CHAPTER IV

CONTRAST BETWEEN EXTENSIVE CLEAR CUTTING AND SELECTIVE MANAGEMENT OF PURE DOUGLAS FIR ON A ROUGH MOUNTAIN AREA

18. Object of study.—The object of this chapter is to indicate the opportunities for successful application of selective timber management to an area which differs widely from that described in chapter III; to show the advantages of motorized methods of transport as a substitute for cable yarding and railroad transport in logging selectively managed timber in rough country; and to show the opportunities for developing. a permanent, low-cost road system, which can become the key to profitable and continuous management.

19. General description of tract.—The tract in question is approximately 74,000 acres of Douglas fir timberland in southern. Oregon. (See Plate I.) The control point to the tract as a whole is the confluence of the two main branch streams, indicated at the left margin of the map. From this point, designated on the map as "proposed mill site", a logging railroad and a highway extend into the tract.

Topography and divisions.—The topography of many parts of the tract is extremely steep and rough-typical of the rugged foothills of the western Cascade region. The main valley, near the proposed mill site, is at an elevation of about 1,000 feet. Thence the slopes rise in all directions to a maximum elevation of 5,000. feet. The north, east, and south boundaries of the tract generally follow watershed divisions, at elevations of 3,000 to 4,500 feet.

Although it forms one compact body of timberland, the tract divides naturally into two major topographic units, which are portions, respectively, of the watersheds of the two main branch streams. The upper unit has for purposes of management been divided into eight blocks, which will be referred to by the numbers given them on the map. The lower unit, much of which is yet unmapped, has not been so divided, and will be referred to as block 9. This block includes an irregular area of about 8,000 acres extending to the southeast beyond the portion shown in the lower right-hand corner of the map; large portions of this area support only noncommercial timber.

Timber.—Of the 73,800 acres included in the tract as a whole, 11,000 acres are classified as nonproductive forest land supporting only non-commercial timber. For the remaining 62,800 acres, classed as productive timberland mainly of sites II and III, three classes of Douglas fir timber are distinguished in different colors on the map:

1. Second growth 1 to 20 years old, occupying 10,000 acres (including block 1, which has been logged).
2. Second growth 60 to 120 years old, occupying 12,000 acres and having a merchantable volume of 400,000 M feet.
3. Old growth, 300 to 400 years old, occupying 40,800 acres, with a total stand of 2,100,000 M feet.

The merchantable volume of both second-growth and old-growth stands thus aggregates 2½ billion feet over an area of 52,800 acres, averaging approximately 50 M feet per acre. The old-growth stands are on the whole very defective, as is typical of timber in this part of the western Cascade region. The best timber lies generally at elevations of 2,500 to 4,000 feet. It consists almost entirely of pure stands of fairly even-aged Douglas fir; only 12 per cent of its total volume is made up of other species, principally western hemlock, western red cedar, and silver fir.

20. Clear-cutting management plan as based on cable yarding.—This area constitutes a sustained yield unit for which a working plan was prepared in 1922. The plan was based on the clear-cutting system of cable logging. It provides for progressive removal of the existing merchantable growing stock at the rate of 36 to 40 million feet per year over a period of. 70 years, followed by 10 years' cut in blocks 1 and 8 (1-20 year age class), by which time a second cutting cycle would begin in the areas cut over first (80 years rotation). Under this plan cutting during the first 10 years would be confined to block 2 (block 1 having already been logged), which contains a total volume of 380 million feet. The next decade would see the cutting of block 3, which likewise contains 380 million feet. Cutting in the third decade would be divided among blocks 4, 5, and 6; and cutting in the fourth decade, between blocks 6 and 7. This would complete the logging on the upper unit, with its total stand of 1½ billion feet. Thereafter the lower unit (block 9) would be logged at the same rate of about 40 million feet per year. The original timber volume on block 9 is 1 billion feet, or sufficient for 25 years of logging. Growth accruing in the 12,000 acres of stands now 60 to 120 years old over a period of about 60 years is expected to supply an additional 5-year cut to fill out to the end of the 70th year.

This cutting program is set out in table 8 (from which is omitted the 8th decade cut in blocks 1 and 8).

TABLE 8.-*Cutting schedule, under clear-cutting management plan, for sustained yield unit by blocks and decades*

Block	Cut in million feet b.m., by decades							
	1st	*2nd*	*3rd*	*4th*	*5th*	*6th*	*7th*	*Total*
2	380	…	…	…	…	…	…	380
3	…	380	…	…	…	…	…	380
4	…	…	170	…	…	…	…	170
5	…	…	140	…	…	…	…	140
6	…	…	70	90	…	…	…	160
7	…	…	…	270	…	…	…	270
8	…	…	…	…	…	…	…	…
9	…	…	…	…	400	400	[1]400	1,200
Total	[2]380	380	380	360	400	400	400	2,700

[1] Including 200 million feet contributed by growth, during first cycle, in second-growth stands now 60 to 120 years old.

[2] Intermingled privately owned timber is available to permit a full cut of 400 million board fee.

The order in which the various blocks enter into the cutting schedule follows a plan of economic selection by large units of area; for example, block 2 is taken first because of its accessibility and heavy stand of mature timber, and a 10,000-acre area of 60- to 120 year-old second-growth timber in block 9 comes last owing to the thrifty character and present low value of this young stand.

The same order of cutting and the same general scheme of clear cutting block by block would probably be followed were this area privately owned. A private owner, however, would probably strive to shorten the 70-year operating period to perhaps 20 or 30 years by increasing the annual output, provided he could obtain so large a share of the available market. The conclusions reached in the following study are no less significant from the point of view of the private operator who at the outset would think of this tract only in terms of a 20- to 30-year liquidation period than they are from that of the public owner which from the beginning plans on sustained yield.

21. Comparison of road layouts, logging methods and costs under cable and motorized logging.—Logging costs, road layouts, and logging methods will be discussed in considerable detail in this case-study for the reason that logging problems demand first attention in any proposed plan of intensive timber management for this rough and mountainous area. The management plan to be successful must be based on practical and efficient methods of logging. This question will be examined by comparing costs of cable logging and motorized logging for block 2, which is the first block on which cutting has been planned. This area, which in topography and timber is fairly typical of most of the old-growth portions of the unit, comprises over 6,000 acres with a stand averaging about 63 M feet per acre and totaling 400 million feet (including 20 million feet of privately owned timber). The stand consists of 91 per cent Douglas fir, mostly old growth; 6 per cent hemlock; and 3 per cent western red cedar and other species. Under the very general scheme shown in Plate I all this timber is classified as “loggable old growth”.

The main-line logging railroad already constructed was designed to tap this and other blocks in the main watershed. The end of the track is at the mouth of the creek which flows south through the center of the block. Under the cable-logging plan, spurs would be built from this main line into all parts of the block so as to provide a practical layout for cable logging.

A detailed topographic map of block 2 is reproduced as Plate II. On this map the railroad-spur layout required under cable yarding is shown for the west half of the block. Superimposed in red lines on the same map is shown the proposed location of roads which might be substituted for the railroad spurs if the area were logged by truck and tractor methods, supplemented where necessary by cable yarding and swinging. Comparison of road construction costs as well as of complete logging costs under these two plans is facilitated by the fact that a detailed appraisal report covering the cable-logging plan is available; This appraisal, by two competent logging engineers, was made in 1928 in connection with a proposed sale of the block.

Sharp contrast shown in road construction costs.—Under cable logging the railroad location and construction problem for this block, as will be seen from Plate II, is rather difficult. The end of the existing railroad is at an elevation of about 1,500 feet. The bulk of the timber lies at elevations of 2,000 to 4,000 feet and steep canyon slopes form difficult barriers against entry into the main parts of the tract. For this reason the projected main spur tapping the west side of the block follows a circuitous route, mostly along steep slopes, and rises for several miles on a 5 per cent compensated grade. This makes for a long, costly haul and high construction costs.

The railroad problem for the east side is quite similar to that of the west side. The entire block would require about 40 miles of spurs, including sidings and loading spurs. The cost of constructing these spurs, excluding relaying of temporary track, is estimated in the appraisal report at $355,850.

Under the plan for motorized logging the existing main-line railroad and its projected extension remain as before; but only 1 mile of spur is retained. This runs north along the creek through the center of the block. From the end of this spur (beyond which the grade becomes too steep for railroad construction) a "one-way" truck road about 21½ miles long would be built along the creek .to the north end of the block. The cost of constructing the railroad spur with sidings and landings, is estimated at $10,000, and that of the truck road at $12,000.

The 30 miles of main tractor roads shown on the map should be considered a part of the primary road system; these are the key roads by which as much of the area as practicable would be made suitable for low-cost downhill tractor logging. The most important of these roads are located primarily with a view to getting direct access from the railroad to the "easy tractor ground" above the steep slopes and bluffs. At the same time, they would serve to break up many of the long steep slopes in such a way that low-cost short-distance yarding with tractor-mounted drum units would become feasible for much of the nearby timber.

Portions of these 30 miles of main tractor roads would be built along very steep slopes. Four miles of such construction are estimated to cost from $1,000 to $4,000 per mile and to average $2,000. For the remaining 26 miles the cost is estimated to vary from $100 to $1,000 per mile and to aggregate $10,000. Many of these roads skirt the lower edges of the favorable tractor logging areas, where they provide an outlet for timber that will be brought in over numerous branch trails. Others provide the most favorable return routes to the more distant portions of the, area. In the latter case the route of travel in bringing the loads to the landing would frequently be more direct than the return route.

The estimated cost of main tractor roads would thus aggregate $18,000, and this together with the estimated $22,000 for the railroad spur and truck road would bring the total cost of road construction, exclusive of the mainline logging railroad, to $40,000, equivalent to $0.10 per M feet. This represents only about 11 per cent of the estimated cost of spur-grade construction under the cable logging plan.

In the foregoing comparison no provision has been made for the construction of perhaps 100 to 200 miles of branch tractor-trails. Many of these would be constructed with a bulldozer in. the same way as the main tractor roads, but the majority of them would simply develop in the course of the yarding operations, because the ground surface on this tract is generally smooth enough to permit tractor travel unhindered except by windfalls. The cost of developing these trails, whether as a part of the yarding operations or through actual construction, is in a practical sense a part of the day-to-day yarding cost, and will be so designated in the following comparisons of logging costs.

Comparison at tractor-logging cost for tractor areas and cable-logging cost for block 2 as a whole.—From the point of view of logging costs and methods block 2 (see Plate II) is divided into the fol1owing classes of areas:

(a) Tractor areas, comprising approximately 280 million board feet of timber located on generally favorable tractor ground. Small portions of these areas will require drum units for yarding.

(b) Intermediate areas, comprising about 80 million board feet located on steep ground. Drum-unit yarding, bob-tail tractor yarding, tractor roading, cable-yarding and skyline swinging may be used for various portions.

(c) Cable-yarding areas, comprising about 40 million board feet on the steep canyon slopes of the upper end of the block; this timber would be hauled by motor truck to the railroad.

TABLE 9.-*Estimated logging costs for tractor areas at Block 2 under tractor-logging plan as compared with estimated costs for Block 2 under cable-logging plan*

Item	Cost per M feet b. m.		
	Cable logging plan All areas		Tractor-logging plan, tractor areas only 1934 Estimate
	1928[1] Estimate	1934[1] Estimate	
Stump to track			
Falling and bucking	$1.57	$1.26	$1.26
Yarding and loading	2.70	2.16	[2]2.50
Rigging ahead	.21	.16	([3])
Wire rope	.30	.24	([3])
Total	$4.78	$3.82	$3.76
Railroad transportation			
Labor and fuel (total)	.54	.43	.22
Maintenance			
Railroad grade	.20	.16	.08
Railroad equipment	.20	.16	.08
Logging equipment	.33	.26	([3])
Total	.73	.58	.16
General expense			
Supervision	.57	.46	.46
Miscellaneous	.18	.14	.14
Total	.75	.60	.60
Depreciation			
Main-line railroad	.20	.16	.16
Spur construction	.80	.64	.02
Railroad equipment	.17	.14	.07
Logging equipment	.45	.36	([3])
Main tractor-road construction	.00	.00	[2].10
Total	1.62	1.30	.35
Forestry requirements (total)	.25	.20	.20
Allowance for profit and risk on investment			
Main-line railroad	.30	.24	.24
Spur railroad	.54	.43	.01
Railroad equipment	.22	.18	.09
Logging equipment	.59	.47	([3])
Cash, supplies, and stumpage deposit	.16	.13	.13
Total	1.81	1.45	.47
Grand Total	$10.48	$8.38	$5.76

[1] Cost estimates for cable-logging in column headed 1928 are those given in appraisal report; those for 1934 represent a reduction of 20 per cent from the 1928 figures.

[2] Full machine-rate costs, including maintenance, depreciation, and allowance for profit and risk.

[3] Absorbed in yarding and loading cost estimates which represent full machine rates.

Table 9 compares estimated logging costs on tractor areas under the proposed plan with costs under the cable-logging plan. The first column gives costs of cable logging as set up in the 1928 appraisal report, while the second shows the same costs reduced by 20 per cent, so as to bring them more closely in line with the 1934 cost level.

This arbitrary blanket reduction may, of course, be challenged particularly with regard to certain items, but it should be noted that all the items listed, except yarding and loading costs, are used as the basis for corresponding estimated costs under the tractor-logging plan. Accuracy of estimates is, therefore, to a considerable extent a question of relative costs affecting both plans alike.

In comparing the last two columns of the table, it will be noted that estimated costs are identical for several items, but differ quite radically for others.

For some items the tractor-logging plan shows a reduction of 50 per cent, which is brought about by lowered railroad operation and maintenance costs. The cable-logging plan requires an average stump-to-mill railroad haul of about 12 miles, much of it on steep grades in rough sidehill country, while the tractor-logging plan requires an average railroad haul of only 6½ miles, mostly on a well-built main line for which both operating costs and maintenance costs per mile would be lower than those for woods spurs.

Estimated spur-construction costs per M feet are reduced from $0.64 to $0.02, and allowance for profit and risk on the investment in spurs from $0.43 to $0.01 per M feet, both reductions corresponding with the reduction of the railroad spur mileage from 40 to 1.

Certain items are eliminated entirely under the tractor-logging plan, owing to their inclusion in yarding and loading costs. The $2.50 estimate for yarding and loading is based on the following break-down of costs:

(a) Direct-yarding (or roading) for 6,000-foot average haul (from table 4)	$1.12
(b) Drum-unit yarding at $0.80 for 25% of total timber volume	.20
(c) Construction of tractor-trails (other than main roads)	.10
(d) Loading	.25
(e) Allowance for profit and risk (not fully covered in machine rate set-up)	.33
(f) Extra allowance for long roading and other factors	.50
	$2.50

The $0.50 allowance (item f) for the handicap of long roading for certain portions of the area gives recognition to the disadvantages in going out so far, particularly where so much timber has to come to one central landing at the end of the track. Fallers and buckers, cold deck crews, etc., would lose a good deal of time in going to and from work, and it would frequently be difficult to keep the operation running smoothly. Construction of truck roads to tap these long corners would perhaps result in a saving, but not clearly so, owing to the problem of reloading. Under a different truck-haul setup that will be further discussed the situation in this respect becomes more favorable.

Cost estimates for "intermediate" and "cable-yarding" areas.—For intermediate areas, which are not accounted for in table 9, costs under the proposed plan are estimated at $7.26 or $1.50 per M more than for tractor areas. This difference is designed to cover increased costs in logging steep slopes that require drum-unit yarding, skyline swinging or expensive tractor-road construction and that cause higher costs owing to increased breakage.

For cable-yarding areas, costs are estimated in round figures at $9.50 per M—$2.24 higher than for intermediate areas. Of this differential $1.65 is the estimated cost of the 2-mile truck haul including road construction and maintenance and reloading, and the balance is for increased costs of yarding on this extremely steep and rough area. The basis for estimation of costs is not so strong in this case owing to the uncertainties of a blanket cost estimate applied to so difficult a logging show. This is, of minor importance in considering the estimate for block 2 as a whole, because the cable yarding areas support only 10 per cent of the total timber volume.

Summary at cost estimates for block 2.—The foregoing logging-cost estimates are summarized as follows:

	Cost per M feet
Tractor Areas (280 million feet)	$5.76
Intermediate Areas (80 million feet)	7.26
Cable-yarding Areas (40 million feet)	9.50
Weighted average (400 million feet)	$6.43

The average estimated cost for the block is $1.95 per M less than the estimated cost of logging the same timber under the cable-logging plan.

Savings from reduction of timber breakage with regard to both cost and values would result also from adoption of the proposed plan. Experience indicates that these savings commonly exceed $0.50 per M.

Truck haul supersedes main-line railroad haul.—One important question that so far has not been touched upon, is whether the main-line railroad should be retained under the proposed plan. By not opening this question it has been possible to refer to the estimates given in the appraisal report for an item by item comparison without introducing too radical a change in the basic set-up of costs. With the comparison completed on that basis the question of motor truck haul versus railroad haul will now be considered.

The main-line railroad, which extends for a distance of 5½ miles from the proposed mill site to the end of the track in block 2 (Plate I) has not been used since its completion in 1928. It is not now in usable condition for logging. Restoration of this road would require new ties throughout, and much other repair work. It is estimated that the cost of this, added to possible salvage value of the steel rails, would be sufficient to pay for converting the railroad grade into a truck road surfaced with crushed rock and wide enough for the most part for two-way traffic. It is further estimated that by substituting truck roads for the previously proposed railroad extensions, enough money would be saved to build 3 to 4 additional miles of truck roads and about 1 mile of expensive tractor road (in section 2) which would provide the means for shortening of roading distances from various "long corners" of the block. (Under the railroad set-up the cost of reloading would preclude some of this truck-road construction but some of it might be justified even then.) Proposed locations of these roads are shown on Plate III.

In addition to these roads, many miles of tractor roads and trails could readily be made a part of the truck-road system, to serve in some cases and at some times of the year perhaps for truck haul of logs, but more generally for light truck and auto travel such as would be needed for transportation of crews, fire protection, and general administrative purposes. Such roads will hereinafter be referred to as truck trails.

Through this radical change in the road layout yarding and loading costs for tractor areas, previously estimated at $2.50 per M, would be reduced by an estimated $0.75 per M. This saving is based in part on direct reduction of roading costs (average roading distance is reduced from about $6,000 to 3,500 feet without figuring possible further reduction through use of truck trails which might be very substantial) and in part on indirect reductions of various items of cost as already discussed. It is this very substantial saving that makes it practical to substitute truck haul for rail haul on block 2.

Study indicates that similar results would be obtained in all the other blocks. The topography and location of these areas are such that rail haul does not offer the best solution of the transportation problems. If the sawmill were to be located much farther away from the tract a different situation would, of course, arise.

Portable log loader is final step toward flexibility in logging.—The final touch in the evolution of the foregoing operating plan is the introduction of a mobile type of log loader. Maximum efficiency in tractor logging, as discussed in the last chapter of the logging cost report *(7)* is best attained by decentralizing the yarding operations and by separating yarding from loading. Under this plan the tractors would bring the logs to the roads at any point where topography permits while the loader would come along a few days or a few weeks later to load out. For this particular operation a loader of the revolving shovel type would serve the purpose, although other types, lower in cost, appear feasible. The use of such loaders would, of course, require a wide roadbed along the landings to provide room for the load-ing rig and truck traffic.

This operating set-up provides a basis for attainment of maximum efficiency and also for the high degree of flexibility needed in intensive selective timber management. A permanent road system would provide quick and convenient access to all parts of the tract and with yarding and loading machinery of the highly mobile type proposed the growing stock would be placed under intensive selective control. For these "cable-yarding" and "intermediate" areas this control relates mainly to donkey settings and small drum-unit settings. For tractor areas selective control would extend for the most part to the individual tree.

22. Selective management plan based on motorized logging.—Under intensive selective management a detailed plan should be worked out first for tractor areas which comprise nearly 75 per cent of the total old-growth area. Since these areas are for the most part favorable tractor logging ground there is no question as to whether intensive selection is practicable from an operating point of view. Even if the management plan should call exclusively for clear cutting, the logging procedure would usually consist in a series of individual tree-selection cuttings, owing to the operating economy and breakage savings attainable by this method of operation.

Basis of selection in old-growth stands during initial operations.-The general character of the old-growth stand is revealed by the stand structure diagrams presented as figure 12. The upper diagram is based on a 10 per cent cruise tally of section 11, of block 2, and the lower on a similar tally of section 10 of block 2.

The size of the timber is shown to vary over a considerable range.[4] The Douglas fir veterans, which constitute about 90 per cent of the total volume of the stand, range in both cases mainly from 30 to 70 inches in diameter.

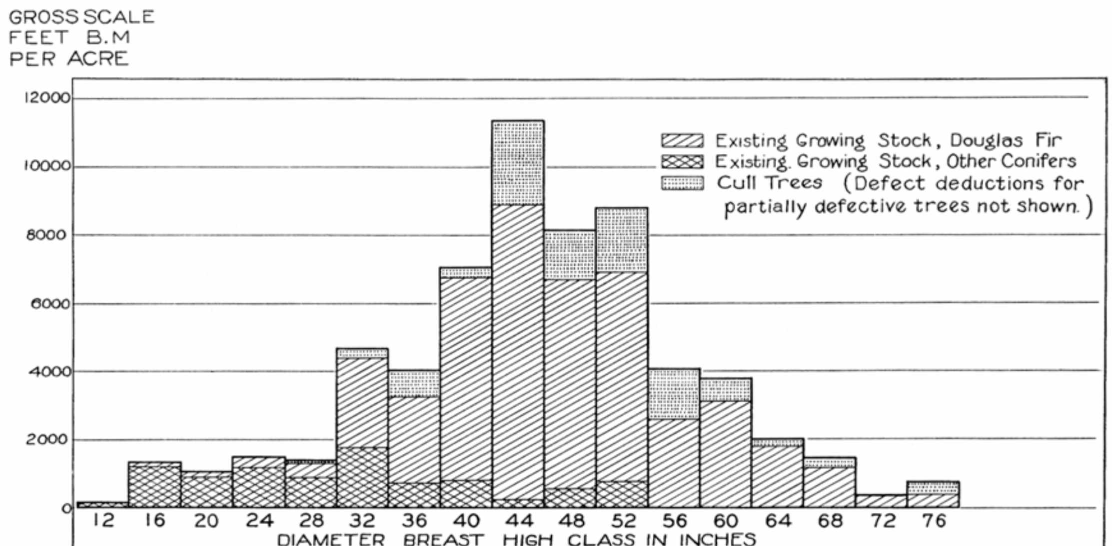
[4] This rather wide diameter range in an even-aged and, broadly speaking, highly uniform stand is true to form for old-growth unmanaged forests. In this respect it will prove of interest to compare these stand diagrams with those of the many-aged spruce-hemlock stand discussed in the preceding chapter (fig. 7), and to note in particular that in all cases a large portion of the volume in concentrated in a relatively few large trees.

Precise variations in stumpage conversion values as based on diameter classes and species have not been determined in this study but the general situation may be stated in approximate terms. The average pond conversion value, as of 1934, is estimated at $10 per M or slightly less—a low value brought about by the unfavorable location of the tract with regard to market outlets. For the tractor areas this would give an average stumpage conversion value of approximately $4 per M. For the bulk of the timber, consisting of Douglas fir from 30 to 70 inches in diameter, relative values are conservatively estimated at $3 for the 30- to 39-inch, $4 for the 40- to 49-inch, $5 for the 50- to 59-inch, and $6 for the 60- to 69-inch classes.

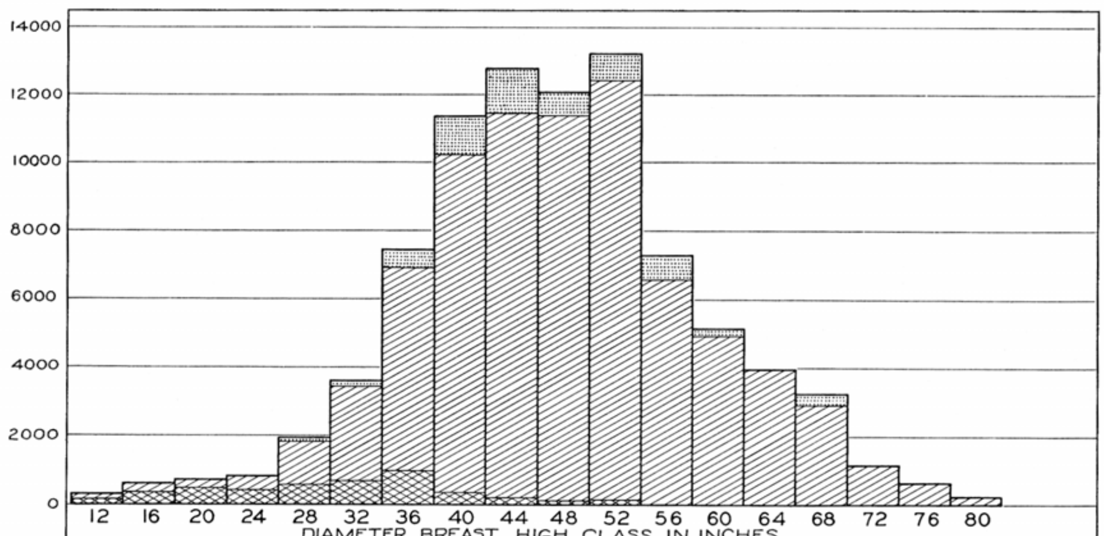
The importance of the precise facts as to the relative value spread is overshadowed by the condition of the stand with regard to defect. This 300- to 400-year-old stand contains relatively few windfalls and snags but, as already stated, is highly defective. The principal defect is red ring rot *(Trametes pini)* commonly called conk or conk rot. This disease is widespread. In block 2 approximately 40 per cent of live standing Douglas firs 30 inches or more in diameter are defective. However, excluding cull trees (trees more than 75 per cent defective), of which there are about 2 per acre, and including trees less than 30 inches in diameter there are on the average acre (fig. 12) about 32 trees 12 inches or more in diameter of which 14 are sound understory trees under 30 inches, and approximately 12 are sound and 6 partially defective old-growth trees in the 30- to 80-inch diameter range.[5]

Boyce, in his report on decay in Douglas fir, states that the fungus causing conk rot almost invariably enters the tree through knots or branch stubs-i.e., generally near the base of the crown-where heartwood is exposed, and only rarely through trunk scars of any kind. This is responsible for the fact that the partially defective trees are conky principally in the upper and central part of the bole and as far down as the defect may extend, but with relatively less defect in the lower and most valuable portion of the bole. Expert and careful culling of defective, low-value portions of the trees should therefore result in a relatively high log value for the portions actually utilized.

[5] In the cruise tally cull trees were recorded by diameter classes as shown in figure 12, while the volume or percentage of defect in the partially defective trees was not so recorded, but was lumped with breakage as a blanket deduction of 25 per cent from the gross cruise volume of the entire stand. Like the cull trees, however, the partially defective trees occur in all diameter classes from 30 to 80 inches and the distribution of relative volume of defect by diameter classes would presumably be somewhat similar to that of the cull trees.



CUMULATIVE VOLUME PER ACRE IN M FEET BM.; CULL TREES EXCLUDED (READ FROM RIGHT TO LEFT)																
51.4	51.3	49.9	48.9	47.4	46.1	41.5	38.5	31.8	23.0	16.3	9.4	6.8	3.7	1.9	0.7	0.4
CUMULATIVE NUMBER OF TREES PER ACRE; CULL TREES EXCLUDED (READ FROM RIGHT TO LEFT)																
32.4	28.1	20.6	17.8	15.1	13.6	10.3	8.7	6.3	3.9	2.4	1.1	0.8	0.4	0.2	0.1	—



CUMULATIVE VOLUME PER ACRE IN M FEET B.M.; CULL TREES EXCLUDED (READ FROM RIGHT TO LEFT)																	
80.3	80.0	79.4	78.7	77.9	76.0	72.6	65.7	55.5	44.1	32.7	20.3	13.8	8.9	4.9	2.0	0.9	0.2
CUMULATIVE NUMBER OF TREES PER ACRE; CULL TREES EXCLUDED (READ FROM RIGHT TO LEFT)																	
32.8	28.0	24.7	22.7	21.3	19.5	17.2	13.8	10.2	7.1	4.7	2.5	1.5	0.9	0.4	0.2	0.1	—

Fig. 12 - Stand Structure Diagrams of Block 2. Chap. IV

Possibilities for highly effective work along this line are, of course, far greater under selective logging with tractors than under wholesale clear cutting and cable yarding. In the latter case logging a highly defective stand of timber is a difficult problem. Cull trees, if left standing, interfere with the efficiency of the yarding operation, or if felled add directly to the cost of logging. Furthermore, excessive breakage in felling and yarding adds to other losses; and the exigencies of high-speed yarding make careful log selection difficult. With tractor logging, on the other hand, the defective trees can be felled and logged one by one, with ample opportunities for careful selection log by log and without serious interference with the efficiency of the yarding operations.

Prudent culling in the partially defective trees would practically result in the elimination of logs of No. 3 commercial grade since these are found almost exclusively in the defective portion of the bole. Logs of this grade would, as a matter of fact, barely pay their own way from stump to mill even if they were sound, because their average value in the mill pond, as of 1934, would not exceed $6 per M (as compared with about $11for No. 2 logs and $16 for No. 1 logs). Elimination of No. 3 logs would leave an average value for logs actually taken approximately $1.50 per M board feet higher than the corresponding value .of sound trees, but this increase in value would, of course, be reduced through unavoidable inclusion of defect in logs actually utilized. Felling costs would rise in proportion to the percentage culled, but yarding, loading, and transportation costs would drop owing to exclusion of small rough logs which are relatively costly to handle. All in all the possibilities appear to be that through careful culling about as high a net recovery per M board feet net scale would be made from partially defective trees as from sound trees.

These apparent possibilities of extracting fairly high returns need not, of course, be dwelt upon as the primary reason for quick removal of the partially defective trees. These trees obviously constitute the declining element of the stand, in contrast to sound trees which are gaining in volume and value. Their priority in selection (on the basis of a low discount rate), is therefore not all in dispute even if they were of much lower relative value than here indicated. They constitute the portion of the growing stock for which physical and financial maturity go hand in hand, and differ in this respect from the cull trees which, though physically overmature, have already been stricken from the inventory of liquidable assets.

Basis of selection in second-growth stands during initial operations.—Under the foregoing management plan it might be difficult to fill market orders for certain grades of lumber, principally No.1 common, if only the old-growth timber should be cut, owing to severe culling of low grade logs. The answer to this situation, if and when it develops, would obviously be to open up portions of the 12,000 acres of 60- to 120-year-old second growth, directing the cut almost exclusively toward improvement of the stand. It is certain that in a 60- to 120-year-old unmanaged stand there are vast opportunities for constructive measures along this line. This timber, with a total volume of 400 million feet, is in the prime of its life, capable if intensively managed of growing at an annual rate of 2 per cent or more by volume. If left unmanaged, on the other hand, gradual stagnation, of growth together with mortality losses from various sources would reduce net increment to a very low figure as indicated by the growth predictions given in the clear-cutting management plan (table 8). By making needed initial thinnings and placing the stand under continuous selective control it should be possible to cut 4 or 5 million feet a year, as may be needed for balancing market requirements, and yet for several decades to keep on building up total stand volume at about the same rate as anticipated under the clearcutting plan.

Logging costs in the second-growth timber can, from all indications, be kept at a reasonably low level even during the initial development period owing to the fact that very little truck-road construction would be required. A portion of the 10,000-acre area in block 9 is already served by a truck road. Other areas would be tapped by roads needed for development of the surrounding old-growth areas, and still other areas might be tapped by constructing cheap truck trails suitable for a couple of months, operation during the height of the summer season. Use of specialized small-timber logging methods-such as bunching by horses or a small tractor-should enable high efficiency in logging and at the same time make it possible to avoid mechanical injury to the stand which is an important matter with regard to prevention of fungus infection. Net stumpage returns would, nevertheless, be very low on the basis of present lumber values, but a high return is not essential since properly selected timber would constitute free, surplus stumpage, the removal of which would enhance future returns.

Development of road system and cutting areas during the first 15 years of operation.—On the basis of the foregoing program rapid development of all tractor areas, both old growth and second growth, is necessary. Operations during the first 15 years would remove 600 million feet of timber (40 million feet per year), of which 60 million feet would be tentatively allocated to second-growth areas and 540 million (36 million per year) to old-growth areas. Of this 540 million feet, partially defective trees would constitute about 420 million (the estimated aggregate net scale of defective timber on tractor areas) and 120 million feet would be sound old-growth timber. Inclusion of this proportion of sound timber is to provide for removal of old-growth sound trees that may be injured in taking out the defective trees—a measure that should reduce losses from fungus infection in the residual stand; of sound trees on small areas that may have to be clear cut; and of sound but stagnant large trees, particularly in the 70-inch and larger size classes, from which unusually high stumpage returns can be obtained.

The manner in which this cutting program would be carried out with regard to road building and opening up of new cutting areas is indicated on Plate III. For the unmapped portions of block 9 it will be assumed that road requirements and percentage of area adapted for tractor logging are the same as for the mapped portions. Operations during the first three 5-year cutting cycles might be as follows:

During the first 5-year period operations in the old-growth areas would be spread over approximately 25,000 acres as shown on the map. The total volume of timber is roughly 1300 million feet of which only 180 million would be removed during the 5-year period. Operations would follow the line of least resistance, with only tractor-arch units used for direct yarding from stump to landing. The cut would be concentrated mainly on large defective trees of high value; of these an average of less than 2 trees per acre need be removed to make up a 180 million foot cut. Where many defective trees occur only a few would be cut so that no serious slash hazard would be created, and the rest would be passed up to the second or third cut; or else, clear cutting of certain badly defective patches of timber would be resorted to and the slash burned in broadcast fashion.

Cutting areas in second-growth timber that might be developed during this period are not shown on the map. Operations would be confined to the west end and central portion of the 10,000-acre area in block 9, or to handy portions of the second-growth areas in blocks 3 and 4.

Road construction during this period would consist in conversion of 5½ miles of existing railroad grade and construction of approximately 31 miles of new truck roads, the latter being estimated to cost $6,000 per mile. Including main tractor-roads, on the same basis as discussed for block 2 the total cost of road construction would be approximately $1.50 per M to be charged off in full against the timber removed during the 5-year period.

During the second 5-year period additional old-growth areas aggregating about 7,000 acres, with an estimated stand of 350 million feet, would be opened up for an initial cut of about 80 million board feet. The balance of the cyclic cut, of old growth, 100 million feet, would be obtained by sweeping back over the 25,000-acre area opened up in the first cut. Within this area spots that are too steep for direct tractor-roading, and that therefore were passed up during the first cut, would now be opened up, using bob-tail tractors or drum units for skidding the logs to the tractor roads or occasionally clear cutting small groups where high leading at distances over 300 or 400 feet might be necessary.

Road construction during this period would include about 15 miles of new truck roads, at an estimated cost of $0.45 per M ($6,000 per mile). For main tractor-road construction the estimated cost would be $0.15 per M, based on corresponding requirements in block 2.

During the third 5-year period approximately 2 or 3 thousand acres of new cutting areas might be developed. These are not indicated on the map. They would consist mainly of certain isolated tractor areas that require a disproportionate amount of road construction and of intermediate areas that are easily accessible from the roads already built, or that can be made accessible at reasonable cost by construction of new roads. The bulk of the cyclic cut would be obtained by sweeping back over areas opened up during the first and second cycles, concentrating on remaining partially defective low-value trees passed up previously.

The cost of truck roads and main tractor roads to be constructed during this period is estimated at about $0.25 per M. The permanent road system would now be nearing its completion with only about 10 more miles of truck roads to be constructed during subsequent cycles. Upon completion of these there would be altogether about 75 miles of truck roads. This does not include a possibly very large mileage of cheap truck trails (the cost of which is treated as a part of yarding costs) which would serve as feeders to the truck roads during the dry season.

Throughout this 15-year period the aim would be to open up new cutting areas as rapidly as possible and at the same time keep the net flow of income at a high level. During the first cycle road-construction costs are relatively high but yarding costs, through selection of the choicest tractor-roading shows, are relatively low. As road-construction costs decrease, other logging costs increase. A fairly steady level of activity is thus indicated. Net returns would be high because on the whole the most high value defective trees are logged during this cycle.

The above brief outline of how the operations would progress over the area and how they would sweep back over previously developed areas at 5-year intervals does not fully indicate the high degree of flexibility and continuous selective control of the timber that readily can be attained. With a 34,000-acre old-growth area to manage, the most efficient operating set-up might well be to divide the area into several divisions or blocks, to each of which would be assigned one or two tractor-roading outfits. Within each division operation would be carried on continuously, shifting from road to road and from landing to landing, and spreading back and forth over the entire operating area often enough to maintain roads and tractor-trails through light but frequent use, and to keep the growing stock under complete selective control as needed for market selection, salvage, and other purposes. With the type of roads and logging and transportation equipment here indicated, possibilities along this line are virtually unlimited.

Disposal of cull trees during and after initial operations.—Cull trees, of which there are on the average about two per acre (exclusive of possible culls among trees less than 30 inches in diameter) would be carefully avoided during the first 15 years. Since they are live, green trees, in contrast to snags, they do not constitute a serious fire menace so long as they are left standing and remain green. On the contrary, they would help to maintain the crown cover and thus to reduce the fire danger by keeping the debris from the tree selection cuttings in the shade of the forest. If felled, on the other hand, they would add to the fire hazard and hinder the felling and yarding operations.

No particular reasons would seem to exist for reversing this policy in later years, at least not so long as individual tree selection is continued without direct aim for regeneration. Where group cuttings occur—and these would progress at a faster rate after the 15-year period—the cull trees if left would be isolated in the open, with the probable result that many would soon drop out from sudden exposure to sun and wind. Scattered culls that survive would not interfere with the establishment of regeneration, although they might retard its growth in their immediate vicinity. Felling of these trees would generally cost from $1 to $3 per tree. Considering that it would take approximately 30 cull trees to use up the growth power of one acre of soil, it is clear that a felling expenditure at the rate of $30 to $90 per acre for freeing the soil of the trees is wholly unjustified in a region where far more accessible and productive forest land, valued at $1 to $5 per acre, is lying idle. It would seem best, therefore, to rely as much as possible on Nature to dispose of them in the same manner as has continually been happening in the past. Since the partially defective trees are removed before they become culls the final solution of the cull tree problem would probably be reached in this manner within a reasonable length of time.

Development at new cutting areas after completion of third cycle.—By the end of the third cutting cycle a total of about 34,000 acres of the "loggable, old-growth" timberlands would have been opened up for logging and brought under intensive selective management. There would remain untouched about 7,000 acres of steep and rugged old-growth areas. The management policy would be gradually to extend operations into these areas, but preferably without resorting to destructive methods of logging. Obviously, it is possible that in the course of time accumulated experience with tractors and allied forms of flexible logging machinery on rough ground, together with mechanical improvements in logging and road-building equipment, may so alter the situation that many portions of this 7,000-acre area can profitably be brought under intensive selective management. It would be difficult to conceive otherwise after watching the progress that has been made along these lines during the last few years. For extremely rough and rocky areas, though, it can hardly be expected that these methods of intensive selective logging will ever become practical. Areas of this character from which reasonably high stumpage conversion values could be obtained might be clear cut (by conventional cable-yarding methods). Some of the others should perhaps never be logged, particularly if their slope and character are such that stripping the timber from them might create serious fire-hazard, reforestation, stream-flow, and erosion problems. In any event, bringing of these areas into full production should wait until two important requirements can be met; first, that operating methods fully compatible with good, conservative forest-land management shall be employed; second, that a reasonably high conversion value shall be obtainable. Pending development of this situation these areas would constitute a reserve into which operations might occasionally be shifted for short periods when demand temporarily placed an unusually high premium on old-growth timber. Truck and tractor roads built and maintained for operations on tractor areas would reach to and into nearly all major parts of the nonoperated areas and so would permit quick action in shifting operations in and out of them.

Fire Protection.—This area is within a climatic zone of fairly high fire hazard. The old-growth stand with a uniform overstory is of a type in which conflagrations have swept in the past, as witnessed by the presence of large areas of even-aged stands of various ages on this particular tract and throughout this portion of the Douglas fir region. Under selective management the conflagration hazard, other things remaining equal, would be gradually reduced through removal of snags, and dead and stag-headed trees and other hazardous elements of the stand, and through the breaking up of the even-aged crown cover by systematic group selection.

Initial fire protection requirements would be the same as those discussed in chapter III, such as felling of snags, exercise of judgment in felling the selected trees, staggering and breaking up of cutting areas, and occasional removal of tops where they happen to lodge against other trees. In addition spot burning, lopping and occasional piling and burning, etc., would probably prove necessary, particularly along the main truck roads and in other strategic locations. However, the bulk of the slash on single-tree selection areas could be left for Nature to dispose of, providing adequate measures were taken for detection and suppression of fires. As experience is gained with respect to the rapidity and thoroughness of natural decay .of the slash both the cutting and the slash disposal programs can be adjusted accordingly. This may require temporary suspension of tree selection cuttings on areas where the slash hazard becomes greater than acceptable safety standards permit, with cuttings to be resumed only after conditions become safe.

On the group selection areas broadcast slash burning would be resorted to in the manner discussed in sections 30 and 45. A more detailed discussion of fire hazard and other elements of risk under selective timber management is presented in chapter VII.

23. Evolution of selective management plan after third cutting cycle.—The proposed plan has so far been centered exclusively on the point that quick removal of partially defective old-growth trees and concurrent establishment of intensive selective control of the remaining growing stock is by far the most urgent step to take in initiating effective management on this property. Since this involves individual tree selection (and to a limited extent small group selection) in a 300- to 400-year-old stand of even-aged Douglas fir, important questions relating to growth, regeneration and other phases of Douglas fir silviculture will arise. Douglas fir, which definitely demands open space for regeneration, presents a silvicultural problem that necessarily must be harmonized with the selective form of management.

The question of how best to obtain adequate and satisfactory regeneration is, of course, only one aspect of the more important question of how to grow utilizable timber. It need not necessarily be answered in its final form during the early stages of selective management.

Owing to extensive clear cutting and fire in the past there are already approximately 10,000 acres of regenerating areas in blocks 1 and 8 (Plate III, 1- to 20-year age class). This is sufficient to meet regeneration requirements under a selective management program at least until the end of the 15-year period. Then too, there are many small patches of young regeneration within the old-growth stands and some regeneration may be expected from the cutting program carried on during the 15-year period, particularly on portions of the area which for one reason or another are clear cut.

Comparison of increment under selective management and clear-cutting management.—The immediate objective under the selective management plan is to obtain net increment from the merchantable timber. To all appearances, it would accomplish this exceedingly well. On the 12,000 acres of 60- to 120-year-old second-growth stands the cutting during the initial development period and the establishment of continuous selective control of the growing stock (and hence, reduction of mortality losses) made possible by construction of a permanent road system should result in a substantial increase in net increment above that to be obtained in the unmanaged stand. On the 34,000 acres of old-growth timber opened up during the 15-year period, net increment would be obtained partly through removal of the losing elements of the stand; and partly through drastic reduction of mortality losses, made possible by keeping the remaining sound growing stock under continuous selective control. As an additional source of increase in net ultilizable volume, the question of utilization standards under tractor logging versus cable logging should be considered also. The aggregate effect of these factors will naturally be to substantially extend the life of the timber supply. Nevertheless, liquidation of merchantable timber would still be going on, principally in the old-growth stands.

In addition to current increment on the existing merchantable growing stock, production would also be under way on the 10,000-acre area of 1- to 20-year-old second-growth (the same as it would be under a clear-cutting system), and also on existing premerchantable, or newly recruited growing stock within the 46,000-acre area in which selective operations are being carried on. Remarkable progress toward balancing current increment against current cut should thus be made within the first 15-year period.

In sharp contrast to this, under a program of extensive clear cutting, current net increment on the existing merchantable timber would be nil.[8] Dependence for any net increment under that program would have to be placed on regeneration of cut-over lands, which during the 15-year period would aggregate approximately 12,000 acres; and, in common with the selective plan, on potential increment from the 10,000-acre area of 1- to 20-year-old reproduction. Potential increment from the 12,000-acre area as carried on to the end of an 80-year rotation would (according to the clear-cutting management plan) average approximately 8 million board feet per year provided that the whole area would be restocked well enough to come reasonably close to yield table standards. As is generally known, regeneration following extensive clear cutting commonly falls far short of these standards.

The contrast between the two systems relates, of course, not only to the quantity but also to the quality and value of the increment. Under the selective program there would be substantial current increment of merchantable timber. This would be relatively valuable material. Particularly valuable, even though the rate is exceedingly low (0.4 to 0.5 per cent), would be the increment of possibly 4 to 5 million board feet a year laid on by approximately 1,000 million board feet of sound old-growth Douglas fir trees. Visualized, as it should be, as outside layers of generally clear and fine-grained wood, much of it suitable for high-grade finish and plywood, which is being laid on by 300- to 400-year-old trees averaging 50 inches in diameter, it will readily be understood that such material may well have an average stumpage conversion value of $10.00 per M or more (as compared with the $4 to $5 average stumpage value of the timber on which it is being produced). This one item of increment alone may amount to as much as $50,000 a year (on the basis of present values) which is practically as much as total annual stumpage returns from liquidating the tract under the cable-logging plan of management.

[8]According to the working plan (table 8) an average annual increment of slightly over 3 million board feet would accumulate over a period of approximately 60 years in the 10,000-acre area of 60- to 120- year-old second growth in block 9 (Plate III); and no net increment at all would be forth-coming from the old-growth" stands, the assumption being that increment and decay balance each other. Boyce's *(6)* findings on rate of decay and other mortality loses, published after the date of the working plan clearly imply that in an old-growth stand as extremely defective as in the case at hand, losses from decay and mortality would normally exceed increment, not strikingly so but quite sufficient on the basis of prudent forecasting to offset fully the predicted 3 million foot annual increment on the second-growth timber.

Regularized group cuttings for Douglas fir regeneration after third cutting cycle.—From the foregoing discussion it is evident that the problem of Douglas fir regeneration is of only secondary importance during the first 15 years of selective management. Effective work in timber growing (as well as in orderly liquidation, and in market selection, fire protection and other phases of management) at this particular stage of development is a problem that calls for individual tree selection, designed primarily to remove the declining elements of the stand (which constitute the financially most overmature timber), and for concurrent construction of a permanent road system designed to provide continuous and intensive selective control of the growing stock. After this has been accomplished the problem of regeneration would become more important. How well the foregoing management program would provide the right solution of this problem should therefore be considered.

In the course of the initial development of the 34,000 acres of old-growth stands a large number of small areas, estimated to aggregate about 2,000 to 3,600 acres, would have to be clear cut for one reason or another. Most of these areas would probably occur on steep and rough ground where full-fledged high leading (as contrasted with ground leading or modified high leading for tree selection) with drum-units may necessitate clear cutting of spots ranging generally from 2 to 10 acres in area. Clear cutting of spots of approximately the same size would frequently be necessary also on favorable tractor-roading ground, particularly in groups of timber consisting mainly of defective trees, or in spots where slash conditions brought about by tree selection may demand clear cutting and broadcast slash burning. Occasionally such areas might be considerably larger than 10 acres.

These areas would as a rule restock in quick order. It is the authors' opinion, based on many years of observation in this region, that the best results in regeneration from the standpoint both of density of stocking and of desirable mixture of Douglas fir and tolerant species, will be obtained on areas of 2 to 5 acres. As to this, however, no preconceived ideas need be accepted as final, because the answer will become self-evident as the cutting program proceeds. In this respect it is clear that all the aforementioned clear-cut areas ranging in size from perhaps less than 1 acre to as much as 10 acres or more may be looked upon as so many sample plots where regeneration results can be observed or studied as closely as may be desired. Here many important facts as to regeneration may be learned first hand; for example: (a) How size of clear-cut area affects density of stocking and how it may control the mixture of Douglas fir with hemlock and other tolerant species; (b) how size of area and density of stocking affect height growth and differentiation of height growth; (c) how Douglas fir regeneration under shelter may come in, or may be induced to come in through tree selection around the margins of the clear-cut spots; (d) how all the foregoing factors vary for different sites or how they differ for north slopes, south slopes and level ground, etc. Silvicultural knowledge so gained can be applied directly and in a practical manner to the management of this particular tract; in fact, not only to the tract as a whole but specifically to its various parts as these may differ from each other with respect to aspect, site, steepness of slope, character of stand, altitude, etc. Past experience will be constantly available as a guide for future action. The entire forest, including both the clear-cut spots and the entire tree selection area, here becomes the proving ground for practical experiments in cutting procedure conducted without cost as a by-product of selective logging.

A fairly well-defined plan of group selection can thus be formulated and put into operation by the end of the 15-year period. This will not mean discontinuance of individual tree selection but it will mean that enough group cuttings will be made to provide for regeneration. Approximately 300 acres per year (½ per cent of the total productive area) probably would be needed for this purpose. As cuttings proceed the precise requirements in this respect will become known from data obtainable under the continuous inventory system described in chapter VIII.

To explain how a group- and tree-selection program can most effectively be combined to carry out the economic aims of intensive selective management it is well first to briefly consider the character of the old-growth stands. As is characteristic of Douglas fir, the timber occurs groupwise with wide variations in stand density (volume per acre). On block 2, for example, for which cruise data are available, several forties carry more than 4 million feet and others have less than 1 million; the heaviest forty on the block supports a stand averaging 120 M board feet per acre but the corresponding volume for the lightest forty is only 10 M. For small, irregular areas the variation is still wider. Many small areas of 5 acres or less support stands averaging 150 to 200 M board feet per acre and others are virtually blank, so far as old-growth merchantable timber is concerned.

Several important points relating to this wide variation in density per acre should be noted. First, the highest-value timber is found, as a rule, in the most heavily stocked groups, owing to the fact that these groups have almost invariably originated from dense patches of even-aged regeneration where early natural pruning and intense competition have resulted in a relatively large percentage of fine-grained, clear timber. Second, in these heavily stocked groups the rate of growth is exceedingly low. Growth of the veterans would generally be as low as 14 per cent, as compared with ½ per cent or more for trees of the same age class growing in lighter stands. (Relation of rate of growth to density of stocking is shown in table 17 of chapter VI.) Third, in the most heavily stocked groups of old-growth the volume of understory timber is negligible (1 to 4 per cent) if not completely lacking, while in stands carrying only a light stand of old-growth, the volume of the understory is relatively large. This is indicated in the stand structure diagrams in figure 12 which show that the volume of understory (conifers other than Douglas fir) is much larger for the stand averaging 51 M board feet per acre than for the one averaging 80 M.

The broad features of the selection program to be followed after completion of the first 15-year period, should now be plain. Group selection (regeneration cuttings) would be centered at first on the most heavily stocked groups. For a decade or so it would probably touch relatively few groups averaging less than 100 M board feet per acre; and another decade or two might elapse before stands which originally supported less than 50 M board feet per acre would be cut to any great extent. Throughout this time the operations would swing back and forth over the entire property (in the same manner as was described above for tree selection) picking out small groups of the described type wherever they occur.

In the meantime individual tree selection would be carried on but at a slower rate than before. Tree selection would thus continue in the 60- to 120-year-old second-growth areas to whatever extent urgent market requirements might dictate or at any rate to a sufficient extent to take care of mortality losses (windfalls, etc.) in the merchantable timber; it would also be carried on throughout the old-growth areas, not only to take care of mortality but also to liquidate the financially most mature trees particularly in stands of medium and light density. Practical experience, accumulating as cuttings proceed, would become the guide in deciding how far individual tree selection should be carried in stands of different character. In stands of medium stocking, it might in many cases be carried on for several decades before the remaining old trees would be removed through group cuttings. In many of the lighter stands, where a heavy understory exists, all the veterans would be removed through individual tree selection, leaving the understory to carryon until some later time when it, too, would be clear cut. Until that time stand management (individual tree selection) would continue without interruption.

Through this procedure group selection, being preceded by tree selection, will not lead to as wide a departure from the tree selection plan as it otherwise would. Tree selection would be carried on to the fun extent that it proves practicable and justifiable, after which group selection would come into the picture as the final step.

From an economic point of view this is essentially the same principle that has been applied for centuries to many European managed forests. Clear cutting in their case is the final cut following a series of thinnings (cuttings consisting of individually selected trees). Clear cutting of this sort on limited areas as needed for effective regeneration or as necessitated by other reasons of a practical nature is part and parcel of selective timber management as defined in this report.

Through the foregoing program of regularized group cuttings, confined to areas of approximately the right size to assure dense regeneration of mixed conifers, the progressive building up of a highly productive forest would take place. These regenerating spots would be scattered throughout the merchantable timber area. A permanent road system paid for and constantly maintained by operations in the merchantable timber, would be continuously available and would naturally play an important role in the management of the young timber. Intensive stand management, beginning with removal of material suitable for posts, poles, piling, pulpwood, and small saw logs could therefore begin at a relatively early age, and would normally continue for many decades before final cuttings again took place. Like clay in the hands of the artist the forest could be gradually remolded to whatever pattern that might be desired. Quantity and quality production would go hand in hand toward attainment of the highest possible return from the land.

24. Summary and conclusion.—The timber property discussed in this study contrasts sharply both as to timber and as to topography with the spruce-hemlock property discussed in chapter III. Nevertheless, many of the essential features of the proposed management procedure are strikingly similar. In both cases the steps toward effective management are: To open up the property quickly for a light initial cut consisting of those portions of the stand that are financially most overmature; to provide permanent roads so that the growing stock can be kept under continuous selective control, and to shift constantly back and forth over the entire area (thus incidentally maintaining tractor-trails, through light and frequent use) as needed not only for orderly liquidation but also for efficiency in logging, and for market selection and salvage. The keynote of the management methods in both cases is flexibility and control.

In certain respects the management procedures differ noticeably between the two studies. Order of selection, of operating areas, for example, is a very important factor in the case at hand, owing to the rough topography. Here the tree selection area is confined at first to the most accessible portions, and is expanded from time to time until all operable portions are brought into production. Some portions of the property might not be logged for many decades.

Log selection likewise appears as a very important factor during the initial period of development, owing in particular to low value of logs in this locality in conjunction with an excessive amount of defect in the timber selected for the initial cut.

No attempt has been made in this study to evaluate the full economic advantages of the proposed methods. After all it is not so essential that all the details as to costs and returns, discount and growth, etc., be known beforehand in order to reach an understanding of how both financial and physical forces operate to establish the superiority of selective timber management over the extensive clear-cutting system. It is only essential to know that selective timber management is based on highly efficient methods of logging; that through construction of a permanent road system it provides complete operating and management control of the growing stock as needed for market selection, orderly liquidation, salvage, etc.; that so far as order of selection is concerned it begins with the things which obviously need to be done first and from then on it constantly proceeds on the basis of experience accumulated as cuttings continue. Under some circumstances one objective may establish the order of selection while under other circumstances, other objectives may rule. At all times the selective procedure is based on the most urgent and immediate considerations, taking the whole property into account, and at no time are operations based on uncertain predictions of distant future rates of growth or occurrences which may influence values.

CHAPTER V

REBUILDING A BALANCED GROWING STOCK ON AREA DEPLETED BY EXTENSIVE CLEAR CUTTING AND FIRE

25. Location and description of area.—This publicly owned forest area is located about 11 miles from a common-carrier railroad, reached by a public highway. Because the mountain valley where it lies has been largely logged out by previous railroad and stream-driving operations, the most economical method of getting out timber at present appears to be to log by truck to a sawmill of about 40 thousand feet daily capacity, which is within easy reach of all parts of the area. A large mill pond provides ample log storage facilities at the mill. From the mill the lumber can, at low cost, be hauled by truck to the common-carrier railroad or to settled areas.

For the purposes of describing different portions of the forest, and of showing how cutting can readily be controlled when the forest is handled under short cutting cycles, leading to sustained yield, the portions of the area having merchantable timber have been divided into 10 blocks, each of which is sufficient, under selective timber management with a short cutting cycle, to constitute an operating unit of the entire sustained yield area. Division of the area is based in part on topography and location of transportation routes and in part on equalization of logging areas and volumes among suggested periodic cutting areas.

On the general map of this locality (Pl. IV) is shown the location of pond and sawmill and the several blocks. A portion of block 1 is depicted with more detail, from various aspects, in Plate V.

As is shown by Plate IV, the floor of the main valley lies at an altitude of about 1,200 feet. From this the slopes of varying degree rise to elevations of 3,000 to 4,000 feet. The merchantable timber zone, determined by soil and steepness of slope as well as by elevation, is nearly all below 3,500 feet.

The classification of timber types and size classes is the same as that adopted by the Forest Survey for the Douglas fir region, except that several noncommercial types and certain regeneration classes have been combined. The most important type is the Douglas fir timber type, which is defined in the Forest Survey working plan *(31)* as follows:

"*Douglas Fir*—Stands containing approximately 60 per cent or more, by volume, of Douglas fir—the characteristic forest west of the Cascades." Within the area shown, four size classes of Douglas fir are delimited by the survey working plan *(31)* as follows:

6. *Douglas Fir A:* Stands where the volume is mainly in trees over 40 inches diameter breast high.

8. *Douglas Fir C:* Stands where the volume is mainly in trees 20 to 40 inches in diameter-young-growth timber.

9. *Douglas Fir D:* Stands where the volume is mainly in trees 6 to 20 inches in diameter.

10. *Douglas Fir E:* Stands in which most of the trees are under 6 inches in diameter.

In addition to the Douglas fir, considerable areas of hemlock, of somewhat inferior development, and a small area of cedar type are present. The map legend shows the symbols which designate these types and size classes.

Perhaps because it is in a transition zone from west Cascades to east Cascades conditions, this valley does not include the high-quality Douglas fir trees that are characteristic of classes A and C under the typical climatic conditions of the Douglas fir region. Site quality is usually not better than Douglas fir site III (medium quality). Besides a tendency toward rough boles from persistent branches, the percentage of defect is high, and many trees are worthless. In Douglas fir A the net stand per acre averages about 50 thousand board feet. On block 1 the trees over 40 inches d.b.h. constitute about 88 per cent of the total volume of all trees above 20 inches. On other blocks the proportion of timber under 40 inches is larger.

Table 10 gives the area of each type by blocks, the total area in each block, and the total for the entire tract.

The southern part of the area has most of the mature and overmature timber which should be cut first. This portion is divided into 5 blocks, designated by numbers 1, 2, 3, 4, 5. The northern portions are

TABLE 10.—*Area of different timber types in management unit, by blocks and d. b. h. size classes.*

Block No.	Douglas fir		Western hemlock 20 in.+	Western red cedar 24 in.+	Immature conifers 6–20 in.	Young conifers 6 in. –	Total productive	Non-commercial[1]	Total area
	40 in.+	20–40 in.							
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Southern portion:									
1	1,182	1,313	...	...	...	2,730	5,225	52	5,277
2	2,959	...	1,011	...	56	3,358	7,384	...	7,384
3	2,050	522	1,081	311	...	1,388	5,352	952	6,304
4	2,493	...	1,961	226	...	687	5,367	1,716	7,083
5	1,762	...	921	...	3,654	1,052	7,389	1,097	8,486
Northern portion:									
A	1,082	...	2,322	...	1,363	1,423	6,190	1,079	7,269
B	1,002	306	200	...	3,384	2,154	7,046	...	7,046
C	95	3,115	...	...	2,402	...	5,612	578	6,190
D	421	2,216	...	...	4,448	111	7,196	3,935	11,131
E	776	4,438	...	...	1,885	333	7,432	...	7,432
Total area	13,822	11,910	7,496	537	17,192	13,236	64,193	9,409	73,602

[1] Including barrens.

stocked predominantly with young age classes which are not ready for stand management under present market conditions; but they also contain limited areas of mature timber, some of which should enter into early management operations. These areas are designated by letters, blocks A, B, C, D, and E.

Table 11 gives merchantable timber volumes and related information for each block by types and the totals for the entire tract. Saw-timber volumes include trees over 12 inches diameter.

26. Logging methods and log transportation.—Unlike the timber described in chapters III and IV, timber from this more depleted property will have to be taken out from the beginning in too small volume and for too short hauls to permit economic use of railroad transportation. With a permanent road system and short truck hauls, logging costs should, however, be very low. Savings in logging cost will be partially offset by the cost of trucking lumber 11 miles from the sawmill to common-carrier railroad or other market outlet. The average log truck haul for the whole area would be about 6 miles, which involves a log trucking cost to the mill of approximately $1.50 per thousand board feet.

TABLE 11.—*Gross volume*[1] *in thousand board feet, log scale of different timber types in management unit, by tracts.*

Block No.	Douglas fir over 40 inches D. B. H.		Douglas fir 20 to 40 inches D. B. H.		Western hemlock[2] over 20 inches D. B. H.		Western red cedar[3] over 24 inches D. B. H.		Immature coniferous timber 6 to 20 inches D. B. H.		Young coniferous types under 6 inches D. B. H.		Total volume by tracts		
	Douglas fir	Others	Douglas fir	Others	Douglas fir	Others	Douglas fir	Others	Douglas fir	Others	Douglas fir	Others	Douglas fir	Others	All Species
	M b. m.	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*	*M b. m.*
1	78,647	5,856	35,808	3,177	...	...	...	...	...	...	...	...	114,455	9,033	123,488
2	72,099	44,148	...	...	11,305	19,268	...	...	588	84	...	...	83,992	63,500	147,492
3	49,950	30,586	14,616	1,044	12,088	20,602	...	12,440	...	...	...	...	76,654	64,672	141,326
4	60,744	37,196	...	...	21,928	37,373	...	9,040	...	...	...	...	82,672	83,609	166,281
5	42,933	26,289	...	...	10,298	17,552	...	...	38,367	5,481	...	...	91,598	49,322	140,920
A	28,132	15,148	...	...	23,220	46,440	...	...	14,312	2,045	...	...	65,664	63,633	129,297
B	26,052	14,028	6,732	918	2,000	4,000	...	...	35,532	5,076	...	...	70,316	24,022	94,338
C	2,470	1,330	68,530	9,345	...	...	...	...	25,221	3,603	...	...	96,221	14,278	110,499
D	10,946	5,894	48,752	6,648	...	...	...	...	46,704	6,672	...	...	106,402	19,214	125,616
E	20,176	10,864	97,636	13,314	...	...	...	...	19,793	2,828	...	...	137,605	27,006	164,611
Total volume by types	392,149	191,339	272,074	34,446	80,839	145,235	...	21,480	180,517	25,789	...	...	925,579	418,289	1,343,868

[1] The volumes given are for trees 12 inches and over in diameter at breast height.
[2] Western hemlock comprises about 60 per cent by volume of this type.
[3] Western red cedar comprises approximately 50 per cent by volume of this type, the remaining being western hemlock, and the balsam fir (Abies spp.)

Truck Roads.—Plate IV shows the present and prospective truck road development. Owing to lighter traffic truck roads, although they should be surfaced with crushed rock or gravel, may be constructed on the average to somewhat lower standards than on the area discussed in chapter IV. The cost is estimated to average about $4,000 per mile. A total of approximately 50 miles will be needed of which 30 miles already exist in partly developed form.

Tractor Roads.—Two classes of tractor roads may be employed in developing the operation: (a) Main tractor roads and (b) tractor trails. The construction and location of tractor roads and trails has also been discussed in chapters III and IV. None of those is shown on the general map (Plate IV) but a typical distribution is shown by Plate V for part of block 1.

Truck and tractor roads and tractor trails are to be constructed only as required and as the costs are very low they should be charged off, as road expense, to current operation. The road cost per thousand feet will gradually decline because complete development of nearly all roads and trails necessary for permanent use will occur during the first three or four cutting cycles. After construction is completed the roads and trails will be maintained through continued use. The principle involved is to charge off investments resulting from expenditure of capital and labor as quickly as possible in order to lift from industry the burden of the resulting capital charges.

Skidding Methods.—Skidding to truck roads will be performed by tractors operating in any of four ways-direct yarding, direct roading, yarding with drum units and a combination of two or more of these, as detailed in the logging cost report *(7)* and in chapters III and IV. Here the first cutting cycle will usually involve use of only direct roading. Later .cycles will bring in yarding with drum units and combinations of the several methods. Detailed allocation of cutting for two cutting cycles shown on Plate V for part of block 1 illustrates how this selective principle works in practice.

27. Plan of group and tree selection.—The basic principles of selecting financially mature trees for early removal, and creating the least possible disturbance in the continuing growth of merchantable trees throughout the forest are discussed in detail in chapter VI. It is to be especially noted that selection of trees and tree groups to make up the current cut must take into consideration rapidly changing quantities and values. In this virgin forest, however, there are many single trees and tree groups that have culminated in value and can make very low returns from further holding. These are mostly within the size classes from 40 inches up, especially those over 50 inches.

The removal of these trees should improve the net current growth for the area in two ways—first, by leaving trees and undisturbed stands that are making the most rapid growth and thus raising the mean average growth; second, by removing trees in which defect, which is offsetting growth in the same and other trees, is progressing and thus directly reducing net growth. In addition to these gains, many of the thrifty trees up to about 30 inches in diameter may be expected to increase their growth rate when released from competition.

Through these means a relatively high rate of growth may be attained on an ample growing stock (including merchantable trees up to large sizes) and earnings from growth in volume, quality, and price can be maintained at the highest practicable level. These basic objectives should never be lost sight of although under some circumstances they may necessarily be subordinated to the immediate objective of high current income. It is reasonable to conclude that on this property neglect of these principles will impair permanent values out of all proportion to any immediate gain in current income.

Without departure from the major objective of maintaining and building up permanent values the immediate objective in allocation of cuttings is to select trees and tree groups which will yield the largest possible current income within reasonable sustained yield limits. It happens that on this area, because of heavy cuttings and fire in the past, sustained yield of valuable tree sizes must for a long time be much less than the growth of all sizes. All evidence available indicates, however, that under conservative selective timber management the sum of the current income that should accrue within a decade plus the capital value maintained in the forest may reasonably be expected greatly to exceed the total values that can be obtained from the forest by any other method of management. Specifically, it appears to be demonstrable that this procedure will be more profitable than liquidation on the one hand or sustained yield under an extensive clear-cutting system on the other.

In order to avoid losses from undertaking truck and tractor road construction prematurely and from deferring utilization of timber that has ceased to grow in value at a reasonable rate, a 5-year cutting cycle is recommended for this area. That is, cutting should take place systematically on each block every five years. During the first cycle only the most accessible part of each block would be reached, during the second cycle a slightly more remote portion would be added and so on. By the end of three or four cycles permanent roads, charged off to current operations, would have been extended nearly everywhere and from then on cuttings would be distributed generally through each block in turn.

Under this program most of the declining, stationary, and slowly increasing values should be recovered within the first three or four cycles. The advantage in doing this is evident.

Timber removed during the first five-year cutting cycle comes out on the average in 2½ years; during the second, in 7½ years; and during the third, in 12½ years. Discounting at only 3 per cent the present value of a dollar due in 2½ years is approximately 93 cents, as against 80 cents for a dollar due in 7½ years and 69 cents for a dollar due in 12½ years. This shows the losses that can occur by holding values that do not increase with time. In addition to avoiding discount losses the removal of decadent or stagnating trees increases the growing space for those that are increasing in value or frees the soil for regeneration of new stands. This general problem of the effect of discount of future income is discussed with detailed illustration in chapter III and summarized in chapter VI.

28. Application of short cutting cycle selection in block 1.—This entire block is within the Douglas fir type and bears a very small volume of conifers other than Douglas fir. It is chosen for detailed discussion because it illustrates the procedure necessary to liquidate overmature trees and to restore depleted growing stock on the property as a whole. For two sections, including most of the merchantable stand in the block, information was obtained by methods described in chapter VIII (see Plate V). Stand averages for these two sections are assumed to apply to the same types in the remainder of the block. The map shows topography, roads, timber types, approximate location of trees over 40 inches in diameter, and location of groups to be clear cut and adjacent tree selection areas for the first two cycles. For the "20 to 40 inch" and "over 40 inch" stands complete information is available on the number, basal area, and volume of trees in each diameter class from 6 inches up. Figure 13 shows graphically for the entire acreage of each of these two classes of stand the distribution of basal area by 2-inch diameter classes. Basal area is chosen for graphic comparison of conditions in different stands because smaller diameter classes are represented inadequately or not at all by board foot volume figures.

Such information as is available justifies the assumption that under selective operation a permanent growing stock of not less than 25,000 to 50,000 board feet per acre should be retained or built up if now lacking. The following discussion of each class of timber on the block shows how far this standard is met at present.

Douglas fir size class A. (volume mainly in trees over 40 inches). There is an area of 1,181 acres which averages 71,745 board feet gross volume per acre. The surplus volume should be gradually reduced to about the above tentative standard, in 3 to 5 cutting cycles. In making this reduction it would be better to err on the side of conservatism and maintain the volume at not less than 35,000 board feet per acre if possible, at least until other areas are built up to a desirable level. The shortage of high-quality timber on this block as a whole, however, will undoubtedly necessitate drawing heavily upon it to hold up the value of the annual cut. (Fig. 13, upper graph.) This stand includes a considerable number of premerchantable

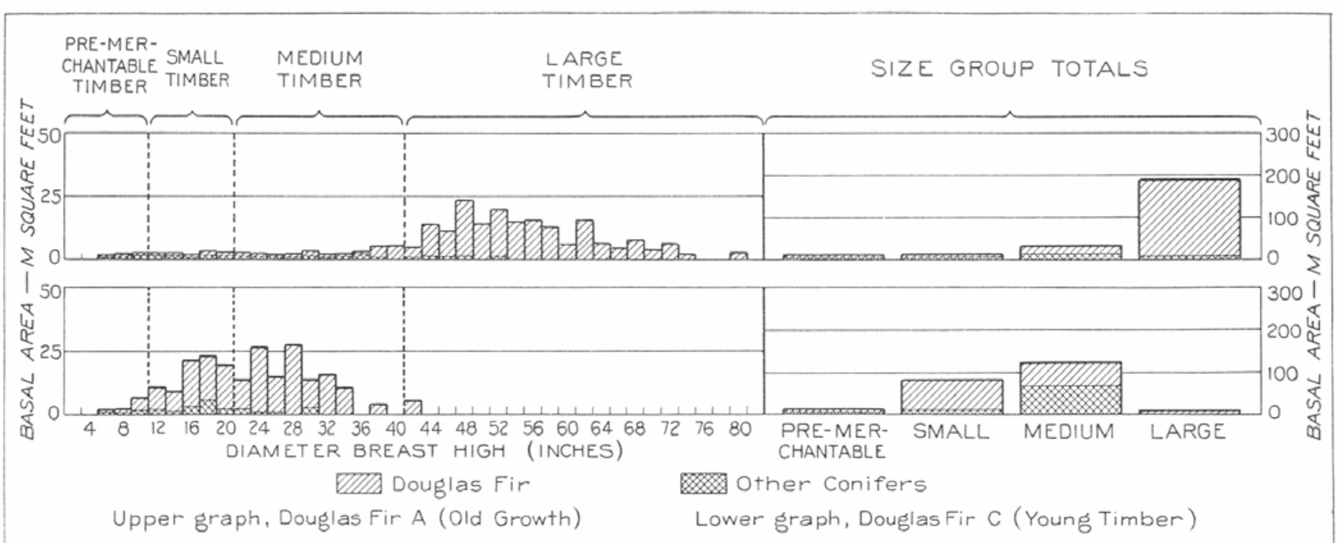


Fig. 13 - Stand Structure Diagrams of Block 2
(Chap. V)

(6- to 10-inch diameter) and small merchantable (12- to 20-inch) tree groups. The Douglas firs among these have come in, as in many other Douglas fir stands, following spot and ground fires.

Douglas fir size class C (mainly trees 20 to 40 inches). This nearly even-aged stand, about 100 years old and 1,313 acres in area, contains an estimated average of about 30,000 board feet per acre in trees more than 12 inches in diameter. There are very few trees over 34 inches in diameter. It would therefore be permissible to cut each cycle an amount nearly equal to the growth, if care is taken to reserve the majority of the 22- to 34-inch trees so as to build up the larger, high-value size classes. Realization on culminated values in Douglas fir class A stands is so much more urgent than cutting in these smaller stands that it should probably be deferred almost entirely for 15 to 20 years (3 to 4 cycles) unless an active demand for piling, poles or posts, or for saw logs with a high percentage of common lumber should arise. In that event light cuttings should be made, confined to the poorer crown classes, to the larger trees which are too rough to retain for future growth, and to spots where dominant and codominant trees crowd each other. During these cycles any practicable cuttings in the suppressed crown class with light removals in the intermediate crown class can be added to the net yield as a surplus not now foreseen. This cutting would principally take the place of mortality which has been allowed for in these size groups in later discussion of yield possibilities for this block (see fig. 14).

Douglas fir class E (volume mainly in trees under 6 inches in diameter). These areas which aggregate 2,730 acres (including a large area of unregenerated spots), are not apt to enter into cutting plans within the next 8 to 12 cycles (40 to 60 years). If the growing stock and yields have in the meantime been maintained in the Class A and Class C stands a gradual increase in the cyclic cut may be permissible beginning at that time. (See fig. 14, 10th to 15th cycles.) From then on a long period of stand management (probably 100 years or more) will be necessary before the yield of the valuable large diameter classes can be restored on this portion of the block. In the meantime, however, each cycle should yield some net income from the small timber cut from these stands.

Clear-cut spots originating under group cutting, as discussed more fully in chapter VI, should be treated in much the same way as the present young even-aged stands except that they may be expected to regenerate with much higher density. On account of slow natural pruning in Douglas fir the dense young growth expected to originate in small openings should be left undisturbed until natural pruning has cleared or at least deadened the branches on as much length of trunk as desired for the life of the tree. Normally this may be expected to produce branch deadening for about the lower 35 to 50 feet by the age of 40 to 60 years. From that time on heavy thinnings should be made in each of the next 5 to 10 cutting cycles, if markets permit. These may be expected to retard shortening of the live crowns, and to maintain the rate of growth on individual trees. If this treatment is successful the lower 35 to 50 feet of trunk will lay on increments of clear wood from about 50 years on, or as soon thereafter as the dead branches have rotted away. The upper portion of the trunk will produce rough logs with sound green knots. If the natural pruning process is prolonged beyond 40 to 60 years, branches at the base of the crown will continue to die but will not completely decay and will form loose black knots which never become covered with clear wood in the upper logs. It will pay, therefore, to carryon thinning regularly if it can be done without loss. Until thinnings begin, little labor or money will have been spent in regeneration or care of these stands. The earnings from older timber surrounding should carry all the costs very easily. From the time thinning begins until the final trees have reached 40 inches or more in diameter and are utilized, these groups will provide some net income every 5 to 10 years.

Summarizing now the cutting policy for the whole block: For about three cycles the cut should consist mainly of large-sized, high-value timber taken from Douglas fir A stands. (See fig. 14.) From then on, an increasing proportion should consist of young timber taken from smaller size classes in the process of rebuilding them to profitable yields. Still later the clear-cut groups will provide similar small material. Eventually stability should be attained in distribution of the cut between the more valuable large sizes and less valuable small material removed in a continuing process of stand management.

The volume of large, high-value trees (40 inches diameter and up) in each cyclic cut should probably not fall much below 40 per cent of the total if skill in management is exercised and if the growing stock has not been depleted in the past. This necessitates the cutting of only one such tree per acre every 15 to 20 years. To meet this requirement the growing stock must include 3 to 8 trees per acre of the large timber class (over 40 inches). These need not be uniformly distributed but may be more or less concentrated on the better sites where growth is prolonged at a more rapid rate. They need occupy no more than one-eighth to one-fourth of the ground space, so that all the rest of the area will be available for smaller and faster growing merchantable and premerchantable trees.

On this block, however, past clear cutting prevents holding the cut of large timber at 40 per cent of the whole beyond the first few cycles until the growing stock has again been built up in the large sizes.

Evolution of the stand on the block as a whole.—Keeping in mind the foregoing treatment of the block and the character of stands within it, it should now be of interest to consider the possible aggregate results on block 1 of short cutting cycle selection. This method of treatment should, if successfully carried out, eliminate permanently the large premerchantable area (now over 50 per cent of the block). More than half the volume growth in fully stocked stands on the premerchantable area occurs in trees which will die out of the stand before they become of utilizable size. All of the remaining volume will yield income only in a distant future. In lieu of this large wastage of growth and long deferment of income due to an excessive area of these stands such stands distributed throughout the block in small groups should occupy only from 10 to 20 per cent of the area. The remaining area should be occupied by merchantable size stands in which the growth losses of premerchantable stands have practically ceased and where at short intervals a volume equivalent to the current growth can be utilized.

In considering evolution of the growing stock under these conditions it should again be strongly emphasized that the actual every day process of selective timber management concerns itself very little with long-time forecasts of future events. It proceeds by means of light cutting and short cutting cycles to make only very moderate changes in the stand at anyone time. These changes are based on very careful study to determine what trees or classes of trees are financially mature and can be removed without injury to the remaining stand. If market conditions permit utilization of the surplus inferior elements of the stand, cutting within these tree classes is also studied. In both cases the nature of the residual stand and the effect of the cuttings upon it are carefully considered. Wherever a heavy growing stock of vigorous trees is maintained under this treatment, there is every reason to believe that the current rate of growth and consequent constant progression of trees from diameter class to diameter class will be satisfactory. Full confidence may therefore be felt in the future; the more so since the maintenance of a preponderant portion of the investment in merchantable trees and the presence of a permanent road system will always permit rapid recovery of the major investment in case this should become necessary. Long term forecasts are considered of doubtful value owing not only to occasional damage wrought by natural agencies but even more to economic factors and to variations in the skill exercised in management.

It should be distinctly understood, therefore, that the following calculations of future desirable evolution of the stand are made solely for purposes of illustration and do not in any sense constitute a forecast of the future. This should be obvious, in view of the fact that the type of management here discussed has not been definitely adopted for the area. Wherever selective management, under full inventory control, is undertaken in actual practice similar records should be built up cycle by cycle as discussed in chapter VIII and illustrated in figure 15 with its footnote.

In thus illustrating how the evolution of the three classes of stands toward a common goal may be brought about, the basal areas of both classes of stand shown in figure 13 are thrown together and shown in composite in figure 14 (1st cycle). Table 12 shows corresponding data starting with number of trees and gross board foot volume in its present condition for each size group. Beginning with this condition before the first cyclic cut, the calculated cut and the additions by growth are shown cycle by cycle for 14 cycles (70 years). The purpose of this somewhat extended calculation and graphic representation is to show the manner in which a stand may, without disturbing conditions required for continual growth on the merchantable size classes, be led into the desired form. Although this may seem somewhat theoretical, it has been done on numerous forest properties in Europe, starting under the adverse condition of a depleted growing stock such as would be the condition over this entire block if no Douglas fir A and C stands were present. (See figure 15 and accompanying note.) With a surplus growing stock on a substantial part of this block, outside of areas devastated by past cutting, the gradual transformation of the stand should be a relatively simple matter for skilled technicians.

The calculations on which the diagrams and the accompanying figures are based were carried out as follows: An intensive cruise was made of the major portion of the Douglas fir A class and of an adequate sample of the class C stand. From these cruises the total number of trees in each diameter class from 6 inches d.b.h. up is known within narrow limits for the entire block. From these figures the basal area- shown in the upper and lower graphs of figure 13, the volume of each diameter class, and the total volume were computed. The first cycle diagram of figure 14 is a composite of the two diagrams, shown in figure 13.

The diagram for the 1st cycle, figure 14, and accompanying data in table 12 therefore represent present conditions and constitute the starting point for calculating the first cyclic cut (assumed to-start in 1935) and the growth by the method explained in section 37 (chapter VI), that is, by calculating for each cycle the number of trees that move up from each 2-inch class to the next higher. In determining the rate of movement of diameter classes in progression through to the larger sizes, data cited in table 17 (Lewis County) are relied upon for large diameters and the Douglas fir yield table (20) for the smaller. In accord with site conditions already described the figures used are for site III. Table 13 shows the rates of growth and other factors used, assuming 60 per cent stocking and that the more thrifty trees are reserved at each cut for growing stock. Obviously what diameter classes should bear the brunt of the cutting during each cycle is a matter of judgment

TABLE 12.—*Summary by size*

		Pre-merchantable trees—6"-10" D B H				Small timber—12"-20" D B H			
		Number of trees	Board foot vol.	Basal area		Number of trees	Board foot vol.	Basal area	
			M bd. ft.	Sq. ft.	%[2]		M bd. ft.	Sq. feet	%[2]
Amt. of growing stock prior to 1st cut	1935	42,906	....	16,720		71,947	14,340	99,423	
Amt. of growing stock removed in 1st cut[1]	1935	1,450	....	695	4.2	1,150	238	1,469	1.5
Amt. of growing stock reserved	1935	41,456	....	16,025		70,797	14,102	97,954	
Growth during 1st cycle	1935-40	....	....	765		....	1,563	10,683	
Amt. of growing stock prior to 2nd cut	1940	50,349	....	16,790		77,737	15,665	108,637	
Amt. of growing stock removed in 2nd cut	1940	2,300	....	715	4.3	2,100	430	2,957	2.7
Amt. of growing stock reserved	1940	48,049	....	16,075		75,637	15,235	105,680	
Growth during 2nd cycle	1940-45	....	....	23,132		....	1,015	6,128	
Amt. of growing stock prior to 3rd cut	1945	159,629	....	39,207		78,352	16,250	111,808	
Amt. of growing stock removed in 3rd cut	1945	11,954	....	2,771	7.1	4,700	971	6,711	6.0
Amt. of growing stock reserved	1945	147,675	....	36,436		73,652	15,279	105,097	
Growth during 3rd cycle	1945-50	....	....	35,382		....	707	4,154	
Amt. of growing stock prior to 4th cut	1950	261,798	....	71,818		75,873	15,986	109,251	
Amt. of growing stock removed in 4th cut	1950	17,252	....	4,337	6.0	4,000	844	5,758	5.3
Amt. of growing stock reserved	1950	244,546	....	67,481		71,873	15,142	103,493	
Growth during 4th cycle	1950-55	....	....	48,867		....	854	5,983	
Amt. of growing stock prior to 5th cut	1955	369,656	....	116,348		76,780	15,996	109,476	
Amt. of growing stock removed in 5th cut	1955	22,800	....	6,406	5.5	4,300	900	6,152	5.6
Amt. of growing stock reserved	1955	346,856	....	109,942		72,480	15,096	103,324	
Growth during 5th cycle	1955-60	....	....	38,220		....	3,272	31,706	
Amt. of growing stock prior to 6th cut	1960	439,165	....	148,162		109,796	18,368	135,030	
Amt. of growing stock removed in 6th cut	1960	28,824	....	8,996	6.1	5,400	973	6,984	5.2
Amt. of growing stock reserved	1960	410,341	....	139,166		104,396	17,395	128,046	
Growth during 6th cycle	1960-65	....	....	29,010		....	5,614	57,646	
Amt. of growing stock prior to 7th cut	1965	484,751	....	168,176		167,611	23,009	185,692	
Amt. of growing stock removed in 7th cut	1965	31,600	....	10,027	6.0	8,000	1,302	9,837	5.3
Amt. of growing stock reserved	1965	453,151	....	158,149		159,611	21,707	175,855	
Growth during 7th cycle	1965-70	....	....	3,664		....	8,551	81,936	
Amt. of growing stock prior to 8th cut	1970	419,666	....	161,813		240,830	30,258	257,791	
Amt. of growing stock removed in 8th cut	1970	18,500	....	6,562	4.1	14,500	2,262	17,330	6.7
Amt. of growing stock reserved	1970	401,166	....	155,251		226,330	27,996	240,461	
Growth during 8th cycle	1970-75	....	....	−11,011		....	12,039	103,367	
Amt. of growing stock prior to 9th cut	1975	349,479	....	144,240		318,166	40,035	343,828	
Amt. of growing stock removed in 9th cut	1975	17,000	....	6,344	4.4	25,000	3,116	26,715	7.8
Amt. of growing stock reserved	1975	332,479	....	137,896		293,166	36,919	317,113	
Growth during 9th cycle	1975-80	....	....	−26,424		....	15,850	123,901	
Amt. of growing stock prior to 10th cut	1980	274,168	....	111,472		394,568	52,769	441,014	
Amt. of growing stock removed in 10th cut	1980	15,264	....	5,738	5.1	25,600	3,536	29,072	6.6
Amt. of growing stock reserved	1980	259,104	....	105,734		368,968	49,233	411,942	
Growth during 10th cycle	1980-85	....	....	−12,547		....	16,295	110,223	
Amt. of growing stock prior to 11th cut	1985	238,815	....	93,187		436,435	65,528	522,165	
Amt. of growing stock removed in 11th cut	1985	13,000	....	4,556	4.9	26,000	3,585	29,752	5.7
Amt. of growing stock reserved	1985	225,815	....	88,631		410,435	61,943	492,413	
Growth during 11th cycle	1985-90	....	....	−10,056		....	17,361	104,631	
Amt. of growing stock prior to 12th cut	1990	211,247	....	78,575		467,114	79,304	597,044	
Amt. of growing stock removed in 12th cut	1990	12,000	....	4,011	5.1	28,219	5,066	37,256	6.2
Amt. of growing stock reserved	1990	199,247	....	74,564		438,895	74,238	559,788	
Growth during 12th cycle	1990-95	....	....	−1,414		....	15,398	83,804	
Amt. of growing stock prior to 13th cut	1995	199,564	....	73,150		473,399	89,636	643,592	
Amt. of growing stock removed in 13th cut	1995	11,600	....	3,832	5.2	35,500	6,825	48,587	7.5
Amt. of growing stock reserved	1995	187,964	....	69,318		437,899	82,811	595,005	
Growth during 13th cycle	1995-2000	....	....	1,311		....	12,199	61,547	
Amt. of growing stock prior to 14th cut	2000	193,919	....	70,629		459,717	95,010	656,552	
Amt. of growing stock removed in 14th cut	2000	11,500	....	3,778	5.4	31,411	6,014	42,907	6.5
Amt. of growing stock reserved	2000	182,419	....	66,851		428,306	88,996	613,645	
Growth during 14th cycle	2000-05	....	....	172	....	....	7,875	37,551	....
Amt. of growing stock prior to 15th cut	2005	180,469	....	67,023		439,992	96,871	651,196	

[1] The figures given for each cyclic cut include estimated mortality.

[2] Percentages recorded indicate percentage of the basal area (of the growing stock existing prior to each cut) removed during each cycle by cut and mortality in each size group.

groups of 14 cycles in Block 1.

Medium timber—22″-40″ D B H				Large timber—over 46″ D B H				All timber—6″ and up				
Number of trees	Board foot vol.	Basal area		Number of trees	Board foot vol.	Basal area		Number of trees	Board foot vol.		Basal area	
	M bd. ft.	Sq. feet	%[3]		M bd. ft.	Sq. feet	%[3]		M bd. ft.	%[3]	Sq. feet	%[3]
38,607	32,733	160,879		12,693	76,415	196,567		166,153	123,488	.....	473,589	.....
552	1,472	2,672	1.7	3,035	19,396	50,524	25.7	6,187	20,106		55,360	
38,055	32,261	158,207		9,658	57,019	146,043		159,966	103,382		418,229	
....	5,644	19,031		....	2,063	3,809		....	9,270	9.0	34,288	8.2
42,528	37,905	177,238		9,827	59,082	149,852		180,441	112,652		452,517	
990	826	3,437	1.9	2,465	18,559	45,687	30.5	7,855	19,815		52,796	
41,538	37,079	173,801		7,362	40,523	104,165		172,586	92,837		399,721	
....	4,599	21,359		....	1,678	4,149		....	7,292	7.9	54,768	13.7
47,160	41,678	195,160		7,565	42,201	108,314		292,706	100,129		454,489	
2,780	2,416	11,211	5.7	1,972	11,288	28,856	26.6	21,406	14,675		49,549	
44,380	39,262	183,949		5,593	30,913	79,458		271,300	85,454		404,940	
....	5,100	24,343		....	1,402	3,447		....	7,209	8.4	67,326	16.6
50,691	44,362	208,292		5,788	32,315	82,905		394,150	92,663		472,266	
3,120	2,479	11,955	5.7	1,011	6,688	16,650	20.0	25,383	10,011		38,700	
47,571	41,883	196,337		4,777	25,627	66,255		368,767	82,652		433,566	
....	5,257	24,912		....	1,301	3,233		....	7,412	9.0	82,995	19.1
53,856	47,140	221,249		4,975	26,928	69,488		505,267	90,064		516,561	
3,120	2,479	11,954	5.4	646	4,625	11,377	16.4	30,866	8,004		35,889	
50,736	44,661	209,295		4,329	22,303	58,111		474,401	82,060		480,672	
....	5,372	25,243		....	1,236	3,134		....	9,880	12.0	98,303	20.5
56,909	50,033	234,538		4,531	23,539	61,245		610,401	91,940		578,975	
3,220	2,513	12,028	5.1	712	4,518	11,162	18.2	38,156	8,004		39,170	
53,689	47,520	222,510		3,819	19,021	50,083		572,245	83,936		539,805	
....	5,535	25,812		....	1,273	3,007		....	12,422	14.8	115,475	21.4
59,859	53,055	248,322		4,024	20,294	53,090		716,245	96,358		655,280	
3,582	3,182	14,891	6.0	703	3,535	9,255	17.4	43,885	8,019		44,010	
56,277	49,873	233,431		3,321	16,759	43,835		672,360	88,339		611,270	
....	5,602	25,951		....	1,146	2,980		....	15,299	17.3	114,531	18.7
62,327	55,475	259,382		3,537	17,905	46,815		726,360	103,638		725,801	
4,430	3,742	17,796	6.9	226	2,005	4,915	10.5	37,656	8,009		46,603	
57,897	51,733	241,586		3,311	15,900	41,900		688,704	95,629		679,198	
....	5,459	25,031		....	1,187	3,119		....	18,685	19.5	120,506	17.7
63,516	57,192	266,617		3,543	17,087	45,019		734,704	114,314		799,704	
4,130	3,560	16,845	6.3	335	1,616	4,258	9.5	46,465	8,292		54,162	
59,386	53,632	249,772		3,208	15,471	40,761		688,239	106,022		745,542	
....	5,432	24,752		....	1,245	3,295		....	22,527	21.2	125,524	16.8
64,842	59,064	274,524		3,461	16,716	44,056		737,039	128,549		871,066	
4,130	3,567	16,845	6.1	204	1,001	2,631	6.0	45,198	8,104		54,286	
60,712	55,497	257,679		3,257	15,715	41,425		692,041	120,445		816,780	
....	5,899	27,188		....	1,328	3,546		....	23,522	19.5	128,410	15.7
67,056	61,396	284,867		3,535	17,043	44,971		745,841	143,967		945,190	
4,178	3,611	17,060	6.0	214	1,064	2,788	6.2	43,392	8,260		54,156	
62,878	57,785	267,807		3,321	15,979	42,183		702,449	135,707		891,034	
....	7,531	35,996		....	1,427	3,824		....	26,319	19.4	134,395	15.1
72,462	65,316	303,803		3,626	17,406	46,007		754,449	162,026		1,025,429	
4,178	3,606	17,032	5.6	212	1,057	2,771	6.0	44,609	9,729		61,070	
68,284	61,710	286,771		3,414	16,349	43,236		709,840	152,297		964,359	
....	10,302	50,809		....	1,531	4,126		....	27,231	17.9	137,325	14.2
83,129	72,012	337,580		3,748	17,880	47,362		759,840	179,528		1,101,684	
5,009	4,164	19,876	5.9	217	1,094	2,856	6.0	52,326	12,083		75,151	
78,120	67,848	317,704		3,531	16,786	44,506		707,514	167,445		1,026,533	
....	14,142	71,176		....	1,648	4,451		....	27,989	16.7	138,485	13.5
99,982	81,990	388,880		3,896	18,434	48,957		757,514	195,434		1,165,018	
9,080	6,997	33,900	8.7	218	1,106	2,885	5.8	52,209	14,117		83,470	
90,902	74,993	354,980		3,678	17,328	46,072		705,305	181,317		1,081,548	
....	18,613	94,384	.....	....	1,736	4,685	.....	....	28,224	15.6	137,292	12.7
120,780	93,606	449,864		4,064	19,064	50,757		745,305	209,541		1,218,840	

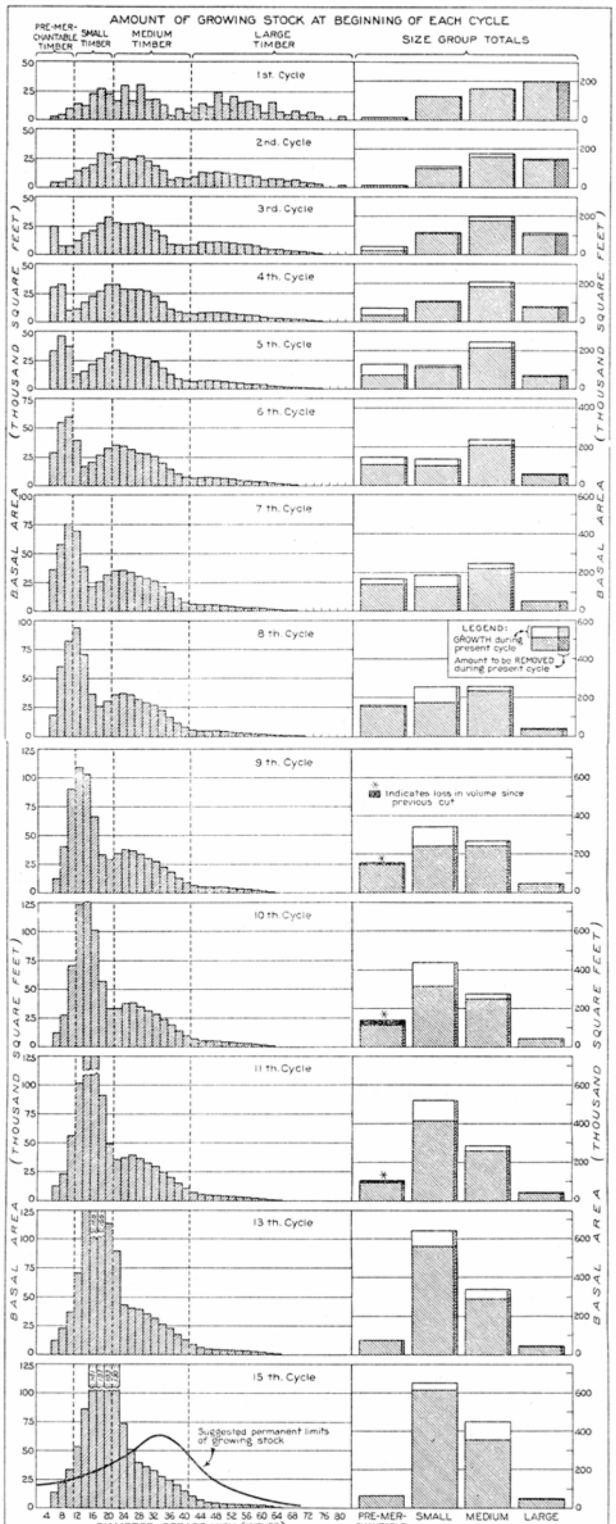


Fig. 14—Evolution of Growing Stock Through 14 Cutting Cycles on Block I

Note concerning Figure 15.—This figure shows the results actually obtained on a single division of the Communal Forest of Couvet, Switzerland, (*10*), during the period from 1890 to 1927. The diagram is based on accurate data from inventories taken at the beginning of each 6-year cutting cycle. It is of special note that during the 37-year period the percentage of basal area represented by trees 22 inches and larger in diameter increased from 15 per cent to 47 per cent of the total basal area. On the other hand the percentage of basal area of trees in the 8- to 10 inch diameter classes (6 to 10 in 1929) declined from 36 per cent to 14 per cent of the total basal area. The largest tree in the stand in 1890 was 32 inches d.b.h. and in 1927 40 inches d.b.h. During the same period the basal area of the average tree utilized increased to approximately double the 1890 figure and the annual yield per acre increased from 74 to 130 cubic feet per acre. The scale has been so adjusted that direct visual comparison can be made between the actual evolution of the growing stock in this specific case and that forecast in figure 14. Although this Swiss forest contains no timber so large as included in figure 14, the same shift from smaller to larger diameter classes is visible as in later cycles of figure 14.

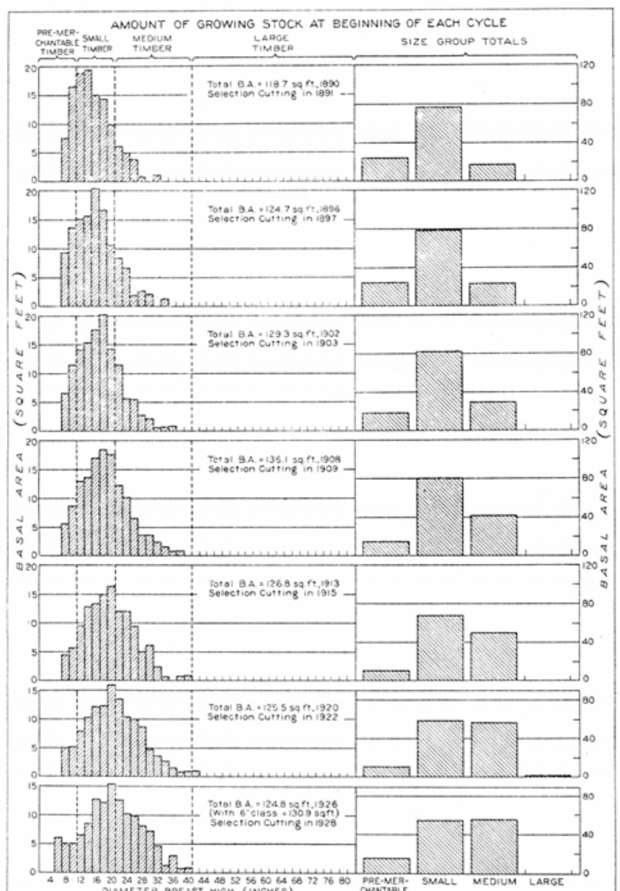


Fig. 15—Evolution of the Growing Stock from 1890 to 1927 on average acre, Division 14 of the Communal Forest of Couvet, Switzerland; Based on inventories Recorded, Prior to Cutting, Each Six-Year Cycle as Noted Above.

based on the objectives already explained. The resulting stand diagrams have therefore very little in common with the "normal" diameter distribution curve for even-aged stands.

Beginning with the conditions now present before the first cyclic cut, the calculated volumes and numbers of trees removed by cutting and mortality are deducted and the numbers of trees moving into each diameter class from the class below are added to those remaining in each class. The volume and basal area at the end of the first cycle can then be computed to show conditions of the stand before the second cyclic cut. This forms the new basis of calculations for the second cycle and in like manner each of the remaining 14 cycles is computed. Each diagram thus shows for the assumed method of management the probable condition of the stand at the beginning of each cycle. Although these calculations have not been carried forward as many years as is frequently done for management plans based on extensive clear-cutting procedure and yield table data, it has already been noted that they are here introduced only for illustrative purposes and not as a definite prediction of results.

The cut for the first cycle is calculated at approximately 12,000,000 board feet net (20,000,000 feet gross) from block 1. In addition to the trees cut, certain mortality from insects, disease, and possibly fire must be allowed for. All of these factors causing tree removal are combined with the trees cut and shown for each cycle in table 12 opposite the caption "Amount of growing stock removed by cyclic cut and mortality." Out of the total gross board foot volume of the trees removed by cutting and mortality only the utilized portion can be credited to the net cut. During the first two cycles it is known that the trees to be removed contain much defect and. that the trees dying in the smaller size classes are not likely to be salvaged. Therefore the net volume utilized is calculated at only 60 per cent of the gross volume removed. By the third cyclic cut utilization is expected to improve slightly and as the permanent road system is extended, markets improved, defective trees eliminated and mortality anticipated, from cycle to cycle, the net utilized volume should constitute a gradually larger percentage of the gross. The assumptions of net utilization for each cycle are as follows:

	Per Cent		*Per Cent*
1st cycle	60	6th cycle	78
2nd cycle	60	7th cycle	81
3rd cycle	65	8th cycle	84
4th cycle	70	9th cycle	87
5th cycle	74	10th and later cycles	90

By the 10th cycle approximate stability may be expected in the standards of utilization. As this is primarily a saw-timber area, the volumes referred to are saw-timber volumes calculated in board feet and do not include the portions of trees not customarily utilized, ,or trees under saw-timber size. If the utilization of such material becomes possible, volumes should be computed in cubic measurement which would, in fact, be desirable even now in place of the present inaccurate system of measurement.

As the dead and down material and defective trees are cleaned up, and as utilization of smaller trees becomes possible, less gross volume has to be removed at each cyclic cut. Accompanying these changes it can readily be visualized that the tangle of dead and down material on the forest floor will gradually clear up. This in itself will facilitate utilization of smaller sizes which for economical handling would probably be bunched by horses.

Another striking change which should be expected during the 14 cycles is the gradual elimination of over-sized trees. Much later, stabilization of the cut should occur on the basis of about 40 per cent of the volume from trees more than 40 inches in diameter and 60 per cent from trees 40 inches and under. In numbers, however, this may not mean cutting more than one large tree to 20 or more small trees. Following is the estimated percentage of the total volume cut each cycle from trees more than 40 inches in diameter:

	Per Cent		*Per Cent*
1st cycle	95	8th cycle	25
2nd cycle	95	9th cycle	20
3rd cycle	75	10th cycle	12½
4th cycle	65	11th cycle	11
5th cycle	55	12th cycle	11
6th cycle	55	13th cycle	8
7th cycle	45	14th cycle	8

After the second cycle the cut would have to be reduced owing to the decrease in quantity of large timber. It could readily be restored to the original volume by the 10th cycle, owing to the expected growth exceeding the cut and to the restoration of the growing stock in volume, if it were not for the persisting deficit in large-sized timber resulting from fire and extensive clear cutting in the past. Logging and manufacturing experience to date and prospects for the future do not warrant the assumption of successful operation in this locality for the general lumber market unless the large timber sizes constitute at least 10 per cent of the cut. Under any conditions that can reasonably be foreseen the cut should be increased very gradually from the 10th cycle on until the growing stock of large-sized timber has been restored in volume. This would require a period

TABLE 13.—*Rates of growth, volumes, and basal areas used in computing movement of trees through diameter classes on block 1 (Site III)*

Diameter breast high	Time required for 2 in.d.b.h. growth	Trees moving into next d.b.h. class in 5-year cycle	Gross volume per tree	Basal area per tree
Inches	*Years*	*Per Cent*	*Bd. ft.*	*Sq. ft.*
6	6.6	76	.....	0.196
8	7.1	70	.....	0.349
10	7.5	67	.....	0.545
12	8.0	62	75	0.785
14	8.6	58	95	1.069
16	9.3	54	197	1.396
18	10.1	50	289	1.767
20	10.9	46	400	2.181
22	11.9	42	480	2.640
24	13.3	38	609	3.142
26	14.8	34	723	3.69
28	16.3	31	848	4.28
30	17.4	29	1,050	4.91
32	18.2	27	1,295	5.59
34	18.8	27	1,562	6.30
36	19.3	26	1,695	7.07
38	19.7	25	1,957	7.88
40	20.0	25	2,822	8.73
42	20.0	25	3,224	9.62
44	20.0	25	3,779	10.56
46	20.0	25	4,279	11.54
48	20.0	25	4,826	12.57
50	20.0	25	5,181	13.64
52	20.0	25	6,200	14.75
54	20.0	25	6,462	15.90
56	20.0	25	6,740	17.10
58	20.0	25	7,474	18.35
60	20.0	25	8,026	19.63
62	20.0	25	8,300	20.97
64	20.0	25	9,290	22.34
66	20.0	25	9,700	23.76
68	20.0	25	10,400	25.22
70	20.0	25	12,195	26.73
72	20.0	25	12,700	28.27
74	20.0	25	13,096	29.87
76	20.0	25	13,400	31.50
78	20.0	25	13,700	33.18
80	20.0	25	14,000	34.91

from 10 to 20 cycles beyond the period represented by diagrams in figure 14. This does not mean that the block would be wholly unprofitable during this extended period. On the contrary, it may be expected to yield a cut every 5 years with some profit; but it cannot be expected to attain full productivity in money yields for a long period. In the meantime cuttings should be made regularly, since if they are not, restoration of valuable tree sizes would be materially delayed while roads and other forest improvements would deteriorate.

Every effort should be exerted toward restoration of the larger size classes in the growing stock to insure that the volume yield of large trees will be restored as rapidly as possible to about a 40 per cent ratio. This should insure that 15 to 25 per cent of the log output will be of the clear grade. If quality of output is not built up to this standard, permanent shrinkage in the financial yield from the property appears unavoidable.

The evolution in the proportion of the trees and volume coming from large timber, in the log grades obtained, and in the parallel development of the road system naturally will be accompanied by changes in the growing stock. Oversized trees will gradually disappear but care must be exercised to insure that sufficient additional trees will advance as rapidly as possible into the classes above 40 inches so as to provide for continued yield of large timber. On this block the present deficiency in medium-sized timber (22 to 40 inches) is a handicap to rapid progress. This means that cutting will have to be very conservative in these size-classes. In the 12- to 20-inch classes cutting can be carried on rather freely whenever there is a market for such material. Such cuttings will remove it majority of the inferior trees as well as surplus trees from overcrowded portions of the stand. These measures will favor the better trees and are expected to help sustain the growth at above the average rates of unmanaged stands.

These cuttings will gradually shape the stand somewhat into the pattern exhibited by the heavy line in the last diagram of figure 14. This pattern, once attained, should have substantial permanence; but no rigid limit should be placed on the future. As noted in the case of the other diagrams this does not follow the pattern of an ordinary diameter class distribution curve for even-aged stands. It merely represents an approximation to the basal area required in each diameter class to provide for the cyclic cut and mortality in that class plus an adequate number of trees for future development into higher diameter classes. Skilled management is, above all else, a continuing process of adapting growing stock size distribution and total volume toward a balance which makes the most of the site on the one hand and performs the greatest industrial or human service on the other.

In working toward this balance the economy of producing lumber and other products from large trees should never be lost sight of. The average tree cut in the group over 40 inches yields about 5,000 board feet. The average tree cut in the 12- to 20-inch group yields about 200 board feet of relatively inferior material (in even-aged stands on Site III the average tree at the age of 100 years is 16.9 inches) *(20, table 3)*. Leaving quality of the product entirely out of consideration the cost of felling and bucking, skidding, hauling, and manufacturing 25 trees containing 200 board feet each is practically certain to exceed the cost of logging and manufacturing one tree containing 5,000 board feet by an amount far greater than the entire out-of-hand cost of producing stumpage of the larger tree sizes under selective management.

The operations within the tract during each cutting cycle may be visualized in more detail as follows:

First cycle (Cut of 1935). In order to obtain the highest conversion values, high quality trees in concentrated groups on accessible and easily logged areas will be selected. The map (Pl. V) discloses that these conditions will best be met by selecting groups

TABLE 14.—*Comparison of logging costs per thousand feet for cutting cycles (all costs prorated over annual outputs)*

Item	Costs per thousand feet board measure: 1st cycle	2nd cycle	3rd cycle	4th cycle
I. Main line transportation	$.00	$.00	$.00	$.00
II. Truck transportation, etc.				
Truck road construction	.30	..	..	..
Truck operation	1.50	1.50	1.50	1.50
Total	1.80	1.50	1.50	1.50
III. Loading (total)	.30	.30	.30	[1].35
IV. Roading (tractors)				
Tractor roads	.30	.30	.20	.10
Roading	1.00	1.00	1.00	1.00
Total	1.30	1.30	1.20	1.10
V. Skidding (tractors)	..	.20	.40	[1].60
Yarding (tractor drum units)	.00	.20	.30	.40
Total	..	.40	.70	1.00
VI. Felling and bucking (total)	1.00	1.00	1.00	[1]1.10
VII. Administration and Fire Protection				
Salaries and overhead	.50	.50	.50	.50
Industrial insurance	.12	.12	.12	.12
Other insurance	.03	.03	.03	.03
Fire protection	.50	.50	.50	.50
Total	1.15	1.15	1.15	1.15
Total logging costs	5.55	5.65	5.85	6.20

[1] Increase due to increasing proportion of small sizes.

designated in the legend and trees from the adjacent tree selection areas. Logs should be trucked partly from two landings directly on the highway and partly over one-half mile of truck road which must be built. (P1. IV.) Tractor road and trail construction will be confined to about 10 miles laid out with some attention to grades and to location of heavy groups. These should cost not over $350 per mile. The total truck-road charge against the net cyclic cut of 12,000,000 feet b.m. will therefore be about 30 cents per M feet, a figure which is about tile same as road cost if the whole tract were logged. The cost items and estimated total cost of getting logs to the sawmill are given in column 1 of table 14.

Second cycle (Cut of 1940). The groups to be cut in the second. cycle (see Pl. V) include many similarly selected, easily logged groups together with adjacent tree selection areas and also some steep areas which will require drum-unit yarding, sufficient to yield about 11,000,000 feet net. The remaining 1,000,000 feet from block 1 should be picked up by tree selection and salvage of windfalls and otherwise damaged timber tributary to the tractor roads built during the first cycle. The cost items and total costs for this cycle are shown in column 2, table 14. As in the first cycle the unsalvaged dead trees scattered through the young stands will be a total loss; but loss by mortality in the old timber should be at a minimum from this time on, owing to the presence of well-distributed roads.

Third cycle (Cut of 1945). Only a little tractor-road construction will be necessary. Most of the groups will be located on ground too steep for direct tractor yarding and drum units will have to be used, at an added cost of about 75 cents per thousand feet. The remaining cut will be obtained by logging scattered trees which can be taken out on roads constructed in previous cycles.

As much of the old timber area is opened up by roads, the unsalvaged mortality can be expected to shrink and the net utilization to rise to 65 per cent of the gross volume removable. From this time on the loss by defect will also be reduced.

Fourth cycle (Cut of 1950). Tractor roads will have been all opened up by this time, except for extensions into the younger age classes. Selection will extend mostly to single trees throughout the mature stands, with group selection where necessary.

Fifth to ninth cycles. Cutting will continue throughout most of the merchantable stands but since younger stands hitherto largely untouched predominate in certain parts of the block considerable concentration will continue, first at one place then at another in succeeding cycles.

Tenth to fourteenth cycles.—The heavy clear cutting in the past, which completely removed the growing stock from over half of the block, has caused a serious shortage of growing stock of large timber which will persist during these cycles and for some time later. This will result in a low percentage of the yield in high-value timber. As it is deemed impracticable to operate if the cyclic cut includes less than 10 per cent of large timber it will become necessary to reduce the total cut far below the calculated growth. The medium growing stock (22 to 40 inches) which yields about 45 per cent of excellent timbers and No.1 common lumber (see chapter II, figures 3 to 6) will tend to hold up average values to a considerable extent. The remaining cut will come from small timber (12 to 20 inches) and must be expected to be of marginal value.

During this period the 2,730 acres of area clear cut between 1915 and 1935 may be expected to come under thinning operations. After the 10th cycle thinnings may also be expected in groups originating on areas cut over in the first cycle. These should be repeated in both cases every 5 to 10 years. Gradually all the young stands will be treated similarly and will yield continuous returns. As enough clean-boled, fast-growing trees should be retained to keep these groups well stocked until trees of large size and maximum value are brought to maturity, group cutting will continue to be the ultimate destiny for most of the stand. While these groups are developing, surplus trees in sufficient numbers to provide a regular cyclic cut will be continually available. They will provide income and pay their way through many decades of tree selection and should hold the cost of producing large timber to a low figure.

Under this procedure the ultimate returns from cutting high grade timber should contribute largely to net income. Compound interest calculations of earnings or costs are unnecessary because all costs, including road construction and maintenance will be charged off annually. The time element, therefore, will not influence the cost of forestry except as it appears in the form of capitalized value of the permanent growing stock which this system of continuous forest growth demands. Essentially the methods proposed hold close to Nature's methods, differing only in the fact that trees will be removed when they reach a zenith of value without waiting for slow decline and death from disease or other adverse influences.

A great mass of recruits from the area which has already been clear cut should come into the premerchantable group from the third to the tenth cycles and by the end of 70 years should have moved into the upper portion of the small timber group and the lower portion of the medium timber group. This is shown in the basal area diagrams for the 13th to 15th cycles in figure 14. Trees can move in large numbers into the large timber group only during a period of 10 to 20 cycles beyond the time covered by these diagrams.

In the meantime, however, if the stand on 1,313 acres of Douglas fir C type has been continuously subjected to selective management, removing inferior and slow growing trees and reducing excess density where necessary, the accelerated growth of the superior individuals in the medium group should bring them into the large timber group at a rate in excess of the removal by cutting. Increase in the volume of the large timber group from this source begins to show in the figures for the 13th, 14th and 15th cycles in table 12. Under sound management this will be an accelerated process when the surviving trees now in the 16- to 24-inch diameter classes move forward to the large timber class during the 15th cycle and later.

It has been noted that if this type of management is continued the stand should gradually take on a form approaching the curve superposed on the last cyclic diagram of figure 14. With the growing stock thus distributed it is estimated that the continuing yield can consist of large, timber about 40 per cent, medium about 35 per cent and small 25 percent by volume. Actually so much of this area is Site III that it may be necessary to be satisfied with a lesser yield of large timber. Table 15 gives a rough estimate of the approximate distribution of the growing stock to different size groups, the estimated yield from each group, and related data designed to throw light on the condition of the growing stock

TABLE 15.—*Probable distribution of the cyclic cut and growing stock to timber groups after restoration of the growing stock (block1).*

Timber size group	Necessary growing stock			Volume of average trees felled	Trees removed each cycle[1]	Volume of 5-year cyclic cut		
	Volume	Trees	Basal area			Gross	Net	Distribution of volume
	M ft. b.m.	*Number*	*Sq. ft.*	*Ft. b.m.*	*Number*	*M ft. b.m.*	*M ft. b.m.*	*Per cent*
Large (over 40 in. diameter)	85,000	17,000	227,000	5,000	1,700	8,500	8,000	40
Medium (22 to 40 in. diameter)	130,000	130,000	540,000	1,000	8,000	8,000	7,000	35
Small (12 to 20 in. diameter)	30,000	150,000	170,000	200	27,500	5,500	5,000	25
Premerchantable (2 to 10 in. diameter)		500,000[2]	100,000		40,000[3]			
Totals	245,000	797,000	1,037,000		77,200	20,000[4]	20,000	100

[1] Includes volume loss due to unsalvaged mortality and breakage.

[2] From this number must come each cycle nearly 40,000 recruits to the small merchantable group to offset thinnings and movement of trees from that group to the medium-size group.

[3] Natural thinnings in premerchantable stand, i.e., unsalvaged waste during premerchantable period.

[4] Surplus allows for mortality losses.

required to maintain the forest in profitable production. The efficiency of such a growing stock in maintaining earnings can readily be realized, when stumpage values and gross stumpage returns are taken into consideration. The following returns are considered representative if present prices apply in future to an annual cut distributed to size classes as shown in table 15.

Timber group where cyclic cut originates	*Net amount of cyclic cut (M ft. b.m.)*	*Value per M ft. b.m. (dollars)*	*Total stumpage value (dollars)*
Large (42" diam. and over)	8,000	5.00	40,000
Medium (22" to 40" diam.)	7,000	2.00	14,000
Small (12" to 20" diam.)	5,000	.50	2,500
Total	20,000		56,500

This is equivalent to an annual return -from the 5,225 acres of productive forest in block 1 of $11,300 per year or $2.16 per acre annually. Since all utilization and road costs and most of the fire prevention have already been deducted to obtain the net stumpage value the remaining forest costs consist of general fire protection and administration both of which should be carried within a cost of 20 cents per acre leaving approximately $1.96 per acre net annual returns before taxes. If the land were privately owned the tax cost would probably be from 25 to 60 cents per acre.

At the higher figure the money outlay, including administration and fire protection, would be about 80 cents per acre per annum, which is equivalent to about $1.04 per thousand board feet of stumpage produced. Whatever amount is realized on stumpage above this figure is available for earnings on the forest property investment. As the average stumpage is estimated above at $2.83 per thousand feet, about $1.79 per thousand feet remains as return on the property investment. This appears adequate for a rough mountain area where land is submarginal for all purposes except forest use. (Prices used are based on present market. It is generally believed that prices and hence net earnings will increase in the future.)

A glance at the estimated returns reveals that if large timber were absent from the cut the returns, on the basis of these estimates, would be very low even if the rate of production remained the same, which is very doubtful. Since the money cost of production would not be lowered, the net return would practically disappear and with it the capital value of the property.

During the first 5 cycles, while evolution of the stand toward a fairly permanent form is taking place, the road system should attain permanent development. As the weight transported each cycle, except for the period needed for the restoration of growing stock, will amount to approximately 75,000 tons, or an average of 15,000 tons a year, heavy duty roads with crushed rock surface would be necessary for trucks. It would probably be desirable during the first 3 cycles to add about 1½ miles of spur roads to the through truck roads already on two sides of the tract.

The remaining transportation would be by tractors with or without tractor roads. With very little expense some of the tractor roads should gradually become permanent. Both types of roads should be charged to current operating expenses and no capital charges created for them. Maintenance would thus be the sole charge against the cyclic cuts and this would be very low long before the first 10 cycles have been gone through.

Recapitulation.—Cutting on block 1 has been traced for illustrative purposes through fourteen cycles at varying rates per cycle, according to the varying conditions of the growing stock. The main cut has been calculated as of the first year of each cycle, namely, every 5 years beginning with 1935. The timber selection methods are assumed to provide current income for each 5-year cycle and at the same time to maintain or, as in this case, gradually to enhance the value of the property. The provision is flexible, however, and in the event of fire, windfall, or disease, salvage cuttings may be undertaken in the same block later in the same cycle. Or should fire or other damage in other blocks within the management unit demand that logging and milling equipment and market outlets be devoted to salvage in those quarters, cutting in block 1 might be suspended for one or more cycles. In other words the keynote of the suggested operating plan is flexibility, leaving each succeeding management free to work toward the most effective balance between the biological condition of the forest and the economic demands upon it.

Under such a short-cycle method of selection, continually seeking high-value trees for cutting, there can at the same time be maintained growing stock with a sufficient number of trees of all sizes to provide for replacements in all diameter classes.

These replacements are brought about by the continuous recruitment of the small timber group (12 to 20 inches) from the premerchantable timber group and the progression of the recruits through each 2-inch diameter class in turn until a selected few come into the large timber group (over 40 inches diameter). Each cyclic cut is eventually made up of three elements—about 40 per cent of the volume to come from large timber, 35 per cent from the medium timber, and 25 per cent from the trees that fall by the wayside in the progression through the small timber classes. In initial cutting in the stands heretofore unmanaged a larger proportion (as shown in table 12) comes from the large timber group.

29. Timber extraction costs.—Net conversion values in each cycle depend on the order of selection of each class of timber and the cost of extraction. Since high quality timber receives continued preference the highest average sale value is assured. In order to maintain extraction costs at a low level, cutting cannot at first be spread through the entire large-timber area. Instead, the selected groups and accompanying tree selection areas should be somewhat concentrated where road costs will be lowest. Plate V shows for part of block 1 the progress of selection for the first two cycles, which is summarized on pages 58 and 59 and in table 12.

In later cycles cutting should proceed more vigorously in the younger, 22- to 40-inch size group, and the yield of big timber would be proportionately reduced as already noted. With this program of selection in mind the logging costs for the first 4 cycles are estimated as shown in table 14 on the basis of present costs.

Conditions disclosed by Plate V indicate that if logging were immediately extended over the whole tract on a selective basis, the average cost would be greater than the cost for the first cycle. Under the plan proposed, some increase will take place in later cycles but not a radical increase. The cost will be held down chiefly by two factors. First, through selecting areas which require only moderate road construction charges, easily absorbed as a current cost, a permanent road system will be gradually provided, extending into the more remote portions and the capital investment amortized. In this way the remote timber will escape much of the capital charges which under prevailing practice would have to be levied. Second, the selective procedure permits a heavy current growth of merchantable material, which will share the burden of maintenance costs as to the close-in roads and will further assist in lifting this charge from the more remote stands.

Under clear cutting no immediate further use of the roads is possible and in consequence the whole road charge for close-in and remote timber must be met at once. In addition, the pooling of the young timber in the immediate cut would raise costs for felling and bucking, yarding, roading, and otherwise probably by $1.00 per thousand board feet, making a total, in spite of tractor operation, of about $7.00 per thousand feet. It is understood that this is about the same as the steam-logging costs on timber removed from the easier ground in the main valley.

As clear cutting by producing a large volume of low-grade logs would also reduce average log value, the net stumpage value under it would approach the vanishing point. The method here proposed is estimated to produce net stumpage values of about $5.00 per thousand feet on the portion cut from large timber under present market conditions.

30. Handling the entire management unit for sustained yield.—Each of the 5 blocks in the southern portion of the property is estimated to be capable of contributing 12,000,000 board feet net during each cutting cycle for two cycles while the surplus growing stock in over mature stands is being reduced. Each of the young timber blocks (A, B, C, D, and E), although understocked, contains some old timber and is estimated to be capable of contributing a minimum of 3,000,000 board feet net each cycle during the next several cycles. In the course of time, barring accident to these young stands, the cut can be increased to more than make up for a temporary decline on the part of blocks 1 to 5 after the surplus growing stock has been liquidated in the old stands.

In 1936 block 2 would be treated in similar manner to the 1935 cutting on block 1 and blocks 3; 4, and 5 would be treated similarly in 1937-1939. On each block the cut during the first cutting cycle should be selected from the timber of high log value which can be logged at the lowest cost and yield the highest conversion values, except for such as may be cut from windfalls, defective trees, etc.

Realization of the maximum income during the first five years, under this light selection policy.—The same policy applied in succeeding cutting cycles will yield for each the maximum income that can be taken from the forest without impairing its future productivity. During the first 3 or 4 cycles the cutting will be confined to Douglas fir of size class A (volume mainly in trees over 40 inches in diameter), and the yield will be nearly all of large timber. By the end of that time the surplus growing stock will have been removed from those stands and the rate of cutting in them will slow up.

To compensate for the loss of volume from this source cutting should gradually spread into Douglas fir C (20- to 40-inch diameter) with a consequent reduction in diameter of the average tree cut. Timber in the 6- to 20-inch classes will gradually grow to merchantable size. Thinnings may be made even in the younger stands. Eventually (probably in 40 to 60 years) the timber tracts that were clear cut in the past will grow to sizes where selective stand management can begin. In this manner the entire area within the unit can be restored to continuous production. The most important principle is to prevent excessive depletion of the existing large timber. Not over 15 per cent of the area should be clear cut in groups even during the liquidation period extending through 3 cycles. Thereafter not more than 2 to 3 per cent should be clear cut during each 5-year cycle.

The aggregate results of cutting these 10 blocks, with cutting cycles running concurrently but starting in successive years, should be sustained annual yield at the rate of about 15,000,000 board feet per annum. The aggregate of mature growing stock behind this cut is of mature growing stock behind this cut is so great and the growth in maturing trees so large that there is no doubt that it can be sustained both in quantity and, what is even more important, substantially in quality for many cutting cycles to come. Barring fire and other accidents to the young stands, production can eventually be increased. Increased output hinges largely on future development of markets for the 12- to 24-inch timber which needs to be removed in stand management.

In managing this entire unit, the same problems of stand treatment are involved as discussed for block 1. Blocks 1 to 5 bear mostly overmature timber which is deteriorating. Cutting on these areas therefore has the object of selecting trees which will yield an adequate net return, recover capital tied up in surplus growing stock, and through removal of slow growing and defective trees leave the remaining stand in a condition of more active growth.

Blocks A to E, on the other hand, except on small portions, are deficient in growing stock both in quantity, and, what is more serious, in quality. There are too few trees of the large sizes needed to yield satisfactory returns from cutting operations. As soon as practicable, management should begin in. these stands, by removing the rough and ill-formed trees of the larger sizes, but chiefly by reducing overdensity and salvaging small-sized material. Otherwise, mortality losses will continue in every diameter class to a degree that will offset a large proportion of the annual growth. This management program looks to building up a growing stock with well-distributed sizes and averaging 25,000 to 50,000 board feet per acre. The better part of a century will be required. for these stands to attain a high earning basis, but, as only cuttings that can yield some net return are contemplated, the process should provide a moderate net income in each cutting cycle. No investment in silvicultural measures other than intelligent utilization practices appear at this time to be necessary.

By the end of the period discussed the growing stock on all blocks should be more uniform in volume and in distribution among size groups, but from 10 to 20 cycles will have to elapse before the growing stock in young even-aged stands will be built up in quality to the conditions which should be maintained in managed stands. As stated in chapter VI, selection of timber for cutting should be based on two complementary principles or aims. The first is .selection on the basis of maximum financial maturity, in order to insure an income sufficient to meet capital charges and other costs continually accruing against the property. With the returns obtained in this manner the forest property can be maintained as a going concern and as a support to community and industrial life. When the foregoing principle has been successfully carried out a second or residual aim comes within the range of practical industrial procedure. This has to do with the practically profitless utilization of surplus elements of the timber stand, the removal of which will benefit the stand. This involves the removal of such products as cord wood and sometimes posts, poles, pulpwood, etc. Even though these may yield little or no profit, their removal, if properly done, will be of benefit to the forest. These benefits may consist of reduction of density so as to permit more rapid growth of the remaining trees; the removal of insect and fungus infested timber so as to prevent spread of insects and disease and accumulation of inflammable refuse; and other benefits resulting from keeping a forest clear of such undesirable stand elements. It is not necessary that these forms of utilization result in much immediate profit because in addition to benefiting the forest they provide employment for labor and serve the needs of consumers.

These two objectives of utilization should be kept clearly in mind although it must be expected that in many cases there will be a continuous gradation of conversion values from zero to the highest values.

Roads.—As noted under discussion of block 1, extension of the truck road system will be made as needed and will be charged to current operating expense. In like manner tractor roads will be gradually developed. Within three or four cutting cycles the road system will be practically complete and though the capital investment has been wholly amortized they will constitute perhaps 5 to 10 per cent of the investment value.

This permanent road system is of the utmost importance. It will provide means of taking timber from anywhere in the forest at the lowest possible cost. It will involve a fundamental change in the economic condition of the forest. Instead of losing millions of feet of timber in over mature or diseased trees, and in standing and down trees killed by fire, insects, fungi, or windfall, it will be possible to salvage most of these trees. Road construction charges, administration charges, and other more or less fixed costs can be spread not only over the volume of timber now standing, as would be the case under clear cutting and liquidation, but also over a large additional volume of timber that will grow from year to year.

Fire protection.—This area is within a climatic zone of special fire hazard. It is therefore very important that a sufficient portion of the savings effected by selective operation should be budgeted for fire protection. A tentative budget item of 50 cents per thousand feet is suggested. With this sum a crew with a tractor can prepare the logged spots for slash burning. Preparation may consist of hauling tops from adjacent tree selection areas into the clear-cut spots and of preparing a crude fire line around these spots by dragging two or three rough logs or other device. The same crew would also fell the snags and do some ax work in preparation for slash burning on clearcut spots. This part of the work should not absorb more than 30 cents per thousand feet. The remainder should be devoted to piling and burning slash.

These activities should be coordinated with regular fire protection in the valley, including patrol and fire crews. The slash disposal crew should always be in readiness to hasten to any fires reported within the unit.

After several cycles devoted to removal of overmature stagheaded trees (which constitute serious fire traps), felling of snags, picking up of windfalls, and extension of roads, fire hazards on the tract as a whole should be measurably reduced. Since light selective cuttings will follow closely or anticipate the natural removal of trees from the stand, the leaves, branches, and tree trunks accumulating on the ground will be of less volume than in the virgin forest. Under these conditions the fire protection budget may be gradually reduced. Fire hazards under selective cutting are discussed more fully in chapter VII.

31. Comparison of financial results with those under clear cutting.—Under the extensive clear-cutting system, starting with a forest where losses from windfall, insects, and disease equal or exceed growth, it is necessary under sustained yield to make the old stand last until a new even-aged stand can be brought to maturity. No rotation for even-aged timber has even been seriously suggested which would produce the large-sized, high quality material contemplated by the application of selective management recommended for this area.. To produce low-quality timber such as is now cut into railroad ties and common lumber a rotation of 70 to 110 years has usually been recommended on public forests.

Of the 64,000 acres of productive surface, approximately 20 per cent is old fir and 12 per cent is old hemlock and cedar. Under a plan calling for 100-year rotation these would be cut over in about 30 years, including all merchantable timber in the stand, and at the present stumpage levels would yield about $2.00 per thousand board feet. This period would clean up all the high quality timber and no more would be produced. From that time on through the first rotation and all future rotations low-quality timber, mostly submarginal or worth at the best no more than $1.00 per thousand under present conditions, would be the only material forthcoming.

It has been brought out in chapter IV that the yield in volume also will be materially larger under selective timber management than under clear cutting. This springs from the fact that this type of management retains a heavy growing stock and provides for continuous production of merchantable timber on all areas except a very small percentage of area in regenerating groups. No attempt is made to evaluate precisely the difference in productivity on this area under the two systems. The authors believe that during the first 15 to 20 cycles, owing to several contributing factors, selective timber management will yield from 20 to 40 per cent more utilized volume .and 100 to 200 per cent more value annually than can be obtained from clear cutting with rotations of 70 to 110 years.

These comparisons do not attempt to take fully into consideration the possibility of thinnings in young stands, because these are to be made only as they were able to pay their way. The potential volume of material from such thinnings, if an outlet for it could be found, would be greater under the extensive clear-cutting system, because about 1 to 1.5 per cent of the area of old timber would be clear cut annually as against 0.5 per cent or less in the groups under selective methods. Owing to the prevalence of permanent and semi-permanent roads everywhere under the selective system, the opportunity for getting out the product of thinnings from young tree groups will be far better than from large areas of young stands which would follow clear cutting. In the latter case roads will have to be reopened at the expense of the material from thinnings. The same considerations hold for salvage of fire- or insect-killed timber.

A third possible method of procedure sometimes urged on public forest administrative officers is to withhold cutting entirely. This would result in annual losses of timber approximately equivalent to the possible annual yield, since every diameter and age class is subject to continuing mortality from numerous causes. Conservative selective timber management, on the other hand, would anticipate these removals. Even the few exceptional trees that would be carried through to large sizes (about 2 per cent of the total that survive the premerchantable period on a given area) would be utilized before loss by death and decay can take place. In contrast, where management is withheld, the trees which grow but which are not utilized are added in annual installments to the debris on the forest floor and together with lack of roads increase the difficulty of protecting such forests from fire. In other words, proper use and flexible management of the forest develop values. Non-use of forests, on the other hand, leads to stagnation and equilibrium between growth and decay.