and 20-year cutting periods are used for a 10,000-acre regulated forest, one-seventh (140/20) of 500 acres (10,000/20) would be regenerated each year. If 10-year periods are used, one-fourteenth of 1,000 acres would be regenerated. The same area would be regenerated in both cases but spread over twice as great a gross area when the shorter period is used. A 20-year cutting period promises greater efficiency than a shorter one in administration and in carrying out the various essential forestry activities.

Is 20 years too long silviculturally? Probably not. Sanitation-salvage cutting has reduced insect losses for 15 years and is likely to be effective for a longer period. In view of this, 20 years is not too long an interval between cuts to keep losses at an acceptable level. Thinning in the ponderosa-Jeffrey pine type must be moderate to heavy to produce substantial increases in diameter growth rate. The increase is not likely to justify cutting at intervals shorter than 20 years.

Twenty years has been selected as the planned future cutting period for the experimental forest. In the past the period varied between compartments and was much shorter than 20 years. The first period was short because of the desire to cover the area rapidly with a sanitation-salvage cut. Some compartments were cut as many as three times in 20 years. At the present stage of development of unit area control, however, it appears that a 20-year cutting period after the sanitation-salvage cut would have been more appropriate.

Ideal Stand Structure

A forest with ideal stand structure will contain each age class through rotation age as small groups in equal areas. On each compartment or area to be cut over once in each cutting period, the number of age classes will equal the rotation divided by the length of the cutting period. For example, where 20-year cutting periods and a 140-year rotation are planned, at any given time, ideal stand structure on a compartment would consist of equal areas of 7 age classes. However, equal areas of all age classes on each compartment is neither practical nor necessary.

Although conventional yield tables do not give a true picture of the number and size of trees in a managed stand, they do give a reasonably good approximation of the volume per acre that might be expected on fully stocked managed stands at given ages. From these, the volume to be expected in an ideal stand structure can be approximated.

The volume just before final harvest can be computed by summing the yield table volumes for each age class and dividing by the number of age classes. The volume just after cutting is obtained by using the same divisor, but the last age class is omitted from the summation. Stocking probably will average no more than 80 percent of yield table stocking on large areas; consequently, normal yield table volumes should be reduced by 20 percent for the computation. The average volume at any given time for the entire working circle is the mean of the volumes before and after cutting.

Ideal stand volumes and mean annual growth have been computed from the interregional ponderosa pine yield tables for site indexes 60 feet, 70 feet, 80 feet, and the average of 72 feet for Blacks Mountain (table 10). For early cutting periods, data for the stand 11.6 inches and larger can serve forest managers as a guide to cutting. For later periods, when utilization of small trees for saw logs will be possible, the values for the stand 6.6 inches and larger will provide a better guide. It is estimated that ultimately intermediate harvests will remove timber equal to half the volume of the final harvest. But they will salvage mortality and stimulate growth. The net effect of such intermediate harvests will be to reduce the average volume per acre at a given time by about 10 percent.

TABLE 10.—*Volume and growth per acre of ponderosa pine stand with ideal structure, 140- and 160-year rotation*[1]

140-YEAR ROTATION

Item	Stand 11.6 inches d. b. h. and over (Scribner rule) at site index—				Stand 6.6 inches d. b. h. and over (Internatl. rule, ⅛-inch kerf) at site Index—			
	60	70	80	72	60	70	80	72
	Bd.-ft.	*Bd.-ft.*	*Bd.-ft.*	*Bd.-ft.*	*Bd.-ft.*	*Bd.-ft.*	*Bd.-ft.*	*Bd.-ft.*
Before final harvest of oldest age class	4,607	7,440	10,891	8,130	8,229	12,194	17,189	13,193
After final harvest of oldest age class	2,789	4,731	7,291	5,243	5,440	8,480	12,331	9,250
Average	3,743	6,086	9,091	6,687	6,834	10,337	14,760	11,222
Yield at final harvest of oldest age class	13,360	18,960	25,200	20,208	19,520	26,000	34,000	27,600
Mean annual growth	95	135	180	144	139	186	243	197

160-YEAR ROTATION

Item	60	70	80	72	60	70	80	72
Before final harvest of oldest age class	6,120	9,260	13,120	10,032	10,030	14,330	19,730	15,410
After final harvest of oldest age class	4,110	6,510	9,530	7,114	7,200	10,670	15,040	11,544
Average	5,115	7,885	11,325	8,573	8,615	12,500	17,385	13,477
Yield at final harvest of oldest age class	16,080	22,000	28,720	23,344	22,640	29,290	37,520	30,928
Mean annual growth	101	138	180	146	142	183	234	193

[1] Computed from ponderosa pine yield table (23). 80 percent of yield table values.

Dominants in natural stands will average 21 inches at 140 years on the average site at Blacks Mountain. If 90 percent of the volume is in dominant trees, the volume would be 18,187 board-feet per acre (0.9×20,208—yield at final harvest as computed from table 10). For the average site at Blacks Mountain, 21-inch trees have a volume of 368 board-feet. Therefore, 49 dominants per acre can be expected in natural stands at 140 years if the average diameter is 21 inches. Under moderately intensive management, however, dominants with an average diameter of 24 inches may be expected at 140 years. Twenty-four-inch trees average 588 board-feet, and the number of dominants per acre at 140 years would be 31 trees. Forest managers, then, can expect between 31 and 49 dominants per acre in the final harvest at 140 years under ideal stand structure.

The ideal area of units in this stand depends primarily on border effects, effective seeding distances, and administrative efficiency.

The degree and distance that borders of older trees reduce growth rate are not known. If border effects are appreciable for 22 feet, growth will be reduced on 56 percent of the total area for a 2- by 2-chain square (0.4 acres), 21 percent for a 6- by 6-chain square (3.6 acres), and 16 percent for an 8- by 8-chain square (6.4 acres). Hence, border effects may not be serious on areas larger than 3.5 acres.

In an early study of conifer seed fall, ponderosa pine seed fell 5 feet per second in still air (*28*). In falling 100 feet, seed could be carried about 290 feet by a 10-mile-per-hour wind. But at Blacks Mountain regeneration was poor in the central part of areas wider than 300 or 400 feet except when bumper seed crops occurred. If unit areas average twice as long as wide, 7 acres might be the maximum desirable size if natural seed fall from border trees is to be relied on. More precise knowledge is needed on the maximum size of areas that can be effectively seeded from the borders.

The maximum size of unit area for efficient administration, cultural activities, and logging can only be determined by experience with different sized units. At the experimental forest, units of less than one-half acre seriously increase planting costs unless several units are concentrated in a small block. All in all, the ideal size of unit areas is considered to be from 4 to 7 acres. In natural stands the units are usually smaller, frequently as little as one-fourth acre. They can be enlarged to more desirable size when the present advance growth is harvested and a new stand regenerated. This should be done at the same time major changes are made in the age-class distribution.

How and when can regularity of age-class distribution be achieved? Data for the sanitation-salvage plots at Blacks Mountain illustrate how this can be determined. The area occupied by present age classes must first be estimated and compared with the distribution for a regulated stand (fig. 22). To show the regulation pattern clearly, an estimate is also needed of the area in each age class at the time the final harvest may be started in the present advance growth. For the Blacks Mountain plots, a chart showing age-class distribution at the beginning of the sixth cutting period, just before the final harvest in the large pole class, was prepared (fig. 23).

Seedlings and saplings were considered to have a present average age of 20 years rather than their actual age. Future age of seedlings and saplings was discounted three-fourths for unreleased periods, and future age of poles was discounted one-half for unreleased periods. On the basis of experience at Blacks Mountain, it was also assumed that all unstocked areas and half of the area inadequately stocked with seedlings and saplings would be regenerated at the time the overmature overstory was harvested.

The equal areas at rotation age needed for a fully regulated stand can be attained late in the second rotation. At the beginning of the sixth cutting period of the first rotation, the age-class distribution will be near the desired one (fig. 23). For nearly six more cutting periods, however, the final harvest will be in age classes that are 5 to 25 years above rotation age. This condition is quite desirable. It permits much greater flexibility in working out a cutting pattern aimed at attaining a regular distribution of age classes. And it permits an increase in the size of the smaller unit areas by consolidation at the time of final harvest and regeneration. An age greater than rotation

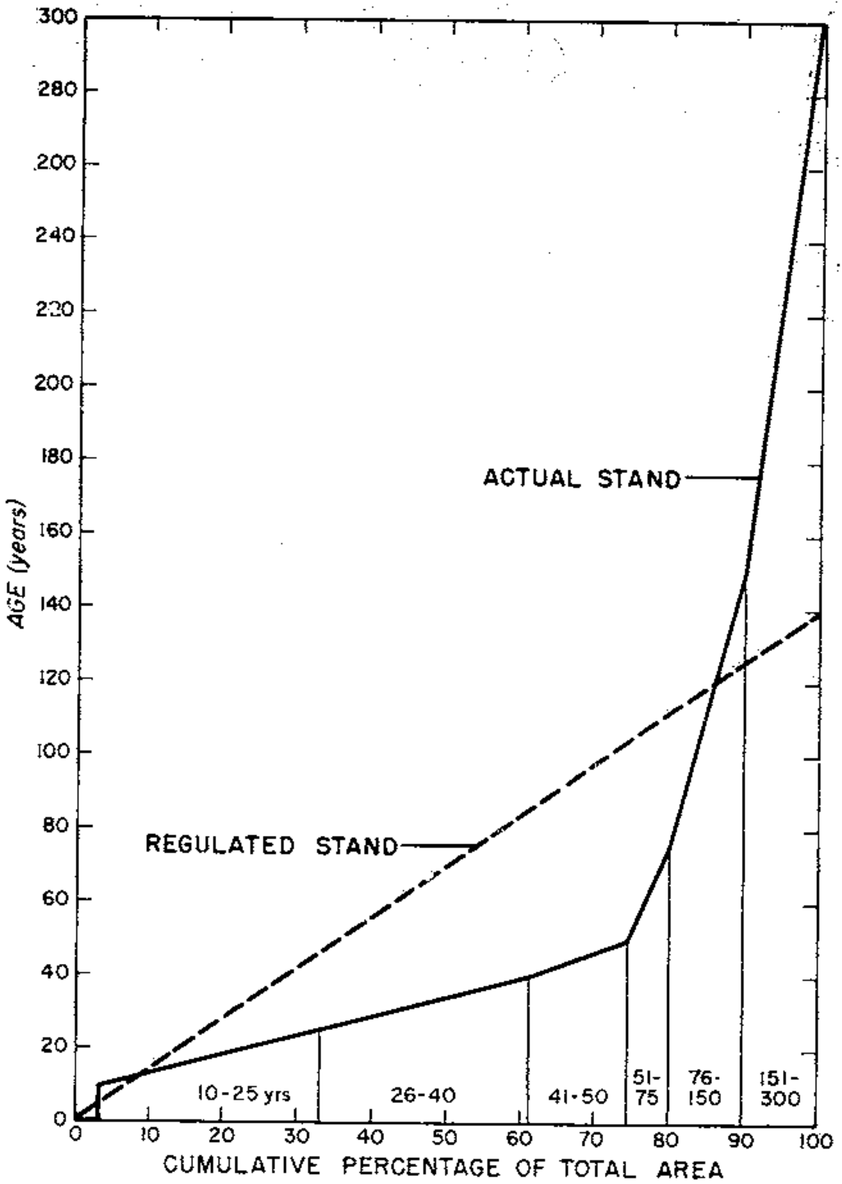

FIGURE 22.—Age class distribution at time of completion of sanitation-salvage cut. Blacks Mountain cutting plots, overmature overstory excluded.

age also compensates for a moderate degree of understocking at time of harvest.

Why should ideal stand structure and regularity of age class be considered if few positive steps can be taken to achieve these objectives in the immediate future? There are at least three good reasons. One reason is that harvesting of advance growth may be deferred and the cut of overmature timber spread over a longer period if a sufficient area of proper age classes is not available for a sustained cut at the time the oldest advance growth reaches rotation age. Secondly, early consideration of stand structure helps set up priorities for the age of advance growth to be released. Finally, such consideration will prevent planning immediate cuts that sacrifice growth in order to obtain regularity of age classes when such regularity cannot be obtained in the immediate future.

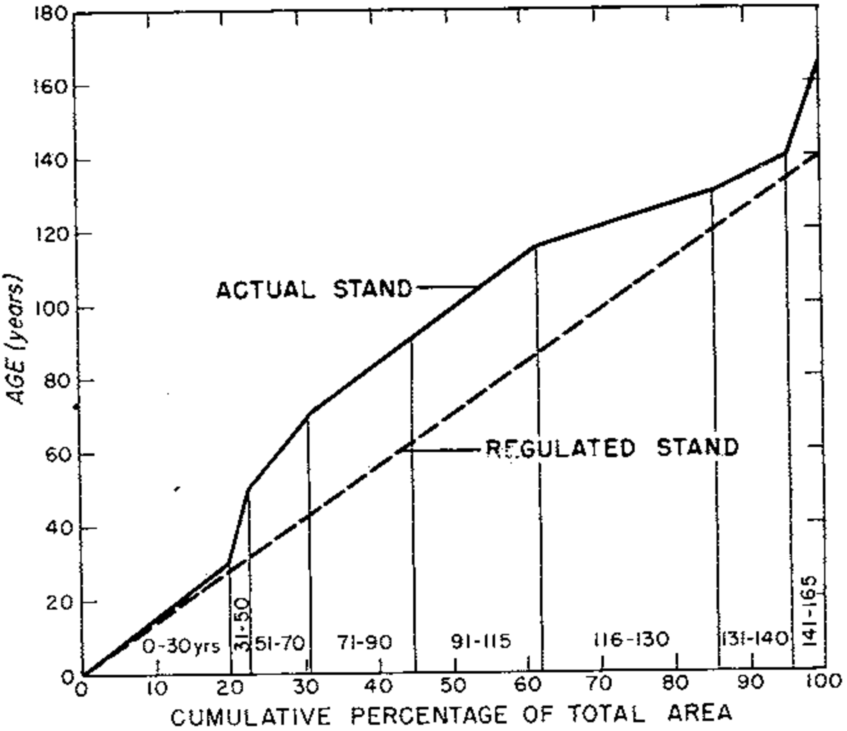

FIGURE 23.—Expected age-class distribution at beginning of sixth cutting period. Blacks Mountain sanitation-salvage plots.

Computation of Allowable Cut

An allowable cut must be computed and made a part of current plans if future harvests are to materialize. Although plans must look long into the future, the lack of precise long-term growth estimates should not create difficulties. As the plans are revised, moderate errors can be adjusted.

Under even-aged management of ponderosa pine, regulation can be achieved by allocating young age classes to the later cutting periods of the rotation and prorating the remaining merchantable volume to the remaining years in the first part of the rotation. Data from the sanitation-salvage plots illustrate a simple method of computing allowable cut. (Computations for a typical tract are shown in the management plan for the experimental forest, p. 80.) Stands were classified by broad age classes. To expedite calculations of allowable cut, average age for each class was estimated from diameter and age curves.

	Estimated ages	
	Average (years)	Range (years)
Seedlings and saplings	20	10–25
Small poles	30	26–40
Large poles	50	41–75
Immature	120	76–150
Mature	225	151–300

Basic assumptions for the sample computation are (1) a 140-year rotation, (2) 20-year cutting periods for the second and succeeding ones (except for a 30-year fifth period), and (3) a complete sanitation-salvage cutting made in the first period of 10 years. Ultimately there will be 7 age classes in 20-year steps on any area that is to be cut once every 20 years. The average large poles, being 50 years old, will reach rotation age in 90 years, at the beginning of the sixth cutting period (3×20+30).

Starting at this time, the age-class distribution will be such that 14.3 percent, or one-seventh, of the area can be harvested at rotation age or greater (fig. 23) and regenerated in each cutting period. Thus, an even distribution of seven age classes can be achieved by area allotment.

But can the desired volume be harvested? Although pole, sapling, and seedling stands of ponderosa pine commonly occur in overdense thickets, their average stocking for large areas is usually much less than 80 percent of normal yield table stocking. Understocked stands increase in stocking with time, but data are lacking that show how fast the stocking changes. Such data are needed in establishing minimum stocking standards and estimating long-term growth. Gehrhardt's formula offers a possible solution. It has been used successfully in the Lake States to compute growth of understocked stands *(7, p. 72)* and seems reasonable for application to ponderosa pine.

When Gehrhardt's formula was applied to board-foot yield table volumes for the stand 6.6 inches and larger, ponderosa pine stands 30-percent stocked at 30 years had a computed stocking of 78 percent at 140 years. But where reasonable care has been used in logging to prevent damage to advance growth, considerably better stocking than 30 percent prevails. The average stocking, based on number of trees, of advance growth is approximately 50 percent. Therefore it is logical to expect that after 90 or more years of management stocking will be close to 80 percent of yield table values and provide the volume needed for final harvests.

When more is known about the effect of time on changes in stocking, the allowable cut can be adjusted to prevent undesirable drastic changes in the future cut. Future adjustments probably will be upward. Consequently, present advance growth is allotted on an area basis to the last two cutting periods of the first rotation and the early cutting periods of the second rotation.

The next problem is to allot the present merchantable volume. Mature and immature age classes occupy 20.2 percent of the total area on the sanitation-salvage cut plots. This area closely approximates the area that should be cut and regenerated in 1⅓ cutting periods. Hence, mature and immature age classes are tentatively allocated to the 30-year period before the 6th cutting cycle—60 to 90 years in the future. These age classes could be harvested in one long 30-year cutting period, or 2 short 15-year periods. The overmature stands and scattered overstory trees plus their estimated growth are prorated over the first 60 years in the rotation. Because mature and immature timber will be harvested and regenerated, ingrowth is included in calculating the cut from these age classes. Ingrowth is not included in calculating the cut for the first 60 years because it is more appropriately a part of the age class released and, consequently, harvested when the advance growth is harvested.

Data for calculations of the allowable cut are summarized in table 11. Data from the sanitation-salvage cutting plots were used for estimating the growth for the present merchantable timber. Growth

TABLE 11.—*Data for computation of allowable cut, sanitation-salvage cutting plots, Blacks Mountain Experimental Forest, site index 70*

Condition class group	Volume per acre	Area [1]	Annual net growth	Average period for growth	Total growth	Ingrowth per acre per year
	Board-feet	*Percent*	*Percent*	*Years*	*Percent*	*Board-feet*
Overmature	21, 661	50. 9	0. 39	30	11. 7	.....
Scattered overstory trees	5, 925	28. 8	. 34	30	10. 2	.....
Mature	22, 086	9. 5	. 65	75	48. 8	13
Immature	9, 447	10. 7	1. 25	75	93. 8	49

Condition class group	Typical acre				
	Original volume	Total growth	Total ingrowth	Growth on ingrowth [2]	Total volume
	Board-feet	*Board-feet*	*Board-feet*	*Board-feet*	*Board-feet*
Overmature	11, 025	1, 290	--	--	12, 315
Scattered overstory trees	1, 706	174	--	--	1, 880
Total	12, 731	1, 464	--		14, 195
Mature	2, 098	1, 024	93	46	3, 261
Immature	1, 011	948	393	225	2, 577
Total	3, 109	1, 972	486	271	5, 838

[1] 0.1 percent nontimbered.

[2] Computation of growth on ingrowth.

Growth percent per year: mature, 1.54; immature, 1. 76

$$\text{Period} = \frac{75-10}{2} = 32.5 \text{ years.}$$

percents computed from the plot records for a 10-year period were applied to the original volume to determine growth for the entire period of prediction. This procedure, rather than compounding by 10-year intervals, was followed because growth rates decline with age. The ingrowth used for the immature age class was the average of the ingrowth for the immature and mature age classes $\frac{(85+13=49)}{2}$ because the present immature age classes will move into the mature age class about 30 to 60 years before they are harvested.

Based on table 11, allowable cut for an area similar to the sanitation-salvage cutting plots is as follows:

Cutting period:	*Length (years)*	*Annual cut per acre (board-feet)*
1	10	[1] 255
2	20	237
3	20	237
4	20	[2] 237
5	30	[3] 195
6	20	[4] 186
7	20	[4] 186

[1] Cut completed.

[2] Annual allowable cut per acre for first 60 years after sanitation-salvage cut is 14,195÷60, or 237 board-feet.

[3] Annual allowable cut per acre for 60 to 90 years after sanitation-salvage cut is 5,838÷30, or 195 board-feet.

[4] Final harvest—80 percent of yield table values for stand 6.6 inches and above. Intermediate harvests will increase the cut by 50 percent or more.

A significant point in the calculation of the allowable cut is that for the first 60 years after the sanitation-salvage cut, growth makes up only 10 percent of the estimated total cut.

So called "safety factors" that some forest managers use to reduce the allowable cut have been intentionally omitted from these computations. These factors are used to insure a supply of timber. But in overmature decadent timber they ultimately defeat their purpose; they maintain age classes most subject to loss, and delay conversion of the entire forest to a young fast-growing stand.

When the cutting budget is prepared, the actual cut on the ground is determined from an intimate, first-hand knowledge of the forest. The best information available is used to select areas most in need of cutting and to estimate the expected cut for individual areas, such as compartments, legal subdivisions, small drainages, or other blocks of land making up annual cutting areas. The areas are then assigned to years in the period for which the cutting budget is being prepared. The assignment should provide practical logging units and an annual cut equal to the allowable cut. Markers may need to adjust the volume between units logged in any one year in order to correct for minor variations in the stand and still harvest the established cut.

The allowable cut should be established so that the objectives of the landowner or manager will be met insofar as the volume of timber and growth rate permit. In many cases this will mean making every effort to maintain a uniform allowable cut for an indefinite period. In other instances the allowable cut may be varied by periods. For example, a large excess of growing stock of overmature timber may be reduced in one or two cutting periods, or the reduction may be spread over a long period. Timber owners with sawmills may vary the allowable cut to fit planned changes in plant capacity.

Computation of the allowable cut, as presented here, requires an understanding of all aspects of the management of a forest property. As has been shown, it is influenced by the method of management—in this instance, unit area control. Therefore, it has been presented last in the discussion of the application of unit area control although its establishment is only the beginning of management for the period ahead.

SUMMARY

Many perplexing problems faced forest managers in the ponderosa-Jeffrey pine type when the Blacks Mountain Experimental Forest was established in the early 1930's. Mortality from bark beetle attacks was high. Regeneration was difficult to establish. Little was known of the growth rates that were possible or of the ways to sustain growth at a high level. Methods of converting the complex virgin forest to managed stands had not been worked out.

Now, 20 years later, the most important silvicultural questions have been answered by special studies, and a workable method of management has been developed by application of unit area control in commercial-scale operation of the experimental forest.

It was found that the high mortality caused by bark beetles can be controlled by sanitation-salvage cutting. Entomologists devised a risk classification by which trees highly susceptible to attack by bark beetles can be recognized. The high-risk trees made up only 15 percent of the total stand volume but accounted for more than 80 percent of the losses. Thus, by harvesting only 15 percent of the stand volume, the forest can be covered rapidly and most of the potential losses salvaged. Sanitation-salvage cutting is recommended as the first step in converting a virgin ponderosa-Jeffrey pine forest into a managed one.

An abundant seed crop, a seedbed of bare soil free from competing vegetation, and a low population of seed-eating rodents were found essential for establishment of natural regeneration. The following steps are necessary if natural regeneration is to be obtained:

1. Leave seed trees bearing a total of 800 or more cones per acre around the edges of clear-cut groups.
2. Prepare the seedbed before seed fall by removing slash and competing vegetation.
3. Bait the cut-over area and a surrounding buffer strip with poison bait before seed fall and one or more times after seed fall.

But seed trap records showed that good crops of pine seed occur at infrequent, irregular intervals. Consequently, regeneration usually must be obtained by artificial means. Planting with nursery stock succeeded on areas free from an overstory and other competing vegetation. Analysis of costs and returns from ponderosa pine plantations showed that planting on the prevailing medium sites is a good investment if interest rates are acceptably low. Direct seeding was unsatisfactory because of the high cost of protecting seed from rodents.

Planting with ponderosa or Jeffrey pine nursery stock is recommended as the most certain means of obtaining regeneration in most years.

Analysis of growth in relation to age classes on harvest-cutting plots showed that—

1. Conversion of virgin forests to young age classes is essential for rapid growth.
2. Removal of the overstory is essential for rapid growth of poles.
3. Growth of poles is further stimulated by removal of older trees around the border of groups of poles.
4. Immature age classes (saw-log timber under 150 years of age) grow more rapidly without older residuals.
5. Overmature stand units grow very slowly unless they contain admixtures of younger trees.
6. Average size of trees in overmature stand units has little effect on growth rate unless there are admixtures of younger trees.

Recognition by Dunning that the ponderosa-Jeffrey pine forests are aggregates of even-aged groups led to the development of unit area control. It provides a flexible method of harmonizing management objectives with the silvical requirements of the species and the variable forest conditions. Silviculture is applied according to the needs and conditions of each unit area in order to provide a sustained harvest of the products desired by the manager. Because of the silvical requirements of ponderosa and Jeffrey pine, even-aged management by the naturally occurring groups in the stand is recommended.

Overmature groups ready for final harvest are clear cut to release advance growth or to prepare areas for new regeneration. Trees of poor form or thrift are removed from groups carried as a reserve in order to improve stand conditions. Where regeneration is desired, the site is prepared by removing slash and competing regeneration. If a good seed crop is present, rodent populations are reduced with lethal bait. When good seed crops are absent, the area in need of regeneration is planted the next spring, before competing vegetation reinvades the area.

Cutting is followed by pruning of selected crop trees and, where economical, by thinning in overdense young stands.

The large amount of overmature age classes and the small amount of intermediate age classes force the manager to carry over mature timber as reserves for long periods if he is to maintain a sustained cut. The desired reserve is kept by deferring the final harvest on selected overmature unit areas rather than by leaving scattered trees over the entire area. To lessen border effects on younger age classes and to improve management and operational efficiency, overmature unit areas but not intermingled younger unit areas are usually harvested in blocks of 5 to 50 acres. The reserve timber is concentrated in adjoining blocks and is given a light improvement cut to salvage potential mortality and increase growth.

The irregular mosaic of age classes in the ponderosa-Jeffrey pine forest can be regulated by a combination of area and volume allotment. First step in achieving an even distribution of the necessary age classes is to allot the present advance growth on an area basis to the later cutting periods of the first rotation and the early cutting periods of the second. The immature and mature age classes can also be allotted on an area basis. They are assigned to the period just before final harvest starts in the present advance growth. Then the volume of the overmature age classes plus their growth can be allotted on a volume basis to the early cutting periods in the first rotation.

Cost of logging and management have not been increased by unit area control.

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APPENDIX

Ponderosa Pine Risk Classification

Four degrees of susceptibility to bark beetle attack were set up and described by Salman and Bongberg (*27*) for ponderosa pine:

"*Risk I: Low Risk.*—Foliage of healthy appearance, needles usually long and coarse, color good—dark green. Foliage complement (needles per twig) normal or above normal. Few twigs lacking foliage. No weakened portion of crown or dead or dying branches.

"*Risk II: Moderate Risk.*—Foliage mostly healthy, needle length average or better, color fair to good. Foliage complement generally average. Some twigs or branches dying or dead, but such injury not localized to form definite 'weak' spots in the crown.

"*Risk III: High Risk.*—Foliage, at least over a considerable portion of crown, average or shorter than average in length, foliage complement on twigs less than normal, thin, bunchy or unhealthy. Foliage color fair to poor. Some to many twigs or branches lacking foliage, fading, or dead, often localized to form 'weakened' portions of the crown.

"*Risk IV: Very High Risk.*—Foliage mostly unhealthy, needles short, color poor, needle complement sparse over considerable portions of the crown. Some to many twigs and branches dead or dying, portions of the crown definitely weakened. Active top killing or partial infestations often present."

In applying this risk rating, classify trees with a risk rating of III and IV as high risk. They should be cut.

Penalty System for Rating High-Risk Trees

The Bongberg penalty rating system, as reported by Sowder (*29, p. 22*), specifies that high-risk trees will have a penalty score of 9 or more. This system is useful in training timber markers and helps sharpen their ability to classify borderline trees correctly. The characteristics of the system and their scoring values are as follows:

"a. *Needle condition.*	
"(1) *Needle complement* (number of needle fascicles per twig):	
Less than normal complement throughout crown. No contrast evident between upper and lower crown	2
Thin complement in upper crown; normal complement in lower crown. Contrast in complement evident between upper and lower crown	4
"(2) *Needle length* (length of individual needles):	
Needles shorter than normal throughout crown. No contrast evident in needle lengths between upper crown and lower crown	2
Needles short in top; normal below. Contrast in needle length evident between upper and lower crown	4

“(3) *Needle texture* (apparent weight of needles—coarse or fine):	
Light needles throughout crown. No contrast in texture evident between needles in top crown and lower crown	1
Feathery needles in top crown; normal or light in texture in lower crown. Contrast in texture evident between top and lower crown	2
“(4) *Needle color* (green color of needles):	
Needle color light green—lighter than normal green	1
Needles definitely off-color	2
“b. *Twig and branch conditions.*	
“(1) A few *scattered*, dead or dying twigs or branches in crown	0
“(2) Many *scattered*, dead or dying twigs or branches in crown	1
“(3) Severe *scattered*, dead or dying twigs or branches in crown	2
“(4) Severe dead or dying twigs or branches in crown which form a definite weak spot or hole in crown, particularly in top one-third of crown (localized weakness)	3
“(5) Severe dead or dying twigs or branches in crown which form more than one weak spot in crown, particularly in top one-third of crown (localized weakness)	5
“c. *Top crown conditions.*	
“(1) Old top kill where there is no progressive weakness or killing green crown below	2
“(2) Old top kill and a progressive weakness killing in green crown below	4
“(3) Old spike where there is no progressive weakness or killing in green crown below	1
“(4) Old spike and a progressive weakness and current killing of limbs and branches below	5
“(5) Long bare spike (one-third or more of total stem length) which leaves only a few widely spaced green branches in crown	6
“d. *Other factors.*	
“(1) Keen tree classes—All C and D crowns	2
“(2) Lightning strike:	
Current strike	9
Old strike (healed)	1
“(3) *Dendroctonus valens* attack in basal bole:	
Current	6
Old, pitched out	2
“(4) Broken tops—current break leaving only a few branches on bole	9
Old break and a new terminal starting	0
“(5) Mistletoe:	
Heavy witches broom	1
Canker on stem	5
“(6) *Fire scar*—50 percent or more of circumference or basal area—which indicates progressive deterioration of wood (mechanical risk)	3
“(7) High-risk trees in group of other trees which might serve as focal point for infestation of entire group	3
“(8) Hot spot—where tree is located in the midst of a large group of snags indicating that the group has been killed gradually over the years	1
“(9) Mistletoe in smaller diameters (not necessarily a high risk tree from an entomological point of view). Very heavy mistletoe witches broom and when crown excluding the witches broom would be D crown	9”

Cutting Plot Data

The data from Blacks Mountain cutting plots are summarized in the following tables. They are presented here for use in growth prediction and to amplify the discussions in this manuscript. For growth prediction the data apply primarily to areas with an average site index of 70.

TABLE 12.—*Area distribution of condition classes, by type of cut, Blacks Mountain Experimental Forest cutting plots* [1]

Condition class	Uncut	Sanitation-salvage cut	Moderate cut	Heavy cut	Clear cut
Overmature:					
Pine:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Pine poles	17. 2	11. 8	3. 8	0. 1	0. 0
Pine seedlings and saplings	37. 9	23. 6	9. 5	4. 0	. 0
Fir and cedar poles	1. 2	11. 2	2. 5	. 2	. 0
Fir and cedar seedlings and saplings	. 5	1. 9	1. 2	. 1	. 0
No understory	3. 8	2. 4	5. 8	3. 8	. 0
Total	60. 6	50. 9	22. 8	8. 2	. 0
Mature:					
Pine	7. 0	9. 1	15. 9	19. 5	0. 0
Fir	. 0	. 4	. 0	. 0	. 0
Total	7. 0	9. 5	15. 9	19. 5	. 0
Immature:					
Pine	5. 1	9. 6	7. 5	5. 8	6. 0
Fir	. 9	1. 1	. 0	. 0	. 8
Total	6. 0	10. 7	7. 5	5. 8	6. 8
No overstory:					
Pine poles	23. 9	20. 2	22. 1	27. 9	37. 8
Pine seedlings and saplings	1. 1	4. 3	16. 0	24. 1	14. 0
Fir poles	. 4	3. 4	5. 5	4. 0	13. 7
Fir seedlings and saplings	. 1	. 3	1. 6	. 6	. 5
Unstocked	. 0	. 6	5. 6	7. 9	12. 0
Total	25. 5	28. 8	50. 8	64. 5	78. 0
Nontimbered	. 9	. 1	3. 0	2. 0	15. 2
Total, all classes	100. 0	100. 0	100. 0	100. 0	100. 0

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[1] Number of $\frac{1}{10}$-acre subplots: 800 each for uncut, sanitation-salvage cut, moderate cut, and heavy cut; 400 for clear cut; in addition, 505 subplots not recut but from whole plots containing some recut subplots also used in parts of the analysis.

TABLE 13.—*Average annual growth per acre,*[1] *all species, Blacks Mountain cutting plots, all tree classes*

Item	Uncut		Sanitation-salvage cut		Moderate cut		Heavy cut		Clear cut		All cuts [2]	
	Bd.-ft.	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]
PINE OVERMATURE CONDITION CLASSES												
Reserve volume	24,008	------	21,861	------	14,879	------	9,835	------	------	------	18,755	------
Growth	80	0.33	114	0.52	82	0.55	100	1.01	------	------	98	0.52
Loss	108	.45	28	.13	10	.06	19	.19	------	------	20	.11
Net growth	−28	−.12	86	.39	72	.49	81	.82	------	------	78	.42
Ingrowth	11	------	18	------	17	------	7	------	------	------	14	------
Total net growth	−17	------	104	------	89	------	88	------	------	------	92	------
PINE MATURE CONDITION CLASSES												
Reserve volume	21,123	------	22,050	------	14,900	------	11,052	------	------	------	15,278	------
Growth	131	0.62	161	0.73	122	0.82	128	1.16	------	------	134	0.88
Loss	251	1.19	18	.08	24	.16	9	.08	------	------	19	.12
Net growth	−120	−.57	143	.65	98	.66	119	1.08	------	------	115	.75
Ingrowth	8	------	13	------	15	------	8	------	------	------	12	------
Total net growth	−112	------	156	------	113	------	127	------	------	------	127	------
PINE IMMATURE CONDITION CLASSES												
Reserve volume	10,722	------	9,447	------	7,144	------	7,004	------	3,101	------	7,755	------
Growth	115	1.08	120	1.27	116	1.62	137	1.96	93	3.00	118	1.52
Loss	37	.35	1	.02	5	.07	0	.00	10	.32	2	.03
Net growth	78	.73	119	1.25	111	1.55	137	1.96	83	2.68	116	1.50
Ingrowth	52	------	85	------	54	------	129	------	94	------	86	------
Total net growth	130	------	204	------	165	------	266	------	177	------	202	------
NO OVERSTORY,[4] POLES, SAPLINGS, SEEDLINGS, AND UNSTOCKED CONDITION CLASSES												
Reserve volume	6,793	------	5,925	------	3,978	------	2,627	------	457	------	3,231	------
Growth	30	0.45	37	0.62	35	0.88	34	1.28	14	2.96	30	0.92
Loss	53	.93	16	.28	18	.46	5	.21	+0	.07	10	.30
Net growth	−33	−.48	21	.34	17	.42	29	1.07	14	2.89	20	.62
Ingrowth	37	------	36	------	25	------	17	------	52	------	20	------
Total net growth	4	------	57	------	42	------	46	------	66	------	40	------
ALL CONDITION CLASSES[5]												
Reserve volume	18,465	------	15,808	------	8,326	------	5,092	------	508	------	8,846	------
Growth	73	0.39	97	0.61	65	0.78	64	1.25	18	3.01	67	0.76
Loss	101	.55	20	.13	16	.19	7	.13	1	.14	13	.14
Net growth	−28	−.16	77	.48	49	.59	57	1.12	17	2.87	54	.62
Ingrowth	20	------	30	------	23		21		51		28	------
Total net growth	−8	------	107	------	72		78		68		82	------

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[1] For 10-year period.

[2] Includes subplots not recut in plots having some subplots recut.

[3] Growth precent computed from sample totals.

[4] Scattered trees larger than 12 inches d. b. h.

[5] Includes mature and immature fir and nontimbered condition classes.

Table 14.—*Average annual growth per acre,[1] for pine, Blacks Mountain cutting plots, all tree classes*

Item	Uncut		Sanitation-salvage cut		Moderate cut		Heavy cut		Clear cut		All cuts[2]	
	Bd.-ft.	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]
PINE OVERMATURE CONDITION CLASSES												
Reserve volume	22,852		10,626		14,166		9,765				17,509	
Growth	69	0.30	92	0.47	76	0.54	97	0.99			85	0.48
Loss	104	.46	24	.12	10	.07	19	.19			18	.10
Net growth	−35	−.16	68	.35	66	.47	78	.80			67	.38
Ingrowth	6		12		12		7				10	
Total net growth	−29		80		78		85				77	
PINE MATURE CONDITION CLASSES												
Reserve volume	20,528		10,712		13,750		10,874				14,198	
Growth	125	0.61	135	0.68	114	0.83	126	1.16			126	0.88
Loss	251	1.22	18	.09	24	.18	9	.08			19	.13
Net growth	−126	−.61	117	.59	90	.65	117	1.08			107	.75
Ingrowth	8		10		14		8				11	
Total net growth	−118		127		104		125				118	
PINE IMMATURE CONDITION CLASSES												
Reserve volume	9,456		8,737		6,831		6,650		2,721		7,402	
Growth	101	1.07	107	1.22	115	1.68	133	1.94	80	2.96	112	1.51
Loss	37	.39	1	.02	5	.07	0	.00	10	.37	2	.03
New growth	64	.68	106	1.20	110	1.61	133	1.94	70	2.59	110	1.48
Ingrowth	39		74		50		126		90		80	
Total net growth	103		180		160		259		160		190	
NO OVERSTORY[4] POLES, SAPLINGS, SEEDLINGS, AND UNSTOCKED CONDITION CLASSES												
Reserve volume	6,596		5,543		3,577		2,525		253		2,991	
Growth	28	0.43	30	0.54	30	0.83	31	1.23	6	2.47	25	0.85
Loss	63	.96	15	.26	17	.47	5	.22	0	.00	9	.30
Net growth	−35	−.53	15	.28	13	.36	26	1.01	6	2.47	16	.55
Ingrowth	35		26		21		15		26		21	
Total net growth	0		41		34		41		32		37	
ALL CONDITION CLASSES[5]												
Reserve volume	17,559		14,205		7,753		4,977		402		8,232	
Growth	64	0.36	79	0.55	59	0.76	61	1.22	11	2.72	59	0.72
Loss	98	.56	18	.13	15	.19	7	.14	1	.15	12	.14
Net growth	−34	−.20	61	.42	44	.57	54	1.08	10	2.67	47	.58
Ingrowth	15		22		19		19		29		22	
Total net growth	−19		83		63		73		39		69	

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[1] For 10-year period.

[2] Includes subplots not recut in plots having some subplots recut.

[3] Growth percent computed from sample totals.

[4] Scattered trees larger than 12 inches d. b. h.

[5] Includes mature and immature fir and nontimbered condition classes.

TABLE 15.—*Average annual growth per acre,*[1] *for pine, Blacks Mountain cutting plots, Dunning (8) tree classes 1, 2, 6 (under 150 years of age)*

Item	Uncut		Sanitation-salvage cut		Moderate cut		Heavy cut		Clear cut		All cuts [2]	
	Bd.-ft.	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]
PINE OVERMATURE CONDITION CLASSES												
Reserve volume	612	------	795	------	833	------	215	------	------	------	686	------
Growth	9	1.46	14	1.76	16	2.00	6	2.82	------	------	13	1.82
Loss	0	.00	0	.00	0	.00	0	.00	------	------	0	.00
Net growth [4]	9	1.46	14	1.76	16	2.00	6	2.82	------	------	13	1.82
	------	(1.47)	------	(1.73)	------	(2.00)	------	(2.98)	------	------	------	(1.81)
PINE MATURE CONDITION CLASSES												
Reserve volume	4,471	------	2,506	------	1,984	------	2,086	------	------	------	2,811	------
Growth	61	1.36	38	1.51	34	1.69	38	1.83	------	------	44	1.56
Loss	2	.05	0	.00	1	.06	7	.35	------	------	3	.12
Net Growth [4]	59	1.31	38	1.51	33	1.63	31	1.48	------	------	41	1.44
	------	(1.34)	------	(1.54)	------	(1.62)	------	(1.49)	------	------	------	(1.46)
PINE IMMATURE CONDITION CLASSES												
Reserve volume	6,246	------	4,874	------	5,269	------	6,402	------	2,675	------	5,328	------
Growth	88	1.41	87	1.77	102	1.94	131	2.04	80	3.01	100	1.88
Loss	0	.00	1	.03	5	.09	0	.00	5	.20	2	.04
Net growth [4]	88	1.41	86	1.74	97	1.85	131	2.04	75	2.81	98	1.84
	------	(1.45)	------	(1.76)	------	(1.85)	------	(2.06)	------	(2.87)	------	(1.86)
NO OVERSTORY [5] POLES, SAPLINGS, SEEDLINGS, AND UNSTOCKED CONDITION CLASSES												
Reserve volume	1,065	------	662	------	594	------	576	------	247	------	507	------
Growth	17	1.60	13	1.99	12	1.93	13	2.19	6	2.51	11	1.99
Loss	4	.41	0	.00	1	.16	3	.58	0	.00	1	.26
Net growth [4]	13	1.19	13	1.99	11	1.77	10	1.61	6	2.51	10	1.73
	------	(1.24)	------	(1.85)	------	(1.76)	------	(1.74)	------	(2.94)	------	(1.85)
ALL CONDITION CLASSES [6]												
Reserve volume	1,296	------	1,292	------	1,205	------	1,184	------	394	------	1,259	------
Growth	19	1.45	23	1.76	23	1.88	24	2.03	11	2.76	23	1.81
Loss	1	.10	+0	.01	1	.09	4	.30	1	.08	1	.11
Net growth [4]	18	1.35	23	1.75	22	1.79	20	1.73	10	2.68	22	1.70
	------	(1.40)	------	(1.74)	------	(1.80)	------	(1.78)	------	(2.95)	------	(1.75)

[1] For 10-year period.

[2] Includes subplots not recut in plots having some subplots recut.

[3] Growth percent computed from sample totals.

[4] Figures in parentheses are net growth percent for all species.

[5] Scattered trees larger than 12 inches d. b. h.

[6] Includes mature and immature fir and nontimbered condition classes.

TABLE 16.—*Average annual growth per acre,*[1] *pine, for Blacks Mountain cutting plots, Dunning (8) tree classes 3, 4 (150 to 300 years of age)*

Item	Uncut		Sanitation-salvage cut		Moderate cut		Heavy cut		Clear cut		All cuts [2]	
	Bd.-ft.	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]
PINE OVERMATURE CONDITION CLASSES												
Reserve volume	4,918	......	4,536	......	5,582	......	7,148	......	......	......	5,046	......
Growth	26	0.53	36	0.79	33	0.58	79	1.11	......	......	37	0.73
Loss	6	.13	3	.06	4	.07	17	.24	......	......	4	.07
Net growth	20	.40	33	.73	29	.51	62	.87	......	......	33	.66
PINE MATURE CONDITION CLASSES												
Reserve volume	9,809	......	10,956	......	6,579	......	6,403	......	......	......	7,232	......
Growth	54	0.55	80	0.73	56	0.85	72	1.12	......	......	64	0.88
Loss	38	.39	16	.14	8	.12	1	.01	......	......	7	.10
Net growth	16	.16	64	.59	48	.73	71	1.11	......	......	57	.78
PINE IMMATURE CONDITION CLASSES												
Reserve volume	958	......	1,683	......	1,345	......	448	......	......	......	1,097	......
Growth	8	0.79	13	0.76	11	0.84	2	0.48	0	0.00	9	0.76
Loss	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
Net Growth	8	.79	13	.76	11	.84	2	.48	0	.00	9	.76
NO OVERSTORY[4] POLE, SAPLING, SEEDLING, AND UNSTOCKED CONDITION CLASSES												
Reserve volume	784	......	898	......	1,162	......	1,400	......	......	......	950	......
Growth	3	0.38	6	0.64	10	0.85	15	1.11	0	0.00	9	0.92
Loss	0	.00	0	.00	3	.22	+0	.02	0	.00	1	.09
Net growth	3	.38	6	.64	7	.63	15	1.09	0	.00	8	.81
ALL CONDITION CLASSES[5]												
Reserve volume	3,951	......	3,751	......	3,006	......	2,776	......	......	......	2,749	......
Growth	21	0.53	29	0.77	22	0.74	31	1.11	0	0.00	22	0.82
Loss	6	.16	3	.08	3	.11	2	.06	0	.00	3	.08
Net growth	15	.37	26	.69	19	.63	29	1.05	0	.00	19	.74

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[1] For 10-year period.

[2] Includes subplots not recut in plots having some subplots recut.

[3] Growth percent computed from sample totals.

[4] Scattered trees larger than 12 inches d. b. h.

[5] Includes mature and immature fir and nontimbered condition classes.

TABLE 17.—*Average annual growth per acre,[1] pine, for Blacks Mountain cutting plots, Dunning (8) tree classes 5, 7 (over 300 years of age)*

Item	Uncut		Sanitation-salvage cut		Moderate cut		Heavy cut		Clear cut		All cuts [2]	
	Bd.-ft.	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]	*Bd.-ft.*	*Pct.*[3]
PINE OVERMATURE CONDITION CLASSES												
Reserve volume	17.323	----	14,296	----	7,752	----	2.403	----	----	----	11,767	----
Growth	34	0.20	42	0.29	27	0.35	12	0.50	----	----	35	0.30
Loss	98	.56	21	.15	6	.07	2	.08	----	----	14	.12
Net growth	−64	−.36	21	.14	21	.28	10	.42	----	----	21	.18
PINE MATURE CONDITION CLASSES												
Reserve volume	6,218	----	6,218	----	5,187	----	2,355	----	----	----	4,155	----
Growth	10	0.16	17	0.27	25	0.48	16	0.66	----	----	18	0.43
Loss	210	3.37	3	.04	15	.29	1	.03	----	----	9	.21
Net growth	−200	−3.21	14	.23	10	.19	15	.63	----	----	9	.22
PINE IMMATURE CONDITIONS CLASSES												
Reserve volume	2,251	----	2,179	----	217	----	0	----	46	----	977	----
Growth	5	0.21	8	0.35	1	0.54	0	0.00	0	0.00	3	0.32
Loss	37	1.62	0	.00	0	.00	0	.00	5	10.00	+0	.04
Net growth	−32	−1.41	8	.35	1	.54	0	.00	−5	−10.00	3	.28
NO OVERSTORY,[4] POLE, SAPLING, SEEDLING, AND UNSTOCKED CONDITION CLASSES												
Reserve volume	4,747	----	3.983	----	1,821	----	540	----	6	----	1,474	----
Growth	8	0.17	11	0.28	8	0.46	3	0.55	+0	1.00	5	0.26
Loss	59	1.24	15	.37	13	.73	2	.37	0	.00	7	.46
Net growth	−51	−1.07	−4	−.09	−5	−.27	1	.18	+0	1.00	−2	−.10
ALL CONDITION CLASSES [5]												
Reserve volume	12,310	----	9,248	----	3,541	----	1,018	----	8	----	4,224	----
Growth	21	0.19	27	0.29	14	0.41	6	0.59	+0	0.64	14	0.33
Loss	91	.74	15	.16	10	.30	2	.16	+0	3.55	8	.19
Net growth	−67	−.55	12	.13	4	.11	4	.43	−0	−2.91	6	.14

[1] For 10-year period.

[2] Includes subplots not recut in plots having some subplots recut.

[3] Growth percent computed from sample totals.

[4] Scattered trees larger than 12 inches d. b. h.

[5] Includes mature and immature fir and nontimbered condition classes.

TABLE 18.—*Average annual growth per acre, white fir and California incense-cedar, all condition classes, ingrowth not included, Blacks Mountain Experimental Forest*

TREES UNDER 150 YEARS (DUNNING (8) TREE CLASSES 1, 2, 6)

Type of cut	Reserve volume	Gross growth		Loss
	Bd.-ft.	*Bd.-ft.*	*Percent* [1]	*Percent* [1]
Uncut	360	6	1. 80	0. 18
Sanitation-salvage	428	9	2. 04	. 33
Moderate	89	2	2. 42	. 42
Heavy	59	2	2. 89	. 00
Clear cut	186	7	3. 67	. 13
All cuts [2]	166	4	2. 41	. 28
TREES OVER 150 YEARS (DUNNING TREE CLASSES, 3, 4, 5, 7)				
Uncut	545	3	0. 47	0. 30
Sanitation-salvage	1, 085	9	. 88	. 10
Moderate	484	4	. 73	. 10
Heavy	56	1	1. 45	. 00
Clear cut	10	+0	2. 31	. 00
All cuts [2]	448	4	. 78	. 08

[1] Computed from sample totals.

[2] Uncut not included.

Management Plan for the Blacks Mountain Experimental Forest

[This plan was prepared as a guide for carrying out the pilot-plant test of unit area control at the Blacks Mountain Experimental Forest. It is included here as an illustration of how unit area control is being applied on a specific forest property. The experimental forest was described earlier in this bulletin. Therefore background descriptive material, which usually makes up an important part of management plans, has been largely omitted here.]

CONTENTS

OBJECTIVES OF MANAGEMENT

The specific object of management of the Blacks Mountain Experimental Forest is to obtain the maximum annual yield of high-quality ponderosa or Jeffrey pine saw logs and peeler logs. Whenever practical, white fir stands will be converted to pine. A rotation of 140 years has been selected. It is expected that the average size of trees cut in the final harvest after removal of the original overmature timber will be 21 to 24 inches d. b. h.

Development of a regulated forest is an essential step in putting a timber property on a sound business basis for permanent production at a high level. A regulated forest is one in which all age classes through rotation age are equally represented. Because ponderosa and Jeffrey pine are intolerant and in the eastside pine type grow predominantly in even-aged groups, the management unit will be developed as a regulated forest composed of small even-aged groups.

A sharp contrast in ages between adjoining unit areas is desirable so that the possible hazards resulting from extensive occurrence of uniform stands is lessened.

BASIC DATA

The area of the experimental forest was divided as follows (see fig. 30, p. 89):

	Acres
Management unit	7, 057
Special uses:	
Cutting plots	1, 348
Compartments for use by the Division of Forest Insect Research	154
Compartment for special problems	96
Natural areas (50 acres nontimbered)	521
Subtotal	2, 119
Other (nontimbered)	617
Total in main topographic unit	9, 793
Outside main topographic unit [1]	459
Grand total	10, 252

[1] Originally inaccessible from the main part of the forest by the Patterson-Cone mountain divide and omitted from plans and records. In 1954 roads built for a national-forest timber sale made the land outside the main topographic unit accessible for harvest, and it will be treated the same as the management unit.

This plan is concerned mainly with the 7,057 timbered acres in the management unit. However, some reference will be made, as needed, to enclosed nontimbered land and to timbered lands that have been set apart from the management unit for special research purposes.

When the plan was written, most of the experimental forest had already been subjected to a sanitation-salvage cut, and final harvesting was in progress (fig. 24). The area and type of cutting on the management unit, 1937–55, was as follows:

Sanitation-salvage cut only	1, 202
Sanitation-salvage cut followed by one recut	379
Sanitation-salvage cut followed by two recuts	1, 447
Silvicultural cut plus sanitation-salvage cut on reserves	2, 395

Silvicultural cut plus sanitation-salvage cut on reserves followed by one recut	1,348
Uncut	286
Total	[1] 7,057

---

[1] 53,114,000 board-feet harvested on management unit; an additional 14,630,000 board-feet harvested on areas outside unit. Most of the pole stands have been released from overwood. Until harvesting of the overmature timber is completed, the bulk of the cut will come from overmature groups to release seedlings and saplings or to prepare areas for establishment of new crops of trees.

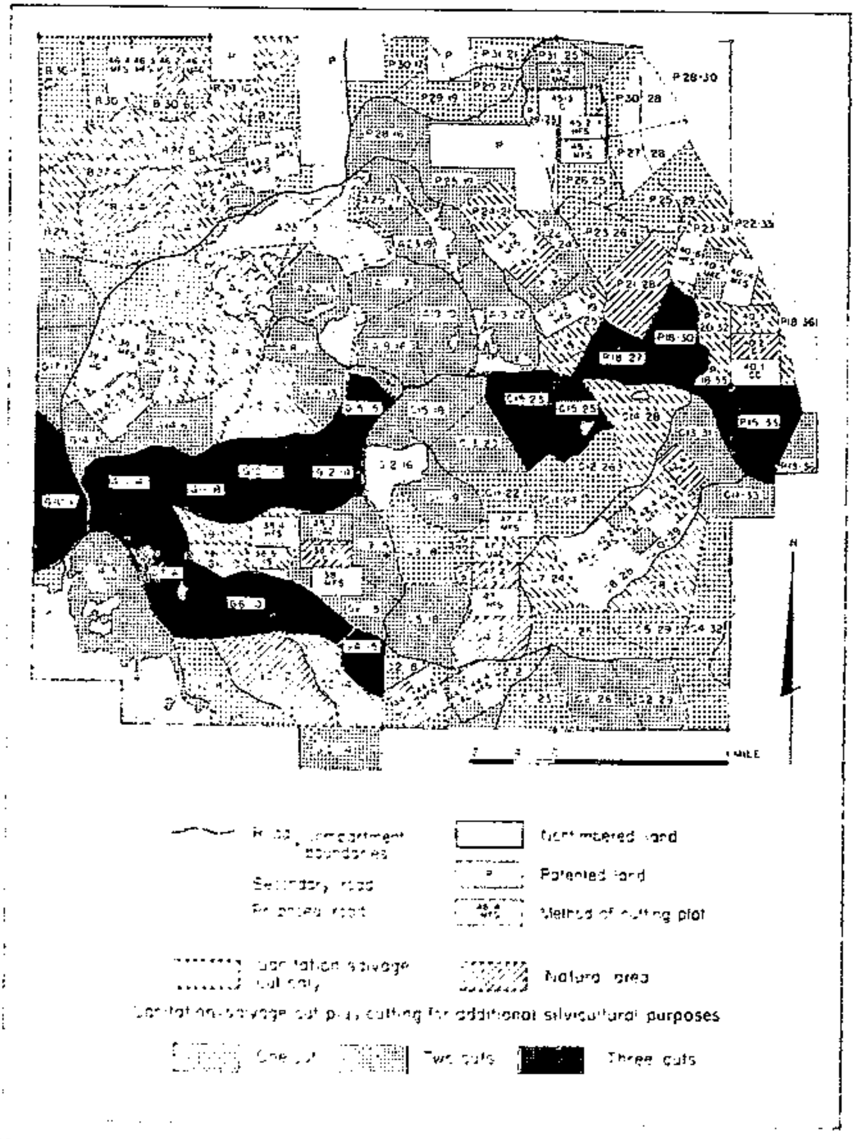

FIGURE 24. Cutting history at Blacks Mountain Experimental Forest, 1937-55.

The 9,793 acres in the main topographic unit originally were divided into 100 compartments averaging 98 acres. Cutting plots superimposed on some compartments have been excluded from them and thus reduced their size. The 459 acres outside the main topographic unit have recently been divided into 5 compartments.

In 1933 and 1934 a 100-percent inventory of merchantable timber and a detailed topographic map were made.

As a basis for preparing this plan, the 7,057 acres in the management unit part of the experimental forest were inventoried in 1949.

Condition Classes

For the inventory, the data were segregated by condition classes based upon overstory age and species, occurrence of seed trees, stocking, occurrence and age and species of understory trees, and the occurrence of brush on areas needing reproduction. Determination of these condition classes is highly important, both for prescribing silvicultural operations, and for planning how to attain the desired stand structure for regulation purposes.

To record condition classes, a system of symbols was devised as a matter of speed and economy of space. The system requires placing code symbols in a regular order above and below a horizontal bar. Symbols above the bar refer to the overstory. From left to right they are arranged in this order: Age, species, seed trees, and stocking. Symbols below the bar refer to understory and ground condition in the order from left to right: Age, species, stocking, and brush (fig. 25).

The complete system of symbols for the condition classes and their definitions are as follows:

Age (*Overstory* above line, *Understory* below line; both in first position).

Symbol	*Definition*
Overstory:	
1	Old or overmature dominants, Dunning class 5, age 300 years or older (tree classes throughout this plan refer to Dunning tree classes (*8*)).
2	Mature dominants, Dunning class 3, age 150 to 300 years.
3	Immature dominants, Dunning class 1, age 75 to 150 years.
Understory:	
1	Young dominants, Dunning class 1, age 25 to 75 years, 4-14 inches d. b. h.
2	Saplings and seedlings, age 0 to 25 years, dominants up to 3.5 inches d. b. h.
Composition (Second position above and below line).	
●	One-third or more of dominants ponderosa and Jeffrey pine.
×	Two-thirds or more of dominants white fir and incense-cedar.
	(Such a small part of the overstory fell in the fir-cedar classification that all old fir-cedar classes were combined into one group (*1x*) and all mature fir-cedar classes were combined into one group (*2x*). No immature fir age classes occurred.)
Seed Trees (Third position above line).	
+	Adequate, about 6 Class 1, 3 or 5 trees per acre, 24 inches d. b. h. or larger, around areas needing regeneration—should be suitable for carrying as reserve.
(blank)	Inadequate or absent.
Stocking (Fourth position above, third position below).	
+	Adequate (see table 19 for standards).
−	Inadequate (see table 19 for standards).
(blank)	Unstocked, less than minimum for inadequate except in the old or overmature age class, which is not rated for stocking.

Symbol	*Definition*
Brush (Fourth position below line).	
+	Brush or other vegetation requiring eradication in areas needing regeneration.
(blank)	None present or no regeneration needed.

TABLE 19.—*Stocking standard by age classes* [1]

Age class	Adequate stocking			Inadequate stocking		
	Trees per acre	Volume per acre	Spacing	Trees per acre	Volume per acre	Spacing
	Number	*M bd.-ft.*	*Feet*	*Number*	*M bd.-ft.*	*Feet*
Seedling and sapling	+250		−13	50–249		14–30
Young	+47		−30	10–46		31–66
Immature	+22		−44	4–21		45–105
Mature		+12			1–11.9	

[1] Stocking not rated for overmature age classes.

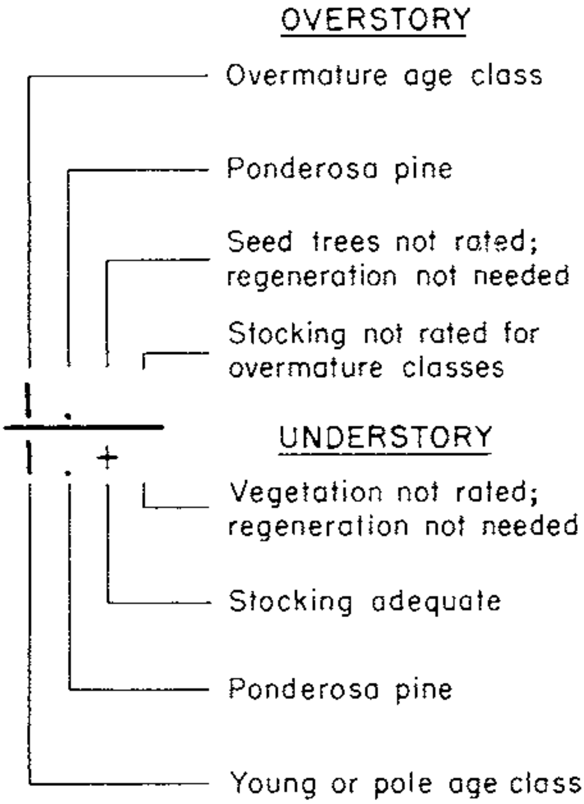

FIGURE 25. An example of the condition class symbols, Blacks Mountain Experimental Forest management unit.

Inventory and Stand Data

A summary of original and 1949 volume is shown in table 20. Volumes, summarized by condition class groups, as determined by the 1949 inventory, are shown in table 21. Area and volume per acre for condition classes are shown in table 22. Stocking of seedlings and saplings is shown in table 23. Stocking of poles is shown in table 24.

TABLE 20.—*Summary of volumes on management unit,*[1] *Blacks Mountain Experimental Forest*

Species	1933–34		1949 [2]	
	Total	Per acre	Total	Per acre
	M bd.-ft.	*M bd.-ft.*	*M bd.-ft.*	*M bd.-ft.*
Ponderosa and Jeffrey pine	116, 315	16. 48	74, 853	10. 61
White fir	8, 261	1. 17	4, 232	. 60
Incense-cedar	3, 406	. 48	3, 418	. 48
Total	127, 982	18. 13	82, 503	11. 69

[1] 7,057 acres.
[2] First re-inventory.

TABLE 21.—*Volume summary, by condition-class groups on management unit, Blacks Mountain Experimental Forest, 1949*

Dunning tree classes and species	Overmature	Mature	Immature	Scattered overstory	All
1, 2, 6:	*M board-feet*	*M board-feet*	*M board-feet*	*M board-feet*	*M board-feet*
Pine	1, 511	402	3, 416	2, 148	7, 477
Fir	731	92	195	319	1, 337
Cedar	25	2	12	0	39
Total	2, 267	496	3, 623	2, 467	8, 853
3, 4:					
Pine	3, 590	2, 672	563	676	7, 501
Fir	291	195	22	11	519
Cedar	217	26	5	0	248
Total	4, 098	2, 893	590	687	8, 268
5, 7:					
Pine	55, 062	1, 045	960	2, 808	59, 875
Fir	2, 266	42	0	68	2, 376
Cedar	2, 871	101	40	119	3, 131
Total	60, 199	1, 188	1, 000	2, 995	65, 382
All tree classes:					
Pine	60, 163	4, 119	4, 939	5, 632	74, 853
Fir	3, 288	329	217	398	4, 232
Cedar	3, 113	129	57	119	3, 418
Total	66, 564	4, 577	5, 213	6, 149	82, 503

TABLE 22.—*Volume per acre, by tree classes in each condition class on management unit, Blacks Mountain Experimental Forest, 1949*

Code No.	Condition class	Area	Tree classes 1, 2, 6	Tree classes 3, 4	Tree classes 5, 7	Tree classes All
		Acres	*M board-feet*	*M board-feet*	*M board-feet*	*M board-feet*
1	1●	534	1.1	1.8	10.7	13.6
2	1●+ 1●	155	.9	1.0	13.1	15.0
3	1●− 1●	1,681	.5	.8	16.3	17.6
4	2●+ 1●	731	.3	.9	19.3	20.5
5	2●− 1●	197	.4	1.1	18.3	19.8
6	1●+	200	.7	2.4	16.6	19.7
7	1●	116	1.2	.6	13.4	15.2
8	1×+ 1●	107	.9	1.8	16.6	19.3
9	2×+ 1●	13	.7	.0	19.7	20.4
10	1× 1×	[1] 23	1.0	2.2	16.2	19.4
	Total	3,757				
	Weighted average		.6	1.1	16.0	17.7
11	2●+	22	1.3	5.1	6.2	12.6
12	2●−	40	.5	3.9	2.7	7.1
13	2●++	47	2.0	11.1	3.8	16.9
14	2●+−	47	.9	11.7	1.6	14.2
15	2●−	139	1.0	5.3	3.0	9.3
16	+ 2●+	60	1.7	12.1	4.0	17.8
17	+ 2×	9	6.7	5.9	.2	12.8
	Total	373				
	Weighted average		1.3	7.8	3.2	12.3

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[1] See footnote at end of table.

TABLE 22.—*Volume per acre, by tree classes in each condition class on management unit, Blacks Mountain Experimental Forest, 1949*—Con.

Code No.	Condition class	Area	Tree classes			
			1, 2, 6	3, 4	5, 7	All
		Acres	*M board-feet*	*M board-feet*	*M board-feet*	*M board-feet*
18	$\frac{3\bullet+}{\ }$	368	7.4	1.1	1.7	10.2
19	$\frac{3\bullet-}{1\bullet+}$	152	3.4	.0	.9	4.3
20	$\frac{3\bullet-}{1\bullet-}$	22	3.2	.0	.0	3.2
21	$\frac{3\bullet-}{\text{other}}$	85	3.8	2.1	2.9	8.8
	Total	627				
	Weighted average		5.8	.9	1.6	8.3
22	$\frac{\ }{1\bullet+}$	1,263	1.3	.4	1.2	2.9
23	$\frac{\ }{1\bullet-}$	536	.8	.2	1.1	2.1
24	$\frac{\ }{2\bullet+}$	143	.7	.3	3.1	4.1
25	$\frac{\ }{2\bullet-}$	61	.5	.5	2.8	3.8
26	$\frac{\ }{+}$	226	.4	.0	.6	1.0
27	$\frac{\ }{1\times+}$	55	1.9	.3	2.2	4.4
28	$\frac{\ }{2\times+}$	13	2.7	2.5	.0	5.2
	Unclassified	3				
	Total	2,300				
	Weighted average		1.1	.3	1.3	2.7
	All classes, weighted average		1.3	1.2	9.2	11.7

[1] 9 acres pole understory, 14 acres seedling and sapling understory.

Site

Site index varies from Site IV–100 to Site III–125, based on Dunning's site classification (*9*). The weighted average is 114. This is the equivalent of site index 72 in Meyer's ponderosa pine yield tables (*23*).

REGULATION

Regulation of cut is based on a combination of area and volume allocation, in which the advance growth is allotted by area and the present merchantable timber by volume.

Rotation

The first step in planning for regulation of the cut is to decide upon the desirable rotation age. For this unit, 140 years was selected because it will provide the type of products desired. This age conforms closely to the culmination of mean annual growth.

Cutting Period

Where even-aged management by groups is used, cutting period refers to the interval between cuts in each compartment or other working circle subdivision and is not necessarily the interval between cuts on any specific acre. Twenty-year cutting periods have been selected for Blacks Mountain. This period provides sufficient volume for efficient logging and is not too long to prevent adequate silvicultural control of the stand.

Ultimate Stand Structure

The ideal stand on a compartment at any specific time will consist of seven age classes. However it is not planned that every compartment will have all seven age classes. Each age class will occur in patches 4 to 7 acres in size. The youngest age class will be between

TABLE 23.—*Percent of milacres stocked [1] with seedlings and saplings, by species and condition class, management unit, Blacks Mountain Experimental Forest, 1949*

Code No.	Condition class	Area, acres	Pine	Fir	Cedar	Total
3	1● 2●+	1,681	39.5	4.7	5.1	49.3
4	1● 2●−	731	20.4	3.0	1.8	25.2
5	1●	197	6.8	2.1	1.4	10.3
6	1●+	200	18.2	1.8	.5	20.5
8	1● 2×+	107	9.5	51.8	2.6	63.9
10	1× 2	14	([2])			
24	2●+	143	44.3	4.9	1.0	50.2
25	2●−	61	15.0	1.1	.0	16.1
26	+	226	2.9	.0	.0	2.9
28	2×+	13	12.5	17.5	.0	30.0
	Unclassified [3]	4				

[1] 100 percent = 1,000 stocked milacres per acre.

[2] Stocking data not available.

[3] Included with area to be regenerated during first four cutting cycles.

0 to 20 years and the oldest between 120 and 140 years. The average volume per acre of the trees 12 inches and larger d. b. h. will be 6,018 board-feet, as computed from ponderosa pine yield table.

This stand structure will not be attained until some time in the second rotation. The desired age-class distribution and desired size of unit areas will be achieved after the final harvesting of the present advance growth is started.

Allowable Cut

When cutting was started in 1937 there was a large excess volume of growing stock—chiefly in the overmature age class. The bulk of this excess growing stock will have been removed by the end of the first 20-year cutting period. This rapid reduction in growing stock was planned in order to convert as many units as possible to a young, fast-growing condition as soon as possible. The planned cut during the first 20-year period was set at 2 million board-feet or more per year in order to provide sufficient volume for a reasonably efficient logging operation. The total cut for the period 1949 through 1956 was established as 20 million board-feet.

To achieve a regular distribution of age classes, one-seventh of the total area, or 1,008 acres, must be harvested and regenerated in each cutting period. On the average the present large pole stands will

TABLE 24.—*Area, number per acre, size of trees and stocking in pole stands, management unit, Blacks Mountain Experimental Forest, 1949*

Code No.	Condition class	Small poles—average age about 30 years			Large poles—average age about 50 years						
		Area	Dominants[1]		Area	Dominants					Total stocking[2]
						Trees under 6 inches[1]		Trees over 6 inches			
			Per acre	Stocking[2]		Per acre	Stocking[2]	Per acre	Average d. b. h.	Stocking[2]	
		Acres	*Number*	*Percent*	*Acres*	*Number*	*Percent*	*Number*	*Inches*	*Percent*	*Percent*
1	$\frac{1\bullet}{1\bullet+}$	343	397	61	191	182	23	96	8	34	57
2	$\frac{1\bullet}{1\bullet-}$	108	176	28	47	100	12	66	9	27	39
7	$\frac{1\bullet}{1\times+}$	55	370	58	31	153	19	56	10	25	44
9	$\frac{1\bullet}{1\times-}$	7	230	41	6	250	31	15	15	13	44
10[3]	$\frac{1\times}{1+}$	3	370	56	2	153	19	56	10	25	44
	$\frac{1\times}{1-}$	4	230	41							
22	$\overline{1\bullet+}$	703	302	54	560	103	15	104	8	37	52
23	$\overline{1\bullet-}$	365	129	22	171	60	8	55	9	23	31
27	$\overline{1\times+}$	24	322	52	31	220	25	120	8	45	73
	Total	1,642			1,039						
	Weighted average			47		116		91	8.3		49

[1] Includes dominant seedlings and saplings.
[2] Stocking computed from fig. 20, p. 46.
[3] Includes both pine and fir in the understory.

reach rotation age in the sixth cutting period. This is the key to the plan of regulation. Starting with the sixth cutting period the required 1,008 acres can be harvested and regenerated during each period without cutting stands below rotation age (figs. 26 and 27).

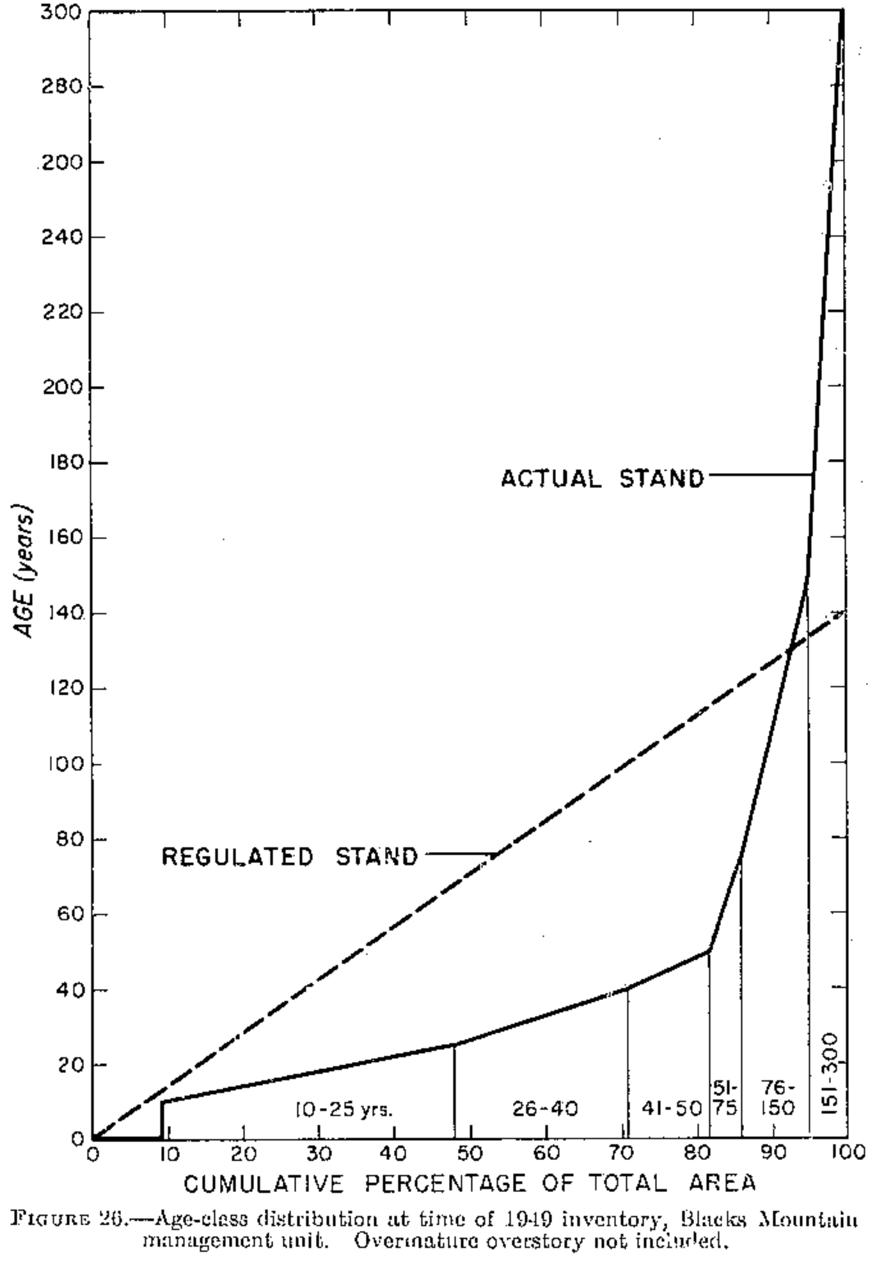

Figure 26.—Age-class distribution at time of 1949 inventory, Blacks Mountain management unit. Overmature overstory not included.

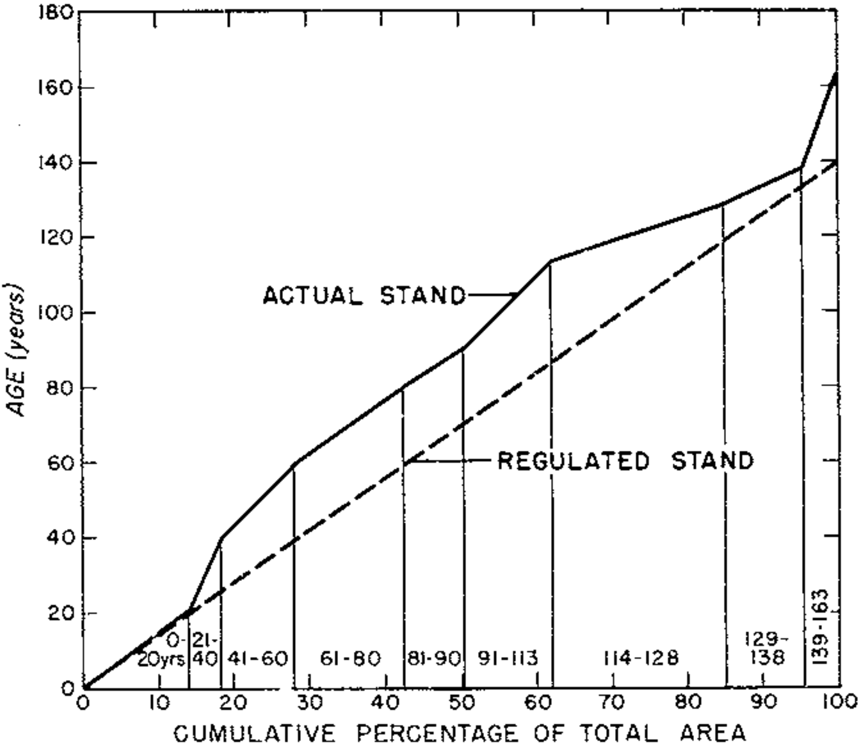

FIGURE 37.—Expected age-class distribution at beginning of sixth cutting period, Blacks Mountain management unit.

The unit areas of poles, seedlings, and saplings with and without an overstory, and the unit areas regenerated in the first five cutting periods, are allocated on an area basis to the sixth and seventh cutting periods of the first rotation and to the first five cutting periods of the second rotation. Starting with the sixth cutting period of the first rotation, an area of 1,008 acres will be cut and reproduced in each cutting period. Consequently a regulated stand with equal areas of each of the necessary age classes is expected at the beginning of the sixth cutting period of the second rotation.

Mature and immature age classes (1,000 acres) will be harvested in the fifth cutting period. Overmature age classes will be harvested in the periods before the fifth cutting period. Scattered overmature trees within the mature and immature age classes will be harvested in improvement cuts before the final harvest of the mature and immature age classes. Scattered merchantable trees in young condition classes without an overwood will also be harvested before the fifth cutting period.

The source of the cut for the first two rotations is summarized in figure 28.

Data from the cutting plots were used in computing the allowable cut. In setting dates for cutting periods and rotations, the first rotation was considered to have started with the beginning of cutting in 1937. However, growth is computed from 1949, the date of the

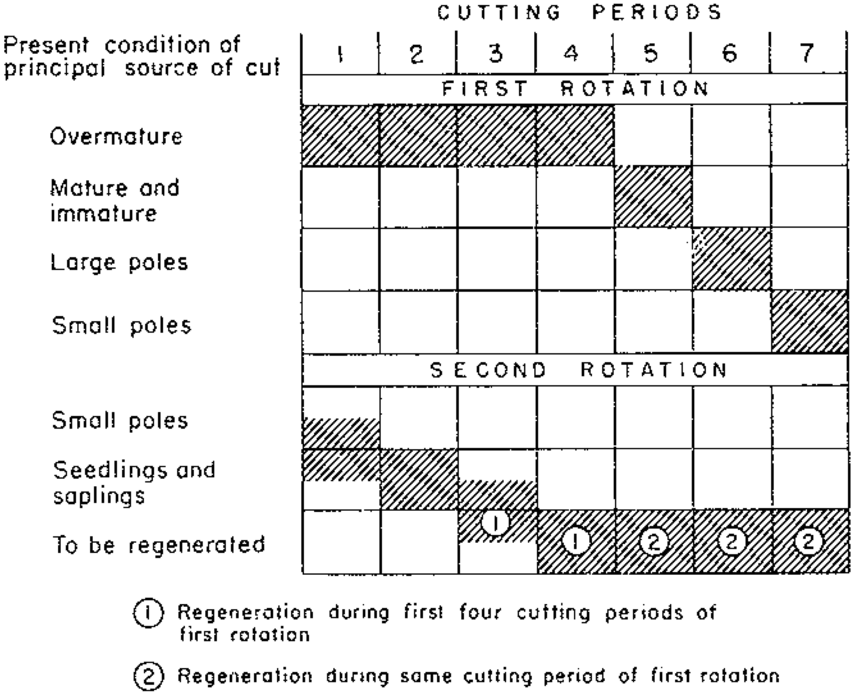

FIGURE 28.—Source of cut by cutting periods, management unit, Blacks Mountain Experimental Forest.

last inventory. The averages for all types of cutting by appropriate age or condition classes were used (tables 13–18).

Ingrowth for overmature age classes was not included because the ingrowth is part of the growth in released young stands and will be cut later. Ingrowth was included for the mature and immature age classes because these age classes will be clear cut and regenerated. For the immature age class, the rate of ingrowth used was the average of the ingrowth for mature and immature stands since immature stands will move into the mature age class before they are cut. To determine the period to which growth data apply, the number of years in which cutting will be carried on in the particular age class was divided by two in order to provide for the decreasing growing stock.

The calculations of the allowable cut for the balance of the first five cutting periods are summarized as follows:

2d, 3d, and 4th cutting periods	*Volume used in computations (M bd.-ft.)*	*Volume available for cut (M bd.-ft.)*
Overmature condition classes, volume in 1949	66, 564	
Cut 1949 through 1956	−20, 000	
		46, 564
Growth on uncut balance of 20,000,000 bd.-ft. (20,000+15,000, +10,000,+8,000,+6,000,+4,000,+2,000) × 0.41 percent		266
Growth on 46,564 M bd.-ft. (46,564×16 percent) (0.41 percent per year for 38 years=16 percent)		7, 450
Tree classes 5 and 7 in immature condition classes, volume in 1949		1, 000
Growth (1,000×11 percent) (0.28 percent for 38 years=11 percent)		110

2d, 3d, and 4th cutting periods	*Volume used in computations (M bd.-ft.)*	*Volume available for cut (M bd.-ft.)*
Tree classes 5 and 7 in mature condition classes, volume in 1949		1,188
Growth (1,188×8 percent) (0.22 percent for 38 years=8 percent)		95
Condition classes with scattered overstory, volume in 1949		6,149
Growth (6,149×24 percent) (0.62 percent for 38 years=24 percent)		1,476
Total		64,298
Allowable cut for 2d, 3d, and 4th cutting period ($\frac{64,298}{60}=1,072$)		1,070

5th cutting period	*Volume used in computations (M bd.-ft.)*		*Volume available for cut (M bd.-ft.)*
Immature condition classes, volume in 1949	5,213		
Growth (116 percent×5,213) (1.47 percent for 78 years=116 percent	6,047		
		11,260	
Tree classes 5 and 7, volume 1949	1,000		
Growth (22 percent×1,000) (0.28 percent for 78 years=22 percent)	220		
		−1,220	
			10,040
Ingrowth (49 bd.-ft.) for 78 years on 629 acres) ($\frac{86+12}{2}=49$)			2,404
Growth on ingrowth (63 percent×2,404) (1.86 percent for 34 years)			1,515
Mature age class, volume in 1949	4,577		
Growth (59 percent×4,577) (0.76 percent for 78 years=59 percent)	2,700		
		7,277	
Tree classes 5 and 7, volume 1949	1,188		
Growth (17 percent×1,188) (0.22 percent for 78 years=17 percent)	202		
		−1,390	
			5,887
Ingrowth (12 bd.-ft. for 78 years on 373 acres)			349
Growth on ingrowth (50 percent×349) (1.46 percent for 34 years =50 percent)			174
Total			20,369
Allowable cut for 5th cutting period ($\frac{20369}{20}=1,018$)			1,020

The source of the cut for the last 2 cutting periods of the first rotation and the first 5 cutting periods of the second rotation are summarized below:

Cutting period:	*Years*	*Acres*	*Present status*
6–1	2037–2056	1,008	Large poles.
7–1	2057–2076	1,008	31 acres large poles. 977 acres small poles.
1–2	2077–2096	1,008	665 acres small poles. 343 acres seedlings and saplings.
2–2	2097–2116	1,008	Seedlings and saplings.
3–2	2117–2136	1,008	1,003 acres seedlings and saplings. 5 acres to be regenerated during first 4 cutting cycles.
4–2	2137–2156	1,008	To be regenerated during first 4 cutting cycles.
5–2	2157–2176	1,009	9 acres to be regenerated during first 4 and 1,000 acres to be regenerated during 5th cutting cycle.

Present pole size and younger stands are expected to average 80 percent of yield table values at time of final harvest. For the stand 6.6 inches and over, the expected annual yield from final harvests will be 1,390,000 board-feet. Intermediate harvests will ultimately produce an additional yield equal to 50 percent or more of the final harvest, or 695,000 board-feet. Thus the ultimate total annual cut will be 2 million board-feet or more.

The allowable cut in terms of net scale is summarized below:

Period:	*Annual allowable cut (M bd.-ft.)*
1955–1956	2,000
1957–2016	1,070
2017–2036	1,020
2037 and thereafter	2,085

The cut is tentative for periods after the next plan revision, which will be after 1962. In 2037, the cut includes 1,390,000 board-feet from final harvesting and 695,000 from intermediate cuts.

This plan will be amended and the allowable cut recalculated if necessary because of excessive losses due to fire or other disasters. The scattered dead trees cut as part of normal cutting will be included in the allowable cut, except when the sale provides for a separate scale of dead trees.

Cutting Budget

The cutting budget until 1962, the year for the next plan revision, is shown in table 25 and the budgeted areas are shown in figure 29. The expected cut from methods-of-cutting plots and compartments not in the management unit is shown. Material harvested from these areas is in addition to the allowable cut from the management unit.

TABLE 25.—*Cutting budget, Blacks Mountain Experimental Forest*

1956

Compartment	Volume cut		Reserve		Area
	Total	Per acre	Total	Per acre	
Management unit:	*M bd.-ft.*	*M bd.-ft.*	*M bd.-ft.*	*M bd.-ft.*	*Acres*
B 25-1	600	5.3	970	8.6	112.7
B 30-1	440	5.2	591	6.9	85.1
B 30-3	330	5.8	430	7.6	56.6
B 30-6	310	6.0	445	8.7	51.3
G 9-10	320	8.6	288	7.7	37.3
Total	2,000				
Plot 1, Block 46	200				
Total	2,200				

1957

Compartment	Volume cut		Reserve		Area
	Total	Per acre	Total	Per acre	
Management unit:					
C 2-21	180	[1] 4.9	537	[2] 11.3	[2] 47.5
C 8-30	810	8.7	817	8.8	93.1
C 9-22	80	2.3	186	5.3	35.0
Total	1,070				
Plot 3, Block 47	200				
Total	1,270				

See footnotes at end of table.

TABLE 25.—*Cutting budget, Blacks Mountain Experimental Forest*—Continued

Compartment	Volume cut		Reserve		Area
	Total	Per acre	Total	Per acre	
1958					
	M bd.-ft.	*M bd.-ft.*	*M bd.-ft.*	*M bd.-ft.*	*Acres*
Management unit:					
C 5-29	350	5. 7	481	7. 9	61. 2
C 11-33	270	5. 0	359	6. 7	53. 4
C 13-31	450	5. 2	606	7. 1	85. 9
Total	1, 070				
1959					
Management unit:					
C 1-23	410	5. 2	412	5. 2	79. 2
C 5-25	660	7. 2	594	6. 5	91. 9
Total	1, 070				
1960					
Management unit:					
P 23-26	1, 070	11. 7	659	7. 2	91. 3
1961					
Management unit:					
P 25-29	620	6. 0	778	7. 5	103. 7
P 26-25	450	9. 3	490	10. 1	48. 3
Total	1, 070				
1962					
Management unit:					
P 27-28	660	8. 5	349	4. 5	77. 2
P 30-28	410	4. 1	480	4. 8	100. 9
Total	1, 070				

[1] Approximately 36.6 acres not cut in 1954 to be cut.

[2] Whole compartment.

Permissible Deviations From Allowable Cut and Cutting Budget

The total cut from the management unit for any one year shall not exceed the allowable cut for that year by more than 25 percent unless there is a cumulative undercut. The cumulative overcut from the management unit at any time shall not exceed 50 percent of the current year's allowable cut.

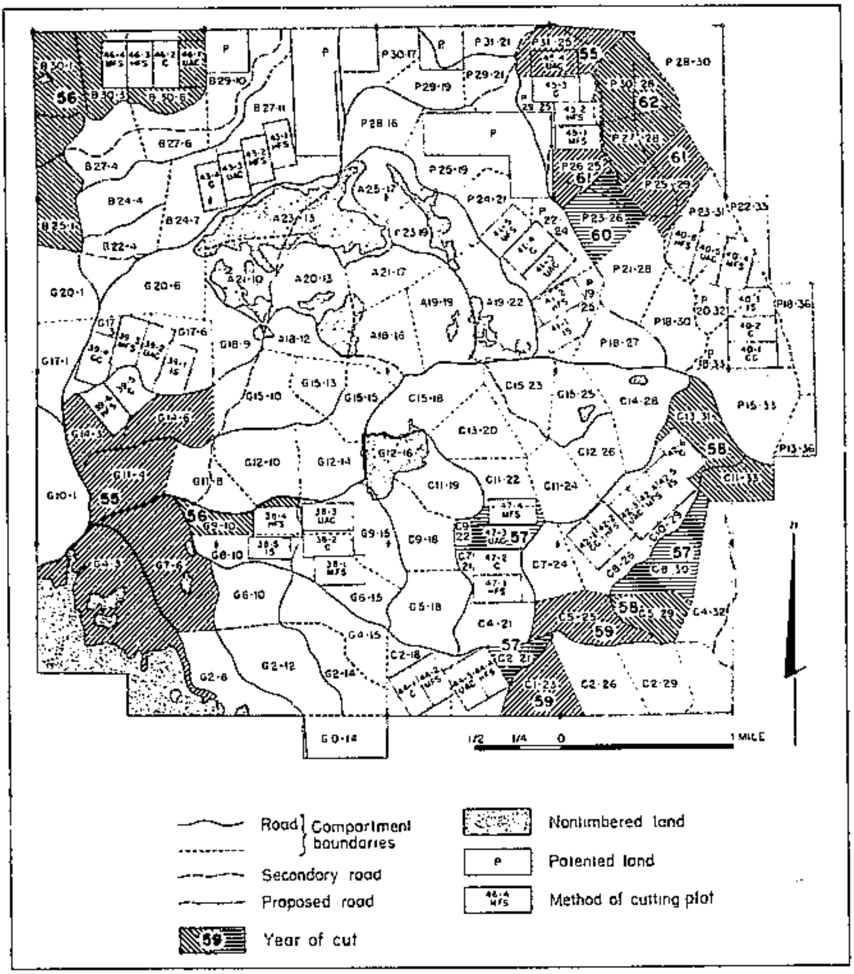

Figure 29.—Areas budgeted for cutting 1956 through 1962, management unit and special plots, Blacks Mountain Experimental Forest.

At the present time there is an undercut of approximately 2 million board-feet. This volume will be held in reserve for unusual operating contingencies. This undercut is based on a planned total cut of 20 million board-feet for the period 1950 through 1956 on the management unit.

The budgeted cut on any single compartment shall not be exceeded by more than 25 percent. Lighter cuts are permissible if stand conditions warrant. The marked tree volumes after estimated adjustments for difference between volume-table volumes and net landing scale will be the base for computing cut on single compartments.

The forest manager can change the location of the annual cut for good reasons that are substantiated by a written record for the files and approved by the project leader.

Cutting Restrictions on Special Compartments

Compartments B 24–7 and GO–14 have been reserved for the use of the Division of Forest Insect Research and will be cut under its direction. Compartment B 24–7 has been cut once for sanitation-salvage. These two compartments are not in the management unit.

Compartments A 21–10, B 24–4, C 4–21, G 2–12, and P 21–28 will be held uncut as natural areas. Compartment B 29–10 is reserved for special research projects. These compartments are not in the management unit.

Compartment B 29–10 and the following compartments in the management unit have been sanitation-salvage cut only: B 27–4, B 27–6, C 7–24, C 14–28, G 2–14, G 8–10, G 15–10, G 17–3, G 17–6, G 18–9, P 18–33, P 20–32, and P 23–31. In order to determine the effect of sanitation-salvage cutting, no additional cutting will take place in these compartments until after 1962. At that time it will be decided in cooperation with the Division of Forest Insect Research which, if any, will be held uncut for a longer period. The restricted compartments are shown in figure 30.

SILVICULTURAL GUIDES

Silvicultural treatments will be controlled by the long-term goals described in the sections on objectives and regulation. In order to reach the objectives, establishing or maintaining control of the ground with trees is essential and has first priority. Testing and demonstrating even-aged management of ponderosa and Jeffrey pine is a specific research objective.

The methods and principles of unit area control will be followed. Each unit area of a specific condition class is given its appropriate cutting and all other necessary treatment at the proper time.

Cutting and Marking

The complexity of the forest prevents drawing hard and fast cutting or marking rules that will cover all situations. Although the following guides will ordinarily be observed, the marker should deviate from them if necessary to meet the management objectives. Rather than follow these guides slavishly, the marker should use his silvicultural knowledge and his ingenuity. He should have sound reasons that he can defend for cutting or leaving trees whether or not he follows these guides.

In order to cut in each compartment during each cutting period, a reserve of 6,000 board-feet or more per acre is desired. The desired reserve will be maintained by deferring the cut on selected unit areas, rather than by distributing the cut more or less uniformly over a whole compartment. However, when a low volume or a decadent condition of the stand preclude leaving the desired reserve, a smaller reserve will be left and a cut in one or more future cutting periods may be omitted. Both of these factors were considered in establishing the cutting budget by compartments.

The initial cutting treatments to be applied are release cuts, regeneration cuts, and improvement cuts. Also, on unit areas for which the final harvest has been deferred, a sanitation-salvage cut will be made if high-risk trees are present.

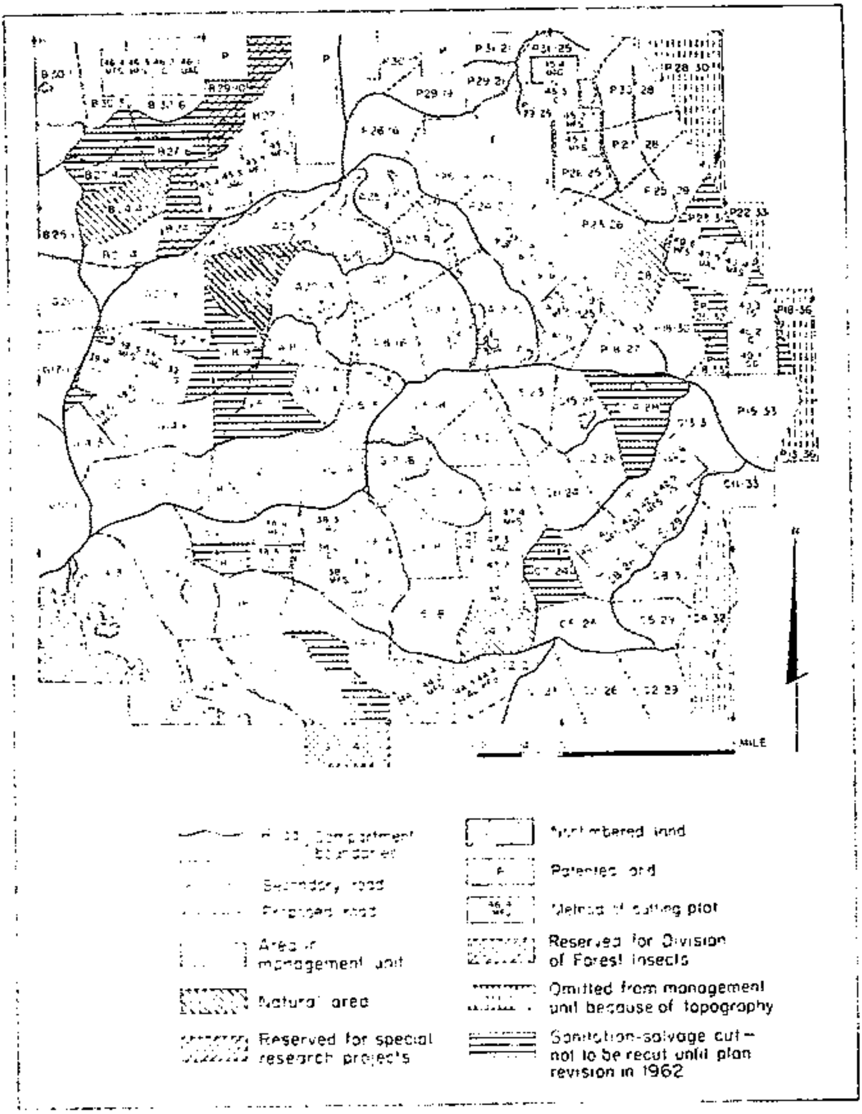

FIGURE 30. Blacks Mountain Experimental Forest, showing management unit and areas set aside for special purposes.

Release cuts will be made in overmature units with acceptable stocking of poles, seedlings, and saplings. A minimum stocking of 25 percent has been set up as a guide; however, fill-in planting is not practical in understocked pole and sapling stands unless the poles and saplings are widely spaced. Consequently, the following standards of acceptable stocking have been set for young growth that is to be released.

A stocking (after logging) of 2 crop trees per square chain in pole stands and 7 crop trees in sapling stands (10 feet or taller) will be accepted. Twenty-five good seedlings per square chain will be required for seedling stands. Where release cuts are made, all of the overstory will be removed. An occasional thrifty tree, class 1, may be left over seedlings and saplings if it can be carried until the first intermediate cut and its growth is likely to be greater than reduction in growth of the seedling stand. Ordinarily, merchantable trees that are thrifty and well-formed and of Dunning tree classes 1, 2, and 6 will be left in pole stands to form part of the final crop or to be cut in intermediate cuts.

Regeneration cuts are made in overmature unit areas with an understory stocking that is less than the acceptable standards just described. Although natural regeneration is preferred, much of the regeneration will be by artificial means because good seed years are infrequent.

If a good seed year is at hand, natural regeneration will be attempted. The unit area will be clear cut except for a border of seed trees. Sufficient seed trees to provide cones at the rate of 800 or more per acre will be left around the border. Seed trees should be suitable for carrying as a reserve until the next cutting period.

Rodents must be controlled with lethal bait and slash and vegetation removed before seed fall in September. Advice from or cooperation with the Fish and Wildlife Service should be obtained before engaging in a large-scale rodent control project. If the natural catch of seedlings is inadequate, the area should be planted during the next planting season.

If a good seed crop is not present or suitable seed trees are not available around the border of the unit area, it will be clear cut and planted the next spring after the slash has been eliminated and competing vegetation eradicated.

The minimum size of unit area that will be considered for a regeneration cut will be one-fifth acre. Regeneration areas less than one-half acre in size should be avoided if possible. Areas less than one-half acre in size will not be regenerated if the central part is adequately stocked. Overmature unit areas less than one-fifth acre in size, or less than 1 chain wide regardless of total area, will be harvested with adjoining areas even though stocking of advance growth is below the minimum.

Artificial regeneration will be confined to unit areas of site 3 and 3½ until more is known about costs, growth rates, and the possible returns of planting on site 4. For unit areas on site 4 needing artificial regeneration, the cut will be deferred until the cost and growth data are available and a definite decision can be made.

Improvement cuts will be made in mature and immature stands. During at least the first two cutting periods, improvement cuts will supply only a very small percentage of the volume removed. The cut will include chiefly high-risk trees, trees of Dunning class 5 whose removal will markedly increase the growth on the residual trees, and poorly formed or defective trees whose removal will benefit the stand. An occasional large, limby wolf tree, even though young, will be removed from immature age or pole stands if its removal releases good, thrifty crop trees, and if it can be removed without excessive danger to the reserve. All high-risk trees in any reserve area will be cut whenever the compartment is cut.

Harvesting isolated trees

Isolated individual trees over pole, seedling, and sapling stands will usually be cut. But young, vigorous trees may be left if their cutting can be deferred until the first intermediate cut and their expected growth will exceed the growth retardation to the poles, saplings, or seedlings.

Isolated trees should also be left if the logging damage to the young stand will exceed the value of the tree. It is not expected that many isolated trees will be left for either of the above reasons.

Treatment of subordinate species

White fir and incense-cedar will be replaced by pine whenever possible. This will be accomplished only when some form of product can be sold. On good planting sites, white fir seedlings and saplings should be sold for Christmas trees when possible and replaced with planted pine. Whenever possible, the Christmas trees should be sold before logging the overstory.

Merchantable white fir of any age should be cut when by doing so a planned regeneration area can be enlarged. Scattered seedlings, saplings, and small poles of white fir in and around the borders of regeneration areas should be removed during site preparation.

Controlling dwarfmistletoe

Dwarfmistletoe is present on small areas. Where infections occur in an overmature stand, final harvest should not be deferred. Trees infected with mistletoe in small units of mature and immature age classes should be harvested if they are a source of infection for adjoining noninfected advance growth. Final harvesting of large blocks of infected mature and immature trees may be deferred.

In seedling and sapling stands, trees infected with mistletoe will be removed in thinning operations after the overstory has been cut. Small scattered patches of seedlings and saplings so heavily infected that there are insufficient uninfected crop trees should be destroyed and the areas planted. If extensive areas of seedlings and saplings are found to be heavily infected with mistletoe, special analysis and plans should be made.

Cleanup of heavily infected pole stands should ordinarily be deferred until the stand is merchantable. In lightly infected pole stands, mistletoe can be eliminated by thinning and pruning.

Marking for efficiency in logging

The effect of marking on present and future logging costs should be considered. Some of the actions that can be taken are (1) blocking out reserves; (2) cutting isolated individual or small groups of trees; (3) marking additional trees for improvement cutting where isolated high-risk trees must be cut; and (4) omitting very light improvement cuts in areas that are a considerable distance from the landing and other cutting. Besides reducing costs, these actions lessen logging damage by eliminating long skidding distances for relatively few logs.

Selection of unit areas for cutting or leaving

To lessen the border effects of older trees, all of the overmature unit areas will be harvested in blocks of 5 to 50 acres. Occasionally, because of decadent stand conditions, the areas of complete harvest may be larger than 50 acres. Reserve timber will be carried on adjoining blocks on which final harvest will be deferred. Occasional extremely decadent overmature unit areas may be harvested in the reserve areas.

Overmature unit areas of highest priority for harvesting will be the starting points in selecting areas on which all overmature groups will be harvested. Mature and overmature units most suitable for carrying as reserve will be the starting points in selection of areas for light cutting. Other units will be balanced between heavy and light cuts to achieve the established cut for the compartment and the desired size of cutting blocks. The blocks on which all overmature unit areas are harvested should preferably be about 20 acres but not less than 5 acres.

Overmature unit areas with a high priority for early cutting are those with (1) high-risk trees making up 25 percent or more of the total; (2) white fir admixtures; (3) relatively large sized trees; and (4) mistletoe present in overstory.

Overmature groups with admixtures of younger trees have a high priority for deferred cut.

Parts of compartments with few overmature unit areas left should usually be selected for complete harvesting and those with numerous mature and immature unit areas should usually be selected for light cutting.

Post-Logging Care of Cut-Overs

Treatments after cutting will be site preparation for regeneration, planting or seeding when adequate seed crops are not present or when natural regeneration fails, pruning of selected crop trees, and thinning in overdense seedling and sapling stands.

Site preparation for regeneration

The ground surface on regeneration areas will be prepared by removing and piling the slash and competing vegetation with a bulldozer. A toothed blade or rake is preferable to the conventional bulldozer blade. Only enough of the slash need be removed to permit easy planting or, when natural regeneration is expected, to expose sufficient bare mineral soil for a good seedbed. However, all competing vegetation should be eliminated.

Planting

At the time of the inventory in 1949, 1,415 acres were classified as unstocked or stocked so low that fill-in planting was needed. However, in the inventory, units as small as 1 square chain were classed as needing planting. Observations during marking and cutting since the inventory indicate that some of the areas so classified are too small to be considered. Consequently, current estimates indicate about 1,000 acres need supplemental regeneration. To restock these areas by the end of the fourth cutting period, 10 to 20 acres should be regenerated in most years. Because of the small area in need of regeneration on some compartments, less than 10 acres may be regenerated in some years.

Estimated areas to be regenerated on the management unit during the period covered by the present cutting budget are as follows:

Year and compartment	*Area to be regenerated (acres)*
1956:	
B 25–1	0
B 30–1	9
B 30–3	4
B 30–6	2
G 9–10	2
Plot 1, Block 46	2
	19
1957:	
C 2–21	1
C 8–30	4
Plot 3, Block 47	1
	6
1958:	
C 5–29	3
C 11–39	4
C 13–31	12
	19
1959:	
C 1–23	1
C 5–25	4
	5
1960:	
P 23–26	7
1961:	
P 25–29	5
P 26–25	3
	8
1962:	
P 27–28	8
P 30–28	12
	20

Because seed crops are infrequent, artificial regeneration will be relied on most of the time. Until satisfactory methods of direct seeding are found, 1–1 ponderosa or Jeffrey pine nursery stock will be planted. Although preliminary tests indicate that ponderosa pine planting stock is preferable to Jeffrey pine, the latter should be used near sagebrush flats where frost damage may be a problem.

A guide for fill-in planting and for determining the width of the marginal unplanted strip around the borders of unit areas follows: Do not plant closer to any live trees than 7 feet plus 1 foot for each inch in diameter of the existing tree or trees, up to a maximum distance of 20 feet.

Pruning

Selected crop trees will be pruned to produce high-quality saw logs or peeler bolts. Trees will be pruned to heights in multiples of 4-foot peeler bolts. Heights ordinarily used will be 10 feet, 14 feet, and 18½ feet above the ground. This provides for 1.2 foot stump and 0.3 foot trimming allowance per bolt.

Crop trees will be selected in advance of pruning by a trained marker. Selected trees should meet the following requirements:

1. Be on areas from which the overstory has been removed. No crop trees should be within 30 feet of or under lean of an older tree.
2. Be either vigorous dominants or codominants made dominant by release.
3. Be capable of a growth of ¾ inch per 5 years or more—13 rings per inch or less.
4. Be selected at the rate of 7 per square chain or less (70 per acre). (Applies to net area of pole group with unstocked areas eliminated.)
5. Be on unit areas where the average d. b. h. of the dominants is 12 inches or less.
6. Have an average branch size of 2½ inches or less.

7. Not have the following disqualifying characteristics:

(1) Crook
(2) Rot
(3) Large scars
(4) Bayonet-top
(5) Mistletoe in:
    (a) Trunk
    (b) Branches above pruning height
(5) Mistletoe in—Continued
    (c) Branches to be removed by pruning if within 1 foot of the trunk
(6) Excessive sweep
(7) Forks

8. Have at least four-tenths of total height of tree in live crown after pruning.

Thinning

Except in seedling and sapling thickets, stands usually will not be thinned unless a marketable product can be harvested. A spacing of 9 by 9 feet will be used in thinning seedling and sapling stands. Occasionally poorly formed trees may be removed to free a potential crop tree for pruning. On some areas, cleanings may be necessary in seedling and sapling stands in order to eliminate mistletoe. An occasional mistletoe-infected tree may also be removed from pole stands.

A large-scale study of thinning costs is planned for overdense seedling and sapling stands. If this study shows that such stands can be thinned economically, they will be thinned after the overstory has been removed.

In mixed stands of pine and fir seedlings and saplings, thinning will be accomplished partly by Christmas tree sales.

STAND ENEMIES

The forest manager must be on the alert to detect any potential losses from insects or disease and take appropriate action. No known conditions require treatments other than those already discussed. Mistletoe damage in seedling and sapling stands, however, needs to be more fully evaluated and special measures should be taken if the damage proves heavy.

Porcupines are a serious hazard to the younger condition classes. A plan of control by poisoning and shooting is in operation and will be continued.

LOGGING

Skidding usually will be done with a skid cat and winch. Arches will not be used unless approved by the forest manager for special situations.

As all compartments have been cut over at least once, existing skid roads will be used. New roads will be held to the absolute minimum.

Tractor roads shall be flagged prior to felling so that trees can be felled towards the roads.

Because the bulk of the volume during the first cutting periods will come from release cuts, prevention of logging damage is a job of very high priority.

SNAG FALLING AND SLASH DISPOSAL

Snags will be felled currently after logging is completed each year. They will ordinarily be felled with a power saw. Pulling, pushing, or burning snags is not recommended. Pulling and pushing snags with

tractors often causes excessive damage to young growth. Burning snags is undesirable because sometimes the fires carry over until spring; also the job cannot be done efficiently during average winters at Blacks Mountain, and consequently snags remain during part of another fire season.

Slash disposal will be carried on only in 50-foot strips on each side of roads, where the slash will either be piled and burned or lopped when the residual stand makes burning undesirable, and in areas clear cut for regeneration. Slash disposal on regeneration areas is conducted as part of site preparation.

TRANSPORTATION

Except for about 2 miles of road on the upper slope of Patterson Mountain, the entire road system for the experimental forest is completed. The road necessary for logging the upper slope of Patterson Mountain will be constructed at the time of logging.

Logs can be trucked over public roads to mills at Little Valley, approximately 15 miles; Susanville, 40 miles; Chester, 45 miles; and in the Burney area, 50 miles. The Western Pacific Railroad passes within 2 miles of the experimental forest and logs could be hauled by rail to mills at Little Valley and Susanville and more distant points, if a suitable rate could be obtained for the small volume of timber cut.

RECORD KEEPING

Records will be kept to aid in carrying out this plan and to furnish a history of the operation of the pilot-plant test of forest management.

Cutting

Trees marked for cutting will be tallied by d. b. h., species, Dunning tree class, and condition class. Annual summaries of volume marked will be prepared for each compartment.

Gross and net scale will be kept for each compartment. Summaries showing annual and cumulative cut by species will be prepared. Where the scale has not been kept separate by compartments, the scale will be prorated to compartments on the basis of marked volume.

A record of the total seasonal cut will also be kept, and will include the cut by years and cumulative cut.

Regeneration and Timber Stand Improvement

Annual and cumulative records by compartments and for the management unit will be kept of the acres and number of trees or seed spots planted. Compartment maps will be prepared showing location of unit areas planted. Records and maps of areas regenerated naturally will also be kept.

The total number of trees pruned will be recorded for each compartment. The trees will be counted at the time of marking for pruning. The d. b. h. and height pruned will be recorded for every tenth tree tallied. Annual and cumulative summaries will be prepared showing number of trees and gross area pruned in the management unit.

Costs and Receipts

The cost of all activities will be recorded and summarized annually. Cumulative records of all receipts will also be kept.

Forms

When necessary the forest manager will prepare new forms or revise existing forms so that the essential records and summaries can be economically kept in readily usable form.

COORDINATION WITH OTHER USES

Water Use

Slopes are moderate, most of the precipitation occurs as snow, and the soil is highly permeable. Surface flow from the experimental forest enters a flat without an outlet. In fact, much of the water sinks into the ground before it reaches this flat. Consequently, special consideration for water relations will be restricted to maintenance of proper drainage on the forest roads and installation of water diversion cross-checks on steep skid roads.

Grazing

The experimental forest is within a regular cattle allotment of the Lassen National Forest. No critical problems have arisen as yet. If grazing damage to new reproduction should become excessive, a supplement to this plan will be prepared to cover the situation.

COORDINATION WITH LASSEN NATIONAL FOREST

Insofar as is consistent with the research objectives of the experimental forest, sales policies, utilization standards, and scaling practices will conform with the policies in effect on the Lassen National Forest.

PLAN REVISION

This plan will be revised in 1962, and the fieldwork for the revision should be completed in 1961. The revision should be based on a condition-class map of the experimental forest. This map should be prepared from aerial photos on a scale of approximately 1:10,000. The pole size and younger condition classes should be separated into three or more age classes instead of the two size classes as in the 1949 inventory. The limits of these age classes will depend somewhat on the distinction that can be made on the photos. Research on techniques in the application of aerial photos in condition class mapping and volume inventory would be highly desirable before the reinventory.

If the conditions warrant, this plan may be amended by memorandum before 1962 if approved by the Chief of the Forest Management Division, California Forest and Range Experiment Station.

U. S. GOVERNMENT PRINTING OFFICE 1959

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