In the perpetuation of the mixed forest and in the continuous production of large high-quality trees lies the future of the diversified forest industries of the Douglas fir region. (Photo by C. F. Todd.)

SELECTIVE TIMBER MANAGEMENT

IN THE

DOUGLAS FIR REGION

By

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FOREWORD

The following publication is the result of profound study by the authors over a term of years of the economics of forest management and exploitation, in which they have made use of a large mass of fundamental data as well as of their own experience and research. They have here proposed a procedure of selective timber management which is new and untried in the forests of the New World, though analogous methods of forest management are practiced in Europe. Their proposal is so revolutionary of existing practices in the Douglas fir region that it may seem to some to be impracticable of application. However, a careful reading of the manuscript cannot help but impress the reader with the theoretical soundness of the procedure that is recommended, and with the tremendous possibilities for thereby promoting a more profitable and stable forest industry and sustained yield forest management. The basic principles which the authors have so well developed are not limited in application to the Douglas fir region, but in a broad way are of equal significance in other forest regions.

As repeatedly disclosed in the text the authors recognize that the Douglas fir region is very heterogeneous in climate, topography, and forest cover and that there are extremely variable economic, silvicultural, and protective problems to be met. These they propose to meet not through a rigid "system" to be applied everywhere, but through completely flexible operating and timber management methods to be always based on and adapted to accumulating experience with operating technic and costs; with the effect of previous cuttings on forest productivity; with slash disposal and the prevention and suppression of fire; and finally with the effect of all these measures on the immediate financial returns as well as on conservation of capital values.

The proposals are not put forth as in any sense the final word in all details. The authors emphasize that the data presented in certain portions of this publication are of a preliminary character and are not supported by sufficient investigation to insure the degree of accuracy that further research should yield. They have, indeed, been presented chiefly for the purpose of pointing to the need for further investigations in the region at large and on individual properties.

The reader should understand that the system of forest exploitation herein described is proposed as a working hypothesis; it has not yet been tried except in an imperfect and fragmentary way. As repeatedly stated in the text, the authors appreciate that there are silvicultural and protective problems which under some conditions may prevent intensive selective management.

It is believed that large portions of the region are physically as well as economically suited to the immediate adoption of this selective system of forest management. In other portions of the region silvical and fire hazard conditions or market conditions may compel woods practices which only in less degree can in the immediate future meet the ideals of selectivity in forest exploitation which the authors envisage.

The reader is especially cautioned to avoid confusing the procedure herein proposed with that type of partial cutting now sometimes practiced with tractors in this region under a liquidation policy, yet called "selective logging". This latter procedure which removes most of the merchantable stand is apt to leave the land in very undesirable condition both from the point of view of regeneration and of fire. It has nothing in common with the authors' proposal which unequivocally presupposes sustained yield forest management through good silviculture and fire control.

The Forest Service, therefore, commends this thought-provoking, original, and constructive thesis to foresters, timbermen, and lumbermen, particularly those of the Pacific Northwest, in the hope that it may lead to changes in forest property management and woods practice which will promote the welfare and security of the industry, the forests, and society.

It is the intention of the Forest Service to initiate at an early date a series of experiments to try out on the national forests of western Oregon and Washington methods of selectivity that may be practicable under a variety of forests types and physical conditions.

F. A. SILCOX,
Chief, Forest Service.

AUTHORS' PREFACE

Selective logging and other similar terms are commonly used to designate various forms of partial cutting. These terms are often so loosely applied that they have come to mean all things to all men, often including highly destructive cutting methods. For example, so-called "economic selection" is often applied to removal from a cutting area of all timber above zero-margin value. This completely disregards sound methods of rapid capital recovery, and sacrifices part or all of the permanent capital values that are inherent in every properly managed productive forest property. In contrast to selective methods applied in this manner, this discussion of selective timber management is directed toward development of a more truly economic approach which gives due weight to all factors involved in forest management. Far from neglecting immediate income from the forests this approach lays special emphasis on the increase of current income, but it does this without neglecting the fact that conservation of numerous resource elements of negative and minor present value will, according to all the evidence from the past, provide liberal future earnings. In other words, this type of management aims at obtaining and maintaining the highest tangible values from the forest property including therein income of the immediate future and the capital values remaining to produce future income. Any cutting methods which create undue fire risk, deteriorate the growing stock or fail to provide suitable regeneration are in gross violation of these principles.

This report does not deal directly with the numerous internal problems of industrial organization or with external economic problems involving relationship with the public and with other industries. It is recognized that sustained yield management can be facilitated by methods of taxation, by terms of credit, etc., suited to the nature of the forestry enterprise. The retirement of manufacturing capacity in localities where it exceeds the productive capacity of the forests is an internal problem of great importance. Obviously, however, the greater the economic pressure from adverse economic sources the more desirable from the financial aspect becomes the recovery of maturing stumpage values in an orderly manner. The authors have endeavored to deal constructively with this problem.

For the convenience of readers having different objectives a brief explanation of the organization of the material in this report seems warranted. For the reader desiring only a general view of the subject, the first and last chapters with some skimming of intervening chapters may suffice. For forest owners, technicians, and others studying selective management intensively it should be explained that the case-study method is used for presentation of the principal data. After exposition in Chapter II of the basis of conversion values, Chapters III to V show, by concrete examples, how the principles of selective management may be applied, emphasizing particularly the immediate steps necessary in bringing under management three tracts typical of different conditions in the Douglas fir region. Chapter VI summarizes present knowledge and endeavors to point the way to further investigations of such subjects as tree growth and other factors which influence selective management in its long-term aspects. Chapter VII is devoted to a discussion of fire hazards and other elements of risk, and the two following chapters to organization and administration of sustained yield operations.

An effort has been made to arrange the several chapters in logical sequence, while at the same time, since the chief interest of some readers may be in one phase of the subject only, each chapter is so presented that it may be considered to a certain extent as a complete unit. This has involved some otherwise unnecessary repetition.

In all chapters where considerable discussion of basic principles and presentation of subsidiary details have been necessary, these have been set in small type.

Collection of the field data upon which the report is based was started by the authors in 1928, when they were members of the faculty of the College of Forestry, University of Washington. Acknowledgment is due to associates of the faculty and student body of that institution for cooperation in the early studies. Since 1931, as members of the United States Forest Service, they have conducted, largely under the auspices of the Pacific Northwest Forest Experiment Station, extensive studies aimed at analyzing the practicability of selective timber management.

The authors wish to acknowledge their indebtedness to all who have aided in any way in the accomplishment of this work, particularly to D. S. Denman, E. P. Stamm, John E. Liersch, and others of the staff of the Crown-Willamette Pulp and Paper Co., to E. F. Rapraeger of the Pacific Northwest Forest Experiment Station for valuable assistance in preparation of certain portions of the manuscript; and to many of their other colleagues in the Forest Service for furnishing valuable data and suggestions and for critical review of the manuscript.

The authors wish especially to express their gratitude to the Charles Lathrop Pack Forestry Foundation for its interest in this study and for furnishing the funds for printing this report and thus making it widely available.

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CHAPTER I

ECONOMIC ASPECTS OF FOREST MANAGEMENT AND SCOPE OF STUDY

1. **History and development of the forest resources of the Douglas fir region.**—The Douglas fir region, as generally defined, comprises all the forested area west of the summit of the Cascade Mountains in Washington and Oregon. Nature endowed this region with a vast and magnificent forest resource, the result of a climate and a forest soil such as are found in few other parts of the world. The history of the region and the story of lumbering in Douglas fir forests are closely interwoven. From these forests came at first riven shakes, hewn logs, and hand-sawn boards to shelter the early settlers of over a century ago. Later came rough boards and planks sawn in small water-driven sawmills, the first of which dates back to 1827 and from which export shipments to California began as early as 1830. Still later, beginning in the fifties, came lumber from steam-driven sawmills; and finally, at about the break of the century, came modern mass production of lumber and other forest products which have found their way to all parts of the globe. These forests cradled early settlements and helped develop many of them into modern towns and large cities. Such communities as Seattle and Tacoma, Hoquiam and Aberdeen, Portland and Vancouver got their start behind the bull-teams and buzzing saws of the pioneers' logging and milling enterprises and have grown and developed with the industry.

These forests, in brief, have been the backbone of industrial development from the days of the pioneer settlers to the present time. They are still the mainstay of industry and trade, furnishing income to numerous business enterprises, taxes to the public, freight revenue to railroads and shipping concerns, and employment to thousands of wage-earners. The forest industries of Washington and Oregon furnish support, directly and indirectly, to roughly 40 per cent of the population and account for about 60 per cent of the industrial payroll, excluding agriculture. In 1929 receipts from sales of forest products amounted to about $250,000,000 and an additional $60,0000,000 was collected by transportation agencies for freight. Directly or indirectly, much of the business done by other industries, by the farmer, the professional man, the banker, and by "the butcher, the baker, and the candlestick maker" exists as a result of distribution and turn-over of income derived in the first place from the manufacture and sale of forest products. Many communities depend entirely or almost entirely on the forest for their support. The forest resource, in fact, to a very large extent, supports the economic and social life of the entire region.

To maintain these social and economic benefits, continuing supplies of high-quality forest raw materials must be obtained. With the soil and climatic conditions prevailing in the region, the existing forests are capable of continuously renewable production, provided they are properly managed. The management practices that will assure this productivity are therefore of the utmost importance.

Though lumbering in this region has been under way on a small scale for over a century and on a large scale for about 30 years, there is still a vast supply of timber in virgin forests —vast enough, probably, to maintain a fairly high level of production for a few decades at least, no matter what form of management is applied. As shown in table 1, taken from the Federal Forest Survey Report *(1)*[1] about 546 billion board feet of timber, almost equally divided between private and public ownership and constituting roughly one-third of the Nation's total saw-timber supply, still remains in western Washington and western Oregon. The vastness of these supplies of timber has somewhat concealed the importance and nature of the forest management problem. Under the piece-by-piece liquidation policy now followed this timber supply is constantly being depleted instead of being maintained as a permanent growing stock. The prevalence of wholesale clear cutting in the region has created an impression, among foresters as well as lumbermen, that the forest management problem is a cut-over land problem. It has seldom been realized that the forests as a whole, including especially the existing stands, are the producing agents which need intensive management in order to make them continuously productive. The supply of existing regional growing stock, if treated as a perpetual revolving fund of forest capital, is not excessive considering that

[1] Italic numbers in parentheses refer to Literature Cited, p. 122.

up to the present time approximately 7 million acres have been stripped of their original forests and that about 200,000 acres are being added to the cut-over area annually.

TABLE 1.—*Volume*[1] *of saw timber in the Douglas fir region, by ownership classes*

	Western Oregon		Western Washington		Total	
	Million feet b.m.	*Per cent*	*Million feet b.m.*	*Per cent*	*Million feet b.m.*	*Per cent*
Private	137,043	46	123,678	50	260,721	48
National forest	112,599	37	88,488	36	201,087	37
Other public and Indian	51,151	17	33,089	14	84,240	15
Total	300,793	100	245,255	100	546,048	100

[1] As of 1933.

The failure of existing methods to maintain productivity is amply shown by examination of cut-over lands. Strip surveys made recently in connection with the forest survey *(1)* on private lands logged from 1920 to 1923, inclusive, aggregating 201 miles in 15 counties of western Washington and western Oregon, show the following degrees of restocking:

Well stocked............12 per cent
Medium stocked.........17 per cent
Poorly stocked..........29 per cent
Nonstocked ....42 per cent

The forest survey also discloses that on the average 3.9 per cent of the acreage logged since 1920 has burned over annually. The conversion of forests into waste lands or into poorly stocked stands of open-grown, low-quality trees is certain to be followed by declines in industry, wealth, population, and tax revenues.

Maintenance of a productive forest resource and of inherent and related capital values is one of the most important and far-reaching problems that the forest industries and the public of this region must solve. It is a problem that must be considered not only for the region as a whole but even more for the various subregions, shipping centers, local communities, and individual forest properties. For even though the regional timber supply as a whole may be ample for a long time to come or perhaps permanently, in a fashion, even under rather crude forms of forest management, serious maladjustments affecting the communities concerned may and usually do follow in the wake of exhaustion or depletion of local supplies. Already, even some of the larger population centers of this region have had a foretaste of the unpleasant prospect that, when the timber resources are gone or badly depleted, the foundations may crumble under their social and economic structure. Severely depressed real estate values, bewilderment, and uncertainty as to what the future may hold are among the first manifestations of how even the mere anticipation of a possible future decline of industry and population disturbs the tranquillity of community life and the stability of all forms of capital values. It would not be the first time such a fate has befallen forest-supported communities. Many small settlements in this region have already been virtually wiped out through this process.

If the forest lands of western Oregon and Washington are to be lastingly productive and the support of a prosperous people, the industries and communities must be established on a permanent basis with continuous supplies of high-quality raw materials. If the lands are not kept productive the industries and population will shift to other scenes of lumbering activity, perhaps of equal impermanence, where the process may be repeated. The same shifting will take place even though the lands are kept under sustained production, if the supply of raw materials is locally intermittent, so that long waits are necessary between crops. When the supply ceases, even for only a few years, the industries must shut down or dismantle their plants and move elsewhere. Such intermittent industries are bound to cause great waste of human effort and community values.

Interest in these matters has been accentuated during the past few years by adoption of the Code of Fair Competition of the lumber and timber products industries. Under the provisions of Article X and Schedule C of the Code the industry pledged itself to handle cutting operations on land destined for permanent forest use in a manner to insure sustained production, which consists in methods of cutting and forest care that insure regeneration and protection of young stands and consequently make probable the development of a future stand of merchantable timber. The measures considered necessary to bring this about with the prevailing type of machinery and methods used by the logging industry have been formulated for the Douglas fir region by the West

Coast Logging and Lumber Division and published in a Handbook of Forest Practice *(33)*. (It is recognized that on many forest properties and in many localities these measures will not insure continuous sustained yield.) The Code also pledged the industry to work toward sustained yield as an ultimate objective, sustained yield being defined on page 26 of the above handbook as *management of specific forest lands . . .to provide without interruption or substantial reduction raw material for industry and community support.* It is with the methods that will permit the attainment of the sustained yield objective with immediate profit and with the least possible delay that this study is primarily concerned.

2. Purpose, scope, and general significance of the study.—The purpose of this report is to demonstrate through detailed studies of representative timber areas the wide possibilities that now exist for bringing the timber lands of the Douglas fir region under intensive selective management so that they will provide abundant and continuous supplies of high-quality products. It is true that continuous supplies of timber can be obtained under a properly executed clear-cutting system. The methods here proposed, however, should produce a larger proportion of high-grade timber than can ordinarily be obtained with extensive clear cutting of areas managed on a short rotation. Moreover, this end should be attained at the same time that current income from the present forest is increased. Though some of the principles involved are new to Douglas fir forestry, they have been thoroughly tried and developed during the last 50 years in Europe. Notable work along these lines has been done in Switzerland by Biolley *(4)* and Borel *(5)*, in Sweden by Wallmo *(32)*, and in these and other European countries by numerous foresters whose work could be readily cited. The application of selective cutting, which is part and parcel of intensive management, has been developed in several regions of the United States, notably in the South by Ashe *(2) (3)*, and in the Lake States by Zon *(34)*.

The arrival of the time for action in this field has been hastened by the remarkable progress of the past decade in motorized and mobile logging machinery adaptable to conditions in the region. The development of trucks, tractors, and road-building and logging technic now makes it feasible and profitable to select timber for cutting in the order of true economic and silvicultural desirability. The first report of this series *(7)*, hereinafter referred to as the "logging cost report", dealt with these mechanical developments from the standpoint of immediate logging and gave careful comparisons with previously prevailing methods. In the present report, application of these methods to long-term management is considered.

Anyone familiar with intensive forest management practice knows that it rests, the world over, on permanent road systems, flexible logging methods, and consequent intensive control of the growing stock. Since the march of events has placed these instruments in our hands, the unique opportunity has now come to the Pacific Northwest to apply intensive management directly to the virgin forests; as a part of that opportunity, as will be demonstrated later in this report, true sustained yield forestry enters into the picture as a matter of course.

Obviously, sustained yield management with its uninterrupted flow of forest raw materials would do away with the annual stumpage depletion charge, which in normal years amounts to more than $20,000,000 for the region. This loss of the capital resource is nearly double the total tax bill of the industry in the western parts of Oregon and Washington. The depletion charge for the industry as a whole is preventable by the following measures: (1) Proper selection of cutting areas throughout the region; (2) proper selection of trees and groups of trees for cutting; and (3) adequate protection of residual stands and regeneration groups from fire and other injuries.

The methods proposed aim first to open up any given tract as soon as possible by developing an intensive permanent transportation system which will make all operable parts of the area accessible and will make it possible to place the growing stock under intensive selective control. The forest thus will become in effect a warehouse in which trees are stored on the stump awaiting market demands. Justification for early construction of a permanent road system arises in the first place through the urgent necessity of effecting quick removal of the most overmature timber. Justification for continuous maintenance and use of the road system arises through the opportunities that this will afford for market selection, fire control, efficiency in operation, and intensive management of the timber. Cutting is not confined to a small subdivision, as in wholesale clear cutting, but is extended to all parts of the tract.

In old-growth stands the initial cut is usually a liquidation cut of financially mature trees, which includes or may consist entirely of those that are decadent. Following this cut, light return cuts will be made at short intervals. In these, the logging operations sweep back and forth over the entire area, with the constant purpose of removing that portion of the growing stock which at any given time is most urgently in need of removal. This should result in the highest practicable productivity in volume and value from the residual stand and the prompt regeneration of small patches of land where mature groups have been removed.

The keynote of the methods proposed is complete and continuous control of the growing stock. After this control is established, as it necessarily must be for immediate economic and operating reasons, each element of the growing stock, of the forest land area, and of the permanent transportation system should thenceforth be put to its best use. If and where this demands cutting, cutting should take place. If and where it demands deferment of cutting, cultural measures, intensive protection, or what not, these measures should be undertaken. Flexibility, continuous control, and facilities for learning through experience how best to solve all the various management problems that arise are essential. In exercising this control a broad view must be held of the entire property. A decision as to what to do on any portion of a sustained yield unit cannot be reached without considering what needs to be done on all the other portions of the same unit. In other words, the treatment to be accorded to any specific stand or its components must be considered in relation to the needs for corresponding treatment of other stands, and the most urgent situations must be dealt with first.

Above all, it should be emphasized that this report does not suggest or advocate the introduction of a rigid "system" of management. On the contrary, the methods proposed depend on the utmost flexibility in the approach to the management problems of every individual tract. They constitute a system only in the respect that decisions on where, when, and what to cut will in each case be based on all of the available facts which arise from the infinite variation in economic, physical, and biological conditions within each stand and in different localities. This is in sharp contrast to clear-cutting methods, which ignore these variations.

Relation of the proposed methods to silviculture.—This report is in no sense a treatise on silviculture. Its approach to management problems is purely from the economic viewpoint but necessarily includes full consideration of physical, industrial, and social factors to whatever extent they can be evaluated. Any method of cutting, whatever the reasons behind it, results in a certain silvicultural form of the forest, and in this sense the discussions in several chapters have a bearing on silviculture.

The forests of the Douglas fir region include a large number of species. The majority of these species are shade enduring and form stands of great density. The only definitely light-demanding species is ponderosa pine, which occurs in rather limited areas in the interior valleys and in the southern part of the region. Douglas fir, which is the predominant species (comprising approximately 60 per cent of the total volume), also definitely demands open space for regeneration but once established develops into extremely dense stands, both pure and mixed. Its inability to regenerate in the stand is largely due to the invasion by an understory of the more shade-enduring species before the upper crown cover has become sufficiently broken to permit regeneration of Douglas fir. The wide distribution of Douglas fir is largely due to periodic fires during the past several hundred years. Its future position as the predominant species is no doubt assured by the extensive clear cutting that has already taken place. Owing to the already wide distribution of Douglas fir many authorities believe it will be good policy in handling the remaining merchantable stands to encourage where feasible the perpetuation of the mixed forest as better fitted to meet the industrial requirements of the region than a pure Douglas fir forest. The mixed forest is also universally recognized as the safest from insects and disease.

In the Douglas fir region, using the flexible operating methods that are now available, selection for economic reasons results in removal of trees both singly and in groups. These methods if slightly regularized (as they obviously should be for silvicultural reasons) will lead to a silvicultural system wherein regeneration occurs in small groups while the remainder of the stand is not intentionally under regeneration but is subject to stand management for many successive cutting cycles. In consequence a relatively small number of selected trees will be held to a late felling age.

Long observation in the forests of this region leads the authors to believe that the clear-cut spots will regenerate densely to the desired mixed-conifer forest. At the age of 40 to 60 years, where pulpwood, post, pole, or saw-log markets permit (and they are already available in much of the region), cutting for stand management purposes in these groups can be begun, using the same roads on which adjacent old timber is continuously being taken out at short intervals. Such early cuttings cannot generally be undertaken in present large areas of young stands because the low-value products cannot stand the cost of forest improvements constructed for their special benefit. Under the proposed methods these improvements are paid for and maintained by the high-quality large timber that is continuously being produced.

In dealing with these problems almost wholly from the economic viewpoint it has not seemed necessary to distinguish the different silvicultural forms of group and individual tree-selection cuttings. They have been dealt with, therefore, as resulting always from financial maturity either because the tree itself cannot earn satisfactorily if left standing or because it is more of a detriment to the remaining stand than can be offset by its individual earnings. In the interest of brevity the methods thus conceived as a whole are called in the text "selective timber management".

Finally, it may be emphasized that silvicultural measures are necessarily governed by economic considerations. Until recently, the machinery and transport methods available for handling heavy timber in the Pacific Northwest, necessitated clear cutting on extensive areas, which definitely circumscribed the choice of silvicultural methods. The authors conceive that within the broad economic limits discussed the shackles that have previously bound silviculture in the Douglas fir region have been struck and that the economic cutting practices recommended will permit the continuous development of stands of as near the right density as the silviculturist can prescribe.

It is not expected that everyone will accept the conclusions drawn in this report. To those who dissent as to the intensity with which selection can be or should be practiced in this region it will no doubt be clear, however, that the transportation system created through the initial liquidation of surplus and declining values will facilitate broad-scale clear cutting of any areas so designated as easily as it permits continuance of intensive selective management. The authors will look with open minds upon the application of any silvicultural method which can be supported in any given case by adequate facts. In view of the controversial nature of some aspects of Douglas fir silviculture it must be assumed that many years will elapse before valid conclusions can be drawn on such points as the proper size of clear-cut areas and numerous other questions that may arise from the radical change in management procedure here proposed. Variations in application to individual properties will always be in order.

CHAPTER II

THE BASIS OF STUMPAGE CONVERSION VALUES

3. **Conversion value of stumpage.**—In the Douglas fir region returns from stumpage constitute almost the sole income from the forest. Standing timber (growing stock) constitutes the major portion of the investment values dealt with in forest management.

Stumpage value, the value of standing timber, is based on the expectation of cash returns from the products derived from the timber. The immediate conversion value of stumpage is the difference between the estimated price received for the product and the estimated cost of conversion and marketing. The stumpage value of timber that is to be logged in the future is determined by forecasting its conversion value and discounting both this value and the anticipated costs of holding. In both cases the principle of valuation is the same. Simple and inescapable as this principle is, its significance is frequently forgotten. It should be emphasized that the true conversion value of stumpage depends neither upon the amount of the owner's investment, with or without compound interest, nor upon the relative bargaining power of buyer and seller, nor upon the value of the timber as assessed for taxation purposes. These misconceptions of stumpage conversion value may psychologically affect the price at which a transaction is made, but the conversion value obtained by the logger who cuts the timber will be the difference between the sale value of the logs and the cost of logging.

The conversion value of stumpage on a given tract is not the same from year to year and from decade to decade. It is affected by growth and decay and, like the value of any other commodity, it is also continually affected by the interplay of economic forces, which influence the price of lumber, wages, supplies, and equipment; and by changes in production technic and many other factors. To such changes of conversion values attention will be given later in this report. The first problem to be considered here concerns the variation in conversion values at any given time within a given tract.

In representative stands of the Douglas fir region, only relatively small numbers of trees have high conversion value. A wide spread in conversion value exists between small and large trees, between different logs within a tree, between defective and sound timber, between inferior and superior species, and between areas or settings within a tract. Under extremely favorable conditions the spread may extend from zero upward; usually under clear cutting as practiced in the Douglas fir region, it starts far below zero, many trees and logs being marketed at a loss. The principal factor controlling this wide spread in conversion value for any given species and area is the size of the log or tree.

Stumpage conversion values for a given stand of timber may be determined, according to circumstances, either on the basis of log values as established in the commercial log markets or on the basis of the value of lumber or other manufactured products as determined by mill-recovery studies. Both methods will be dealt with here by presenting several specific cases. The object of these presentations is to show in a general way the methods used in determining stumpage conversion values, the technic of mill studies, and to illustrate values arrived at in typical cases. None of these conversion value figures is used in calculations elsewhere in this report.

4. **Values as established by log market.**—About one-third of the log output of the Douglas fir region comes from loggers who sell their logs in the open market. In different districts of the region independent loggers, in cooperation with sawmill owners, have established agencies that govern the scaling, grading, and selling of logs. The prices paid for the various grades of logs furnish an index of the market value of similar standing timber. The logger can determine the average stumpage conversion value of a given stand by subtracting the estimated cost of logging from the market value of logs.

The most important log markets in the Douglas fir region of the United States are the Puget Sound, Grays Harbor, Willapa Harbor, and Columbia River markets, of which the principal one is the Puget Sound market. The scaling and grading association established there has maintained a continuous existence, under different names, since 1899. In the past slight differences have existed between the different markets in the wording and interpretation of grading rules. At the present time uniform scaling and grading rules applicable to the entire region are being considered. In the main the proposed rules are the same as have been in effect during the last 35 years.

The primary purpose of log grading is to classify logs according to suitability for different manufacturing purposes and to establish values.

Douglas fir grades are the foundation for grading other species of the region.

Grades of Douglas fir logs.—Three merchantable grades and a "cull" grade are recognized. Logs of the first and best grade are those that will yield a high percentage of clear flooring and other choice material. Some logs of this grade sell at a premium because of their suitability for plywood manufacture. Logs of second grade yield a high percentage of construction material such as No. 1 common. Logs of the third grade yield principally low-grade lumber. Finally, "cull" logs yield less than 33⅓ per cent of sound lumber.

Relation of log size to conversion value.—Figure 1 presents the results of four studies dealing with the relationship between log size and quality and net back-to-the-stump returns to the logger who sells his logs. Each diagram in the figure represents a study of a logging operation in which an analysis was made of the "bucking-to-pond" cost, the "yarding-to-pond" cost, and total logging cost for logs of given diameters and volumes. The differences between log values and the "bucking-to-pond" cost, the "yarding-to-pond" cost, and (line A-A), and the total cost (line C-C) are significant in deciding whether marginal logs can profitably be removed from the woods.

The yarding-to-pond cost represents labor and supplies and capital cost items incurred after yarding begins. The bucking-to-pond cost includes the same items plus the cost of bucking. Total cost covers in addition the cost of felling and all per-acre costs (for road construction, etc.). Further information on these costs is given in chapter XVII of the logging cost report (7). The case-study numbers given here in figure 1 are the same as those given in chapter XVII of that report.

At the points where the horizontal lines representing the market value of different grades of logs intersect the curved lines representing yarding-to-pond and bucking-to-pond costs, values and costs are equal. The corresponding size of the log in terms of board-foot volume or of diameter in inches may be read on the scale at the bottom of the graph. Logs of this size will hereinafter be termed zero-margin logs, to denote the fact that although they pay their own way from the point where yarding or bucking begins they contribute nothing to costs previously incurred, such as costs of felling, road construction, or stumpage, or to profits. (Zero-margin costs exclude the items mentioned because these items do not influence the decision on whether to take the felled log from the woods.) Sizes shown to the left of the zero-margin sizes are those of logs the conversion value of which is negative as determined by the spread between the value line and the cost curve as read from the left-hand scale. These will be referred to as minus-value logs. Sizes to the right of the zero-margin sizes are those of logs having positive conversion values, which will be termed plus-value logs. Since costs and values are continually changing these margins are not fixed for any length of time.

Relation of tree size to conversion value.—Log value margins are by themselves a rather erratic guide to the trend of conversion values for trees of different sizes. By correlating the size and quality of logs, their value, cost of production, etc., with the size of the standing tree, however, an index can be obtained of the conversion value of trees of different diameters.

Small trees, as a rule, yield low-value logs for lumber. No. 1 Douglas fir logs, for example, cannot be obtained from trees less than 40 inches in diameter at breast height, and No. 2 Douglas fir logs are rarely obtained from trees less than 24 inches in diameter. The size of a tree is thus a general indication of the value of its product, just as it was found in the logging-cost study (7) to be an indication of logging costs.

The relationship between tree diameter and tree value as expressed by log grades can be determined by scaling and grading the logs cut from individual trees. The data taken for an individual tree should consist of its diameter at breast height and the grade and scale (gross and net) of the logs cut from it. When sufficient samples have been taken, the percentage of volume in each grade can be computed for the different breast-height diameters. Losses due to defect and breakage can likewise be correlated with tree diameter. From these data the average market value per 1,000 board feet can be determined for trees of different diameters. Where logging is not in progress, log grades can be estimated in the standing tree. The log grade survey can be conducted simultaneously with the cruising, or if a general cruise is unnecessary strips can be run through the timber and a tally made of tree diameters and log grades.

In figure 2 is shown the relationship between felling-to-pond cost and market value for trees of different breast-height diameters. The four graphs correspond in their numbering to the graphs in figure 1. The tree values in figure 2 were built up from the data on logging costs and log values shown in figure 1. The cost curves (B-B) in figure 2 express the relationship between felling-to-pond cost and tree diameter, not bucking-to-pond cost and diameter as in the case of logs.

5. Values as determined by mill-recovery studies.—From the point of view of the independent logger the market price of standard commercial grades of logs as dealt with in the foregoing is a convenient and logical basis for stumpage valuation. The market price is presumably established temporarily on the basis of supply and demand and in the long run represents the net back-to-the-pond returns obtained by sawmill operators in manufacturing the various grades of logs into lumber, or by manufacturers of pulp, plywood, etc., from other uses of logs; even if this assumption is not exactly true in all cases, they represent the returns received by the independent logger. The individual logger-sawmill owner, on the other hand, must look for his returns to the results obtainable in manufacturing his own logs in his own more or less efficient and specialized plant and to the prices actually received

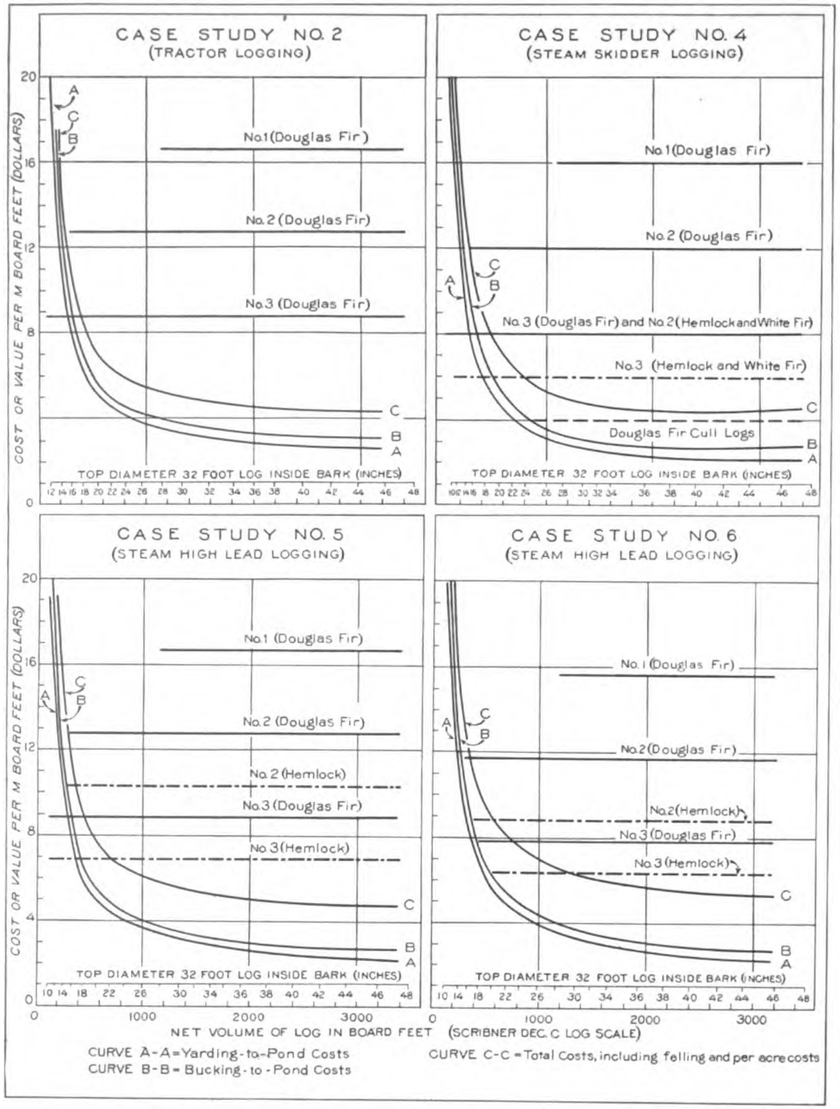


Fig. 1- Logging Costs, Market Values and Stumpage Conversion Values of Logs

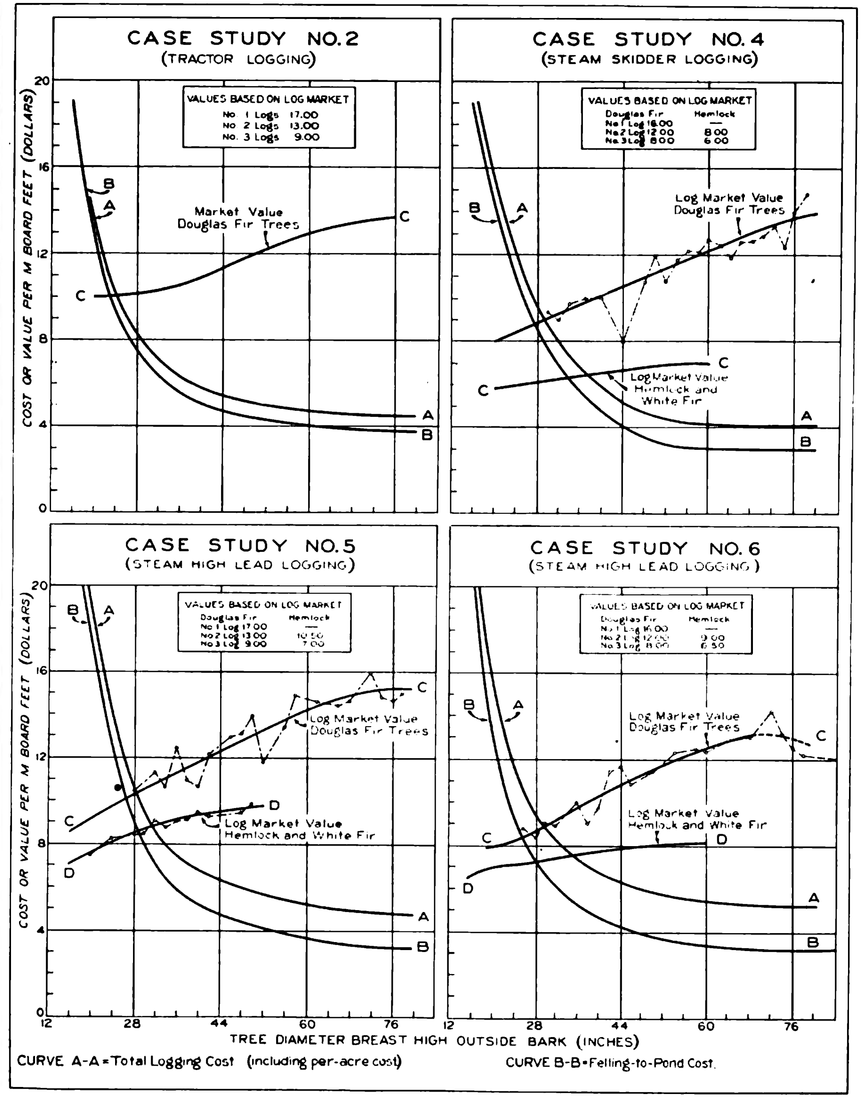
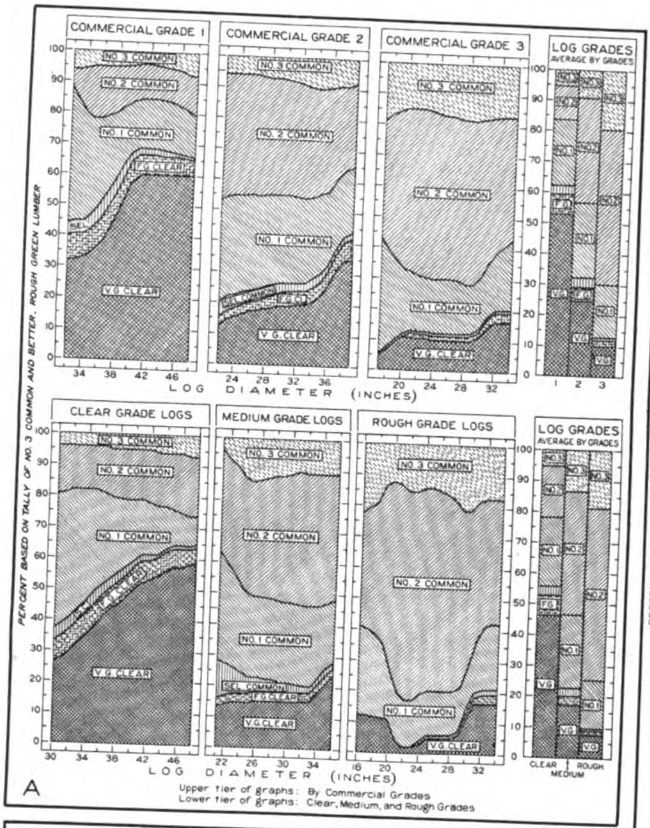
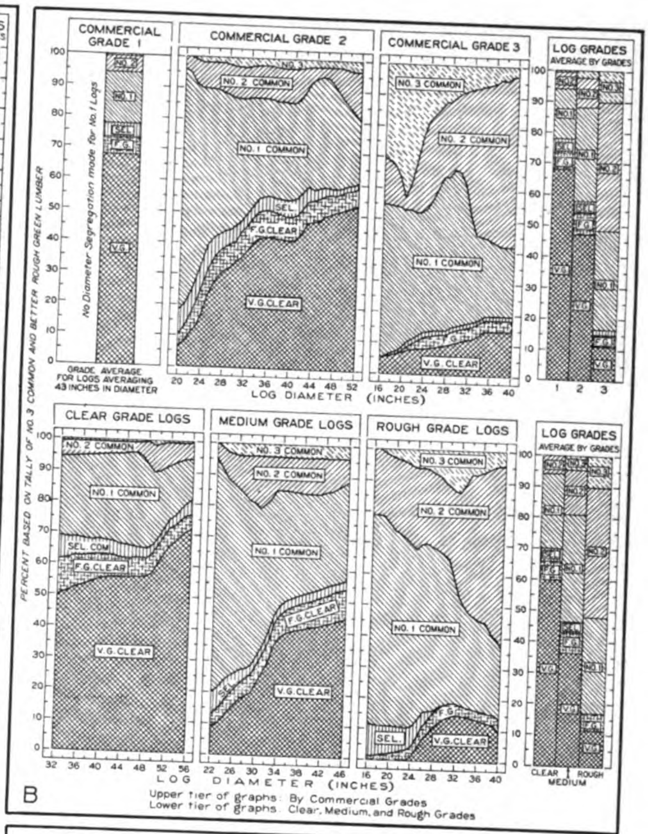
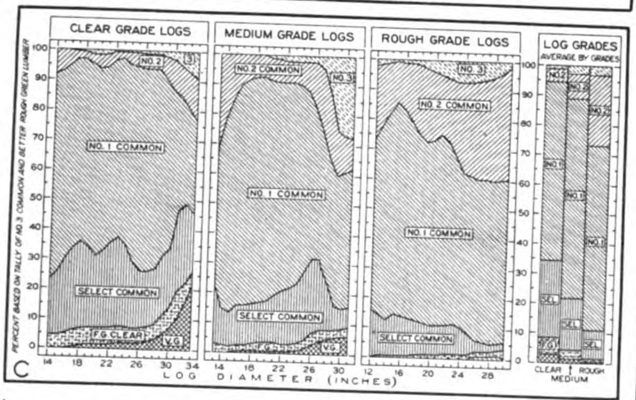


Fig. 2- Logging Costs, Market Values, and Stumpage Conversion Values of Trees







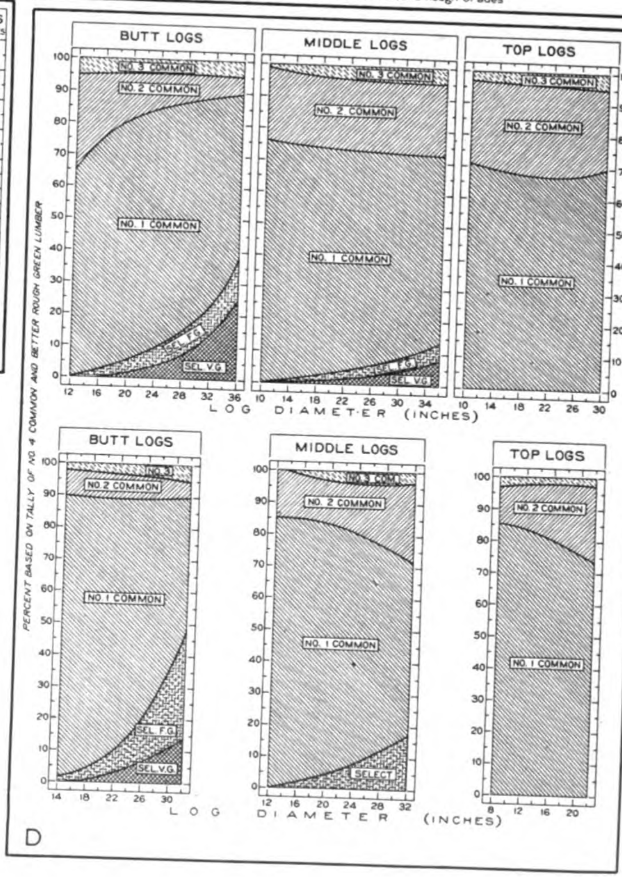


FIG. 3 – GREEN-LUMBER GRADE PRODUCTION IN DOUGLAS FIR LOGS

A - From Medium-Grade, Old Growth Timber
B - From High-Quality, Old Growth Timber
C - From Small Old Growth (Red Fir) Timber
D - From Young (Red Fir) Timber

by him in selling the lumber or other products through whatever market connections he may have. It is well known that for any given mill the returns do not generally conform very closely to the corresponding log-market values, and that results obtained in one mill may differ widely from those obtained in another. In this situation it must be recognized that log-market prices reflect composite values established through competitive production and through competitive bidding for raw material required by manufacturing plants differing in capacity, design, and efficiency and in market connections and sales opportunities. To determine with approximate accuracy the conversion values established by the conditions affecting any given plant requires a mill study in which lumber grade recovery and manufacturing costs are ascertained for different classes of logs. Several studies of this kind were made in 1931, in conjunction with logging studies (case studies 1 and 3) reported in the logging-cost report *(7)*, through cooperation of the United States Forest Service, the West Coast Lumbermen's Association, and the respective sawmill owners. This work was done by Hessler and Co., production engineers, and will be discussed here on the basis of their general study reports *(13)*. Other reports of detailed case studies made by the Pacific Northwest Forest Experiment Station *(19)* are also drawn upon for information in this chapter.

Methods of study.—The general method of determining net conversion values of the various sizes, types, grades, and species of logs in the pond was to tally the recovery, by grades of lumber, from individual logs; to determine the cost of sawing these logs; to classify the logs in various size and grade groups; and to determine the value of these groups. The values assigned to the various grades of lumber were their values before pulling on the green chain. These values were derived from average invoice prices of lumber sold, corrected for trim and degrade losses and manufacturing costs from green chain to form in which sold. The lumber on the green chain was classified in only six grades, variation in width and other minor differences being disregarded in order to retain the utmost simplicity in the study. Consequently the results tend to be conservative as regards differences in conversion value between small and large logs.

Scaling was done on the log deck with the Scribner Decimal C rule, both gross and net log scale being recorded. Diameter as listed represents the average of measurements taken two ways across the small end of the log and recorded to the nearest inch, according to U. S. Forest Service practice. Length was taken to the lower even foot. The logs were graded in two different ways: (1) By the three standard commercial grades of 1, 2, and 3, the basis of which has already been discussed; and (2) by three grades termed clear, medium, and rough.

The latter classification is based on the degree of surface clearness and smoothness, to the exclusion of limitations in regard to diameter, density of grain, and other specifications written into the present commercial log-grading rules. To the clear grade are admitted logs that are surface clear except for occasional shallow defects. All commercial No. 1 logs fall into this grade, and in addition some clear butt logs and occasional second logs from trees in the 20-to-40-inch diameter range, which are too small to be admitted to the No. 1 commercial grade. The medium grade takes in logs having knots confined to one quadrant or to one-fourth of the length, or with a corresponding degree of roughness in the form of a few scattered knots or other defects. In the rough grade are included the generally rough and knotty logs. Most butt logs go into the clear grade, most middle logs into the medium grade, and virtually all top logs into the rough grade.

In comparison with the commercial log-grading system, the clear, medium, and rough classifications have the advantage that they are easily applied to logs in the standing tree. Further, for any given timber type in restricted localities, they show a more consistent relationship between log size and log value within each grade than do the commercial log grades. The disadvantage of the system is that it does not indicate so reliably as the commercial grading system the differences in log value corresponding with differences in timber type or locality. Under the latter system a "No. 1 log", for example, means about the same thing regardless of type of stand, site, or locality. For application within a self-contained logging-milling operation, the clear-medium-rough classification is distinctly better.

Lumber grade recovery.—Figure 3A presents an analysis of green lumber grade production for various sizes of Douglas fir logs in a mill study based on a cut of 340,833 board feet, lumber tally. The upper row of diagrams shows the results by commercial log grades, and the lower row on the basis of the clear-medium-rough grades. The diagrams to the extreme right give summary comparisons by grades regardless of variations from one diameter class to another. The lumber is classified into six grades, namely vertical grain clear, flat grain clear, select common, and No. 1, No. 2, and No. 3 common. Production by grades is expressed in percentage of the total green-chain tally of No. 3 common and better, built up cumulatively from high to low grades with total production in each diameter class equal to 100 per cent.

Figure 3A shows clearly the progressive increase of the relative yield of low-grade lumber and the corresponding decrease of high-grade lumber between high-quality and low-quality logs. Within each diagram, i. e., for any given grade of logs, it further shows that the relative yields of the various lumber grades are governed by variations in the diameter of the logs, although in some cases these relationships are extremely irregular, particularly for "rough" and No. 3 log grades. Figure 3B shows a similar analysis for a mill study based on a cut of 616,040 board feet, lumber tally, of Douglas fir. The effect of variation of log diameter on lumber yield is not shown for No. 1 commercial logs, owing to insufficiency of data.

In figure 3C, the results of a similar analysis are given for a mill operating in "red fir", with the logs graded only as clear, medium, and rough. The data cover a cut of 300,593 board feet, lumber tally.

Figure 3D displays the results obtain in studies *(19)*, conducted in 1933 by the Pacific Northwest Forest Experiment Station, covering two mills operating in "red fir" timber in the Willamette Valley. The logs in these two cases were graded as butt, middle, and top logs, which for the type of timber involved is substantially equivalent to grading them as clear, medium, and rough. A total of 1,336 logs was included in the study represented by the upper row of diagrams, and 609 logs in that represented by the lower row.

A comparison of the results in the five studies discussed in the foregoing shows that for any given mill and type of timber a fairly definite and consistent relationship holds from one log grade to another and, within a given log grade, from one diameter class to another; at the same time it shows rather striking differences as to lumber grade recovery by log grades and diameter classes, between different mills and different types of logs. This may be accounted for in part by the fact that figures 3A and 3B represent typical old-growth "yellow fir", while figures 3C and 3D represent "red fir"; but the differences go far beyond these general classifications.

Determination of pond conversion values of logs.—The average green-chain lumber value in logs of different grades and diameter classes is determined by multiplying the percentages of total log volume in each grade of lumber by the sales price for that grade (reduced to allow for the costs and manufacturing losses incurred after the lumber leaves the green chain). The pond conversion value, or the value of the logs in the pond, is next determined by deducting from green-chain values the manufacturing costs incurred from pond to green chain. The steps involved are illustrated in table 2, which presents data obtained in the mill study, the results of which are presented in figure 4.

For this mill and for the time of the study the lumber prices received, adjusted for trim and degrade losses as well as yard costs, were as follows:

V. G. Clears......	$26.47	per M feet
F. G. Clears......	19.22	per M feet
Select Common ...	12.22	per M feet
No. 1 Common....	10.22	per M feet
No. 2 Common....	6.22	per M feet
No. 3 Common....	3.22	per M feet

Since this study was made, lumber prices and costs have fluctuated violently; but obviously once the percentage of lumber grade recovery, relative sawing costs, and mill overrun have been determined it is a simple matter to recompute values on the basis of new cost levels. Just as in the case of logging costs presented in the previous report *(7)*, the basic relations hold even though actual costs and prices may vary widely.

Determination of stumpage conversion values of logs and trees.—With the pond conversion value of logs known, similar procedure is followed in arriving at stumpage conversion values of logs and trees. Figure 4 gives an analysis of conversion values of logs, and figure 5 gives corresponding values of trees, for the two mill studies from which the lumber grade recovery data are presented in figures 3A and 3B.

6. Factors affecting pond conversion values in different operations.—Striking differences will be noted when the returns obtained in these two studies (figures 4 and 5) are compared grade by grade and size by size. One factor in this situation is that one mill is a cargo mill and the other a rail mill, and that for the latter no allowance has been made for underweights—an item that will vary considerably according to the destination of the shipments and that, on the whole, will raise the values of the high-quality material while not raising in the least the values of much of the low-quality material disposed of locally or shipped to tidewater for cargo. Many factors other than underweight contribute to the wide differences shown in sawmilling and remanufacturing costs and in sales prices of lumber sold, and consequently to differences in the value of the timber. Along this line the following statement on the factors that may affect the results obtained in different mills, quoted directly from Hessler and Co.'s report *(13)* on the mill studies, is enlightening:

"*Sawmill Costs.*—There is actually a radical difference between the cost of operating one sawmill as against another. Obviously, this affects the actual value of the logs in a given operation. Costs between rail mills vary as much as $4.00 per thousand for performing similar work. The spread between cargo mills is about $2.00 per thousand. Of course, the spread between a cargo and a rail mill can be much greater. This differential may be offset, in part at least, by a differential in sale prices. One case was found in tests of this nature where there was a difference of $5.00 per thousand in sawing cost between two mills cutting the same logs, and this difference was not reflected in a different sales price.

"*Transportation.*—If a mill is shipping dry lumber on a long freight haul, it may recover as much as $3.50 per thousand in the form of underweights. In such a case there is a difference in value to be added to the value of the logs so as to find their net conversion value. If, however, shipments are being made to tidewater for cargo, the amount of this rate constitutes a differential against the value of the logs.

"*Markets.*—Some mills have developed special market outlets for their products, which yield considerably more value to them, grade for grade, than is received by mills shipping into ordinary channels. This difference may amount to $4 to $5 per thousand on the average sales value of the product to the mill.

"*By-products.*—Some mills are so located that they have no convenient outlet for their by-products such as the various forms of wood fuel. Those located in the larger cities have, of course, the largest chance of recovery of this nature. Recovery from these items ranges from 0 to $2.00 per thousand board feet.

"*Overrun.*—Some mills recover considerably more lumber and saleable material than others even from the same species and type and size of log. This difference in recovery is the result of variations in methods of manufacture, orders being cut, width and sizes being produced. This factor can result in a variation of over $1.50 per thousand on the basis of 1929 prices.

"*Grade Recovery.*—Some operations recover much higher grades from the same logs than others. This can amount to a difference of from $5 per thousand on good logs to about $1 per thousand on poor grade logs."

TABLE 2.—*Lumber grade recoveries, costs, and returns for Douglas Fir Logs.*

Top diameter of log	Lumber recovery by grades in per cent of total green lumber tally							Average lumber value[1]	Costs in dollars per M.			Pond value per M based on mill tally	Overrun multiplier	Pond value per M based on gross log scale
	V. G. Clear	F. G. Clear	Sel. Common	No. 1 Common	No. 2 Common	No. 3 Common	Total		Sawmill	Remanufacture	Total			
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
							Rough Grade Logs.[2]							
16	0.0	1.2	10.5	67.3	21.0	0.0	100.0	9.69	2.73	0.13	2.86	6.83	1.450	9.90
18	0.0	1.5	9.7	67.5	20.3	1.0	100.0	9.67	2.72	0.13	2.85	6.82	1.390	9.48
20	0.0	2.1	9.0	63.0	23.0	2.9	100.0	9.45	2.72	0.13	2.85	6.60	1.330	8.78
22	0.0	3.0	7.8	61.0	24.2	4.0	100.0	9.39	2.71	0.13	2.84	6.55	1.275	8.35
24	1.0	3.2	7.0	58.0	25.7	5.1	100.0	9.41	2.70	0.13	2.83	6.58	1.225	8.06
26	7.0	4.0	5.0	54.0	24.0	6.0	100.0	10.43	2.27	0.12	2.39	8.04	1.175	9.45
28	11.2	4.5	1.0	51.5	23.8	8.0	100.0	10.93	2.19	0.11	2.30	8.63	1.140	9.84
30	14.0	4.5	0.0	47.0	23.0	11.5	100.0	11.16	2.18	0.11	2.29	8.87	1.115	9.89
32	15.0	4.0	0.0	34.0	33.0	14.0	100.0	10.71	2.16	0.12	2.28	8.43	1.095	9.23
34	14.5	3.0	0.0	30.0	44.5	8.0	100.0	10.51	2.16	0.12	2.28	8.23	1.080	8.89
36	13.5	3.0	0.0	29.0	47.0	7.5	100.0	10.27	2.15	0.11	2.26	8.01	1.070	8.57
38	12.5	3.0	0.0	26.0	53.0	5.5	100.0	10.03	2.13	0.11	2.24	7.79	1.060	8.26
40	10.0	4.0	0.0	23.0	58.0	5.0	100.0	9.54	2.10	0.11	2.21	7.33	1.055	7.73
							Medium Grade Logs.							
22	9.0	4.0	7.0	75.0	5.0	0.0	100.0	11.99	2.40	0.12	2.52	9.47	1.275	12.07
24	11.5	5.0	7.0	65.0	8.5	3.0	100.0	12.13	2.40	0.13	2.53	9.60	1.225	11.76
26	16.0	5.3	5.0	59.0	10.7	4.0	100.0	12.70	2.40	0.13	2.53	10.17	1.175	11.95
28	19.0	5.7	3.0	54.0	14.3	4.0	100.0	13.04	2.35	0.13	2.48	10.56	1.140	12.04
30	23.0	6.0	3.0	47.0	17.0	4.0	100.0	13.60	2.30	0.14	2.44	11.16	1.115	12.44
32	30.0	6.5	3.0	42.5	14.0	4.0	100.0	14.90	2.24	0.21	2.45	12.45	1.195	13.63
34	38.0	7.0	3.0	37.0	11.0	4.0	100.0	16.37	2.19	0.24	2.43	13.94	1.080	15.06
36	40.0	7.5	3.0	34.0	11.5	4.0	100.0	16.72	2.11	0.24	2.35	14.37	1.070	15.38
38	41.0	8.0	3.0	32.0	12.0	4.0	100.0	16.91	2.07	0.24	2.31	14.60	1.060	15.48
40	41.5	8.5	3.0	31.0	12.0	4.0	100.0	17.04	2.06	0.24	2.30	14.74	1.055	15.55
42	42.5	9.0	3.0	30.0	11.5	4.0	100.0	17.27	2.06	0.24	2.30	14.97	1.055	15.79
44	43.5	9.5	3.0	30.0	10.0	4.0	100.0	17.53	2.06	0.24	2.30	15.23	1.055	16.07
46	44.5	9.5	3.0	30.0	9.0	4.0	100.0	17.74	2.06	0.24	2.30	15.44	1.050	16.21
							Clear Grade Logs.							
32	49.7	11.5	7.5	25.5	5.2	0.6	100.0	19.24	2.66	0.24	2.90	16.34	1.095	17.89
34	51.4	10.5	6.5	26.0	5.0	0.6	100.0	19.41	2.59	0.24	2.83	16.58	1.080	17.91
36	53.0	9.3	6.0	26.4	4.7	0.6	100.0	19.56	2.40	0.23	2.63	16.93	1.070	18.12
38	54.2	8.5	5.2	27.0	4.5	0.6	100.0	19.68	2.24	0.22	2.46	17.22	1.060	18.25
40	55.5	7.5	4.7	27.5	4.2	0.6	100.0	19.79	2.10	0.22	2.32	17.47	1.055	18.43
42	56.0	6.7	4.5	28.2	4.0	0.6	100.0	19.81	2.04	0.21	2.25	17.56	1.055	18.53
44	56.0	6.0	4.2	29.5	3.7	0.6	100.0	19.74	2.02	0.21	2.23	17.51	1.055	18.47
46	56.1	6.0	3.5	30.1	3.7	0.6	100.0	19.76	2.04	0.20	2.24	17.52	1.050	18.40
48	56.5	5.5	3.2	27.0	7.2	0.6	100.0	19.64	2.14	0.20	2.34	17.30	1.050	18.17
50	60.3	5.8	2.5	21.5	8.7	1.2	100.0	20.16	2.24	0.20	2.44	17.72	1.050	18.61
52	65.8	5.9	3.0	17.2	7.5	0.6	100.0	21.17	2.32	0.19	2.51	18.66	1.050	19.59
54	69.0	5.5	3.5	15.5	5.9	0.6	100.0	21.72	2.38	0.19	2.57	19.15	1.050	20.11
56	71.6	4.6	5.0	13.0	5.2	0.6	100.0	22.11	2.40	0.19	2.59	19.52	1.050	20.50

[1] Based on the following green chain values: V. G. Clears............. $26.47
F. G. Clears............. 19.22
Select Common.......... 12.22
No. 1 Common.......... 10.22
No. 2 Common.......... 6.22
No. 3 Common.......... 3.22

[2] Average length 34 feet; No logs over 15 per cent defective included.

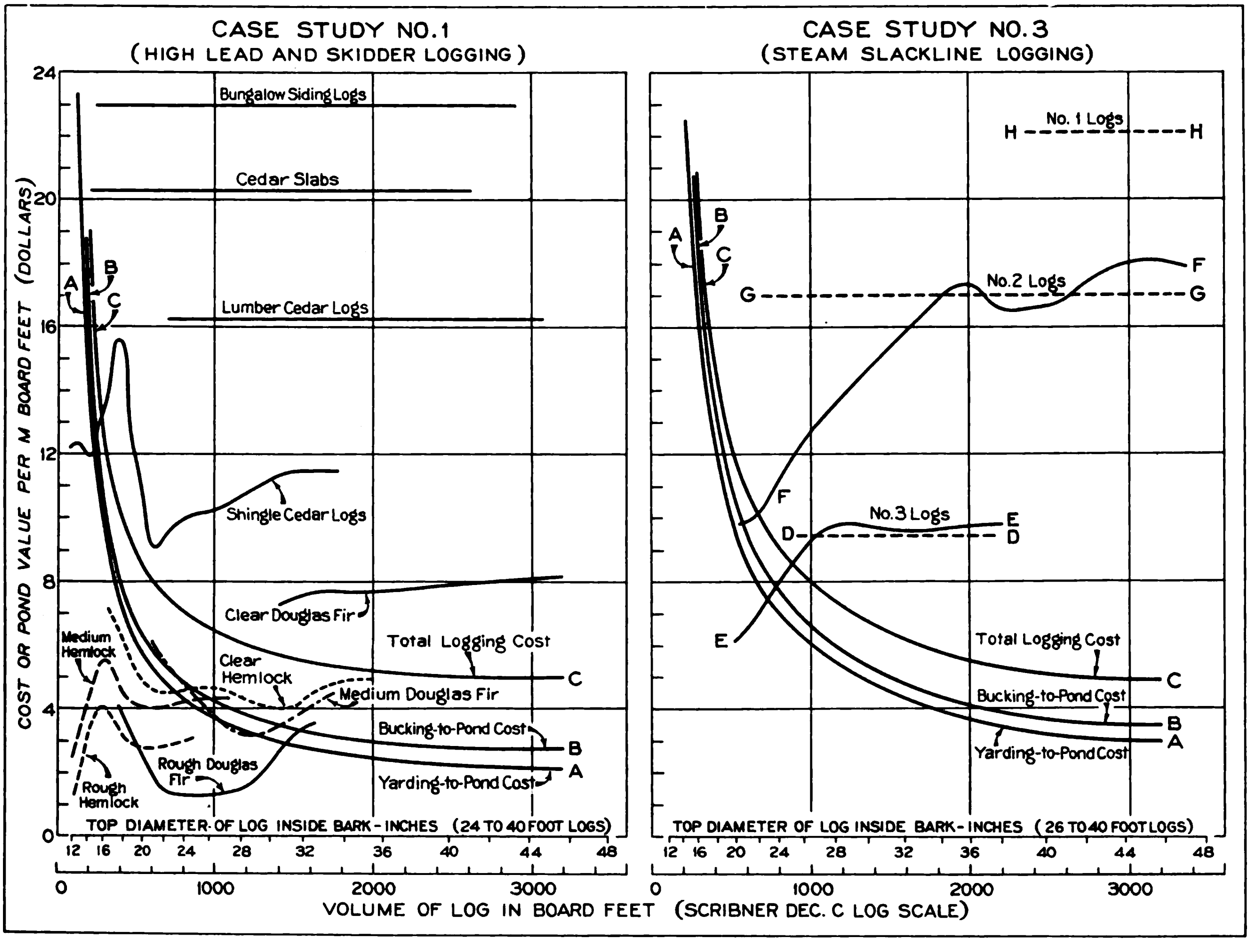


Fig. 4- Logging Costs, Pond Values, and Stumpage Conversion Values of Logs
(Pond Values based on Mill Recovery Studies - Year 1931)

7. **Value spread and value progression are important factors in timber management.**—The foregoing stumpage conversion diagrams represent six different tracts located in different parts of the Douglas fir region. All of these represent old growth stands of medium to high quality; for second growth or low quality stands the rise in relative value from small to large trees would be less pronounced than in the cases studied. While each diagram differs in many details from the others, they all tell the same general story of the relations of log and tree size to logging costs, log values, and stumpage conversion values. In a sense these may be spoken of as basic cost and value relations although it is obvious that there are innumerable factors that from time to time will bring about more or less important changes, not only with respect to constantly rising or falling cost and value levels, but also, though generally to a lesser extent, with respect to relative costs and values. In this connection it should be strongly emphasized that the logging cost relations shown represent conventional clear-cutting practices only and that, as pointed out in the logging cost report *(7)*, these relations will change considerably, especially for small trees, under a selective system of logging where different size classes of timber are logged separately with specialized equipment and methods—a point that is brought out in the case study discussed in the next chapter. It should also be emphasized that the value relations shown represent lumber logs, and that values based on other special products, such as poles, piling, pulpwood, fuelwood, Christmas trees, etc., may, in some cases, introduce entirely different values for some trees of a particular size class and species. Nevertheless, these diagrams give a general idea of how stumpage values rise with increasing size of tree. Small trees, it is here seen, yield as a rule only low-grade timber and

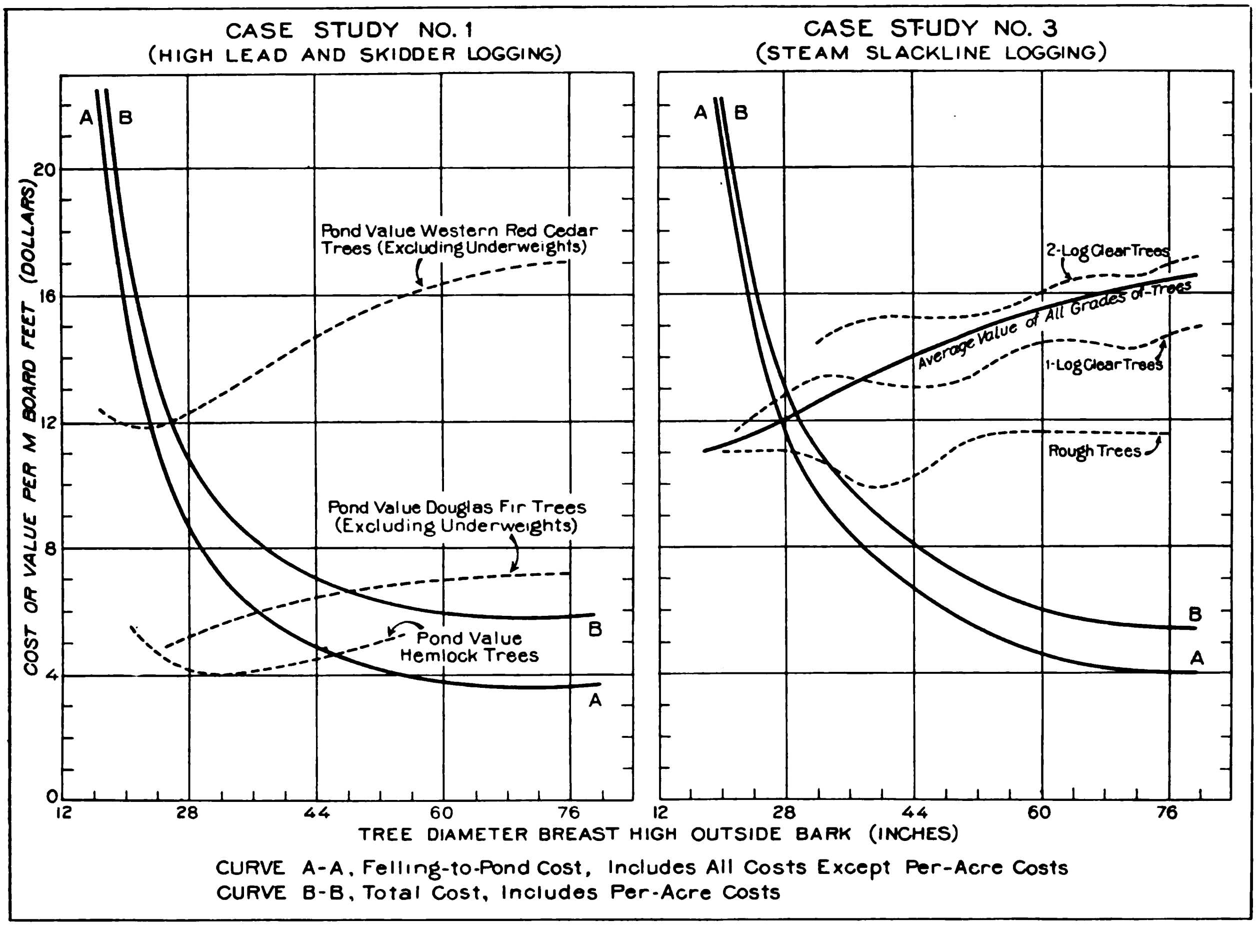


Fig.5 - Logging Costs, Pond Values, and Stumpage Conversion Values of Trees
(Pond Values Based on Mill Recovery Studies, Year 1931)

are costly to log, with the result that the net stumpage recovery is low or negative; the zero-margin Douglas fir trees usually vary between 24 and 30 inches d. b. h. Large trees, on the other hand, yield a relatively high-quality product and can be logged at relatively lower costs, leaving a wide margin for stumpage.

These facts as to relative costs and values should be borne in mind at all times in dealing with selective timber management. A wide spread in stumpage conversion values is in part the underlying basis for the intensive methods of management discussed in the following chapters. The most important point to recognize here is not so much that some logs and trees are of minus value and hence should be excluded from the cut, but that there is a wide spread in relative values; for selective timber management, it will be shown, does not center on the segregation of plus-value logs and trees from those of minus value—it aims at the segregation of value classes on the basis of differentials both in relative value and in relative earning power. Under this form of management a wide spread in value becomes important from the standpoints of both liquidation and timber growing; from the standpoint of liquidation it governs the order in which the timber should be logged and the length of the cutting cycle; from the standpoint of timber growing it governs the selection of growing stock for continuous production of high-quality timber. In the latter respect it can readily be reasoned from a study of the conversion diagrams that a growing tree increases in value through (1) growth in volume, (2) growth in quality, and (3) decrease in logging cost (owing to low cost of handling large sizes), and may, in addition, benefit from (4) price increment and (5) improved logging technic. The way in which these and other considerations enter into selective management will be brought out in the following chapters.

CHAPTER III

FINANCIAL ASPECTS OF VARIOUS MANAGEMENT PROCEDURES AS APPLIED TO A LARGE PROPERTY IN THE SPRUCE-HEMLOCK TYPE

8. **Object and scope of study.**—This chapter deals with the immediate and long-term operating results obtainable through applying various plans and methods of timber management to a large area of privately owned timberland in the spruce-hemlock belt of the Douglas fir region, and develops and illustrates principles of management believed to be generally applicable to such areas in the region. The logging methods involved were developed through experiments carried out in 1932 and were described in chapter XXI of the logging cost report *(7)*, and were further improved through large-scale experiments in 1933. The method found most effective is individual tree selection by size classes, with the use of tractor-arch outfits, although under some topographic conditions group selection is necessary with tractor-mounted drum-units or other flexible yarding methods, combined where necessary with skyline swinging. Attention will be centered on the application of this highly efficient method of selective logging to long-term timberland management, leading step by step from wholesale clear cutting to intensive selective sustained yield management.

This case study is used as an illustration of a number of theoretical principles such as the effect of discount, considerations which determine the length of the cutting cycle and other questions which must be considered in effective timber management. Such theoretical and subsidiary considerations have for the most part been set in small type in order that the concrete case itself may more readily be followed through.

9. **General topography and timber distribution, and character of the timber.**—The characteristic topography of the tract under consideration is illustrated by the topographic map of the 60-acre Plot A presented as figure 6. For the purpose of this study this plot will be considered representative also as to distribution of large trees shown on the map. The data on Plot A were obtained through a 100 per cent cruise. In figure 7 detailed information on Plot A and two other sample areas, Plots B and C, is given in the form of stand-structure diagrams. Plots B and C are located many miles from Plot A. These three plots are representative of a timber type that covers large portions of the property under consideration and, for the hypothetical case that will here be set up, it will be assumed that the same type extends over the entire property.

As is shown by a comparison of the three stand-structure diagrams, the general character of the stand is about the same on all three plots except as to proportionate representation of species. Each plot is occupied by a fairly thrifty many-aged forest of hemlock, or of hemlock and spruce in mixture, generally 100 to 160 years old and ranging up to about 50 inches in diameter, with scattered spruce and fir veterans generally about 250 to 600 years old and ranging from 50 to 100 inches in diameter. While the veterans are relatively few in number they constitute, as shown in figure 7, a relatively large portion of the total volume. (Such concentration of the volume in relatively large trees generally occurs, though not always in quite so pronounced a degree as in this particular case, in both uneven-aged and even-aged old growth stands in the Douglas fir region. From several points of view, it has an important bearing on selective timber management.)

The veterans on these plots are in general physically overmature, so that about 25 per cent of their otherwise merchantable volume has to be culled in the woods. As a class they are deteriorating through decay, windfall, and other causes at a rate that on the average no doubt far exceeds their current volume increment. The small and medium-sized trees, mostly hemlock and spruce trees less than 160 years of age and less than 50 inches in diameter, as a rule either are growing at a fairly substantial rate or are capable of increased growth if released. On the whole it will be assumed here

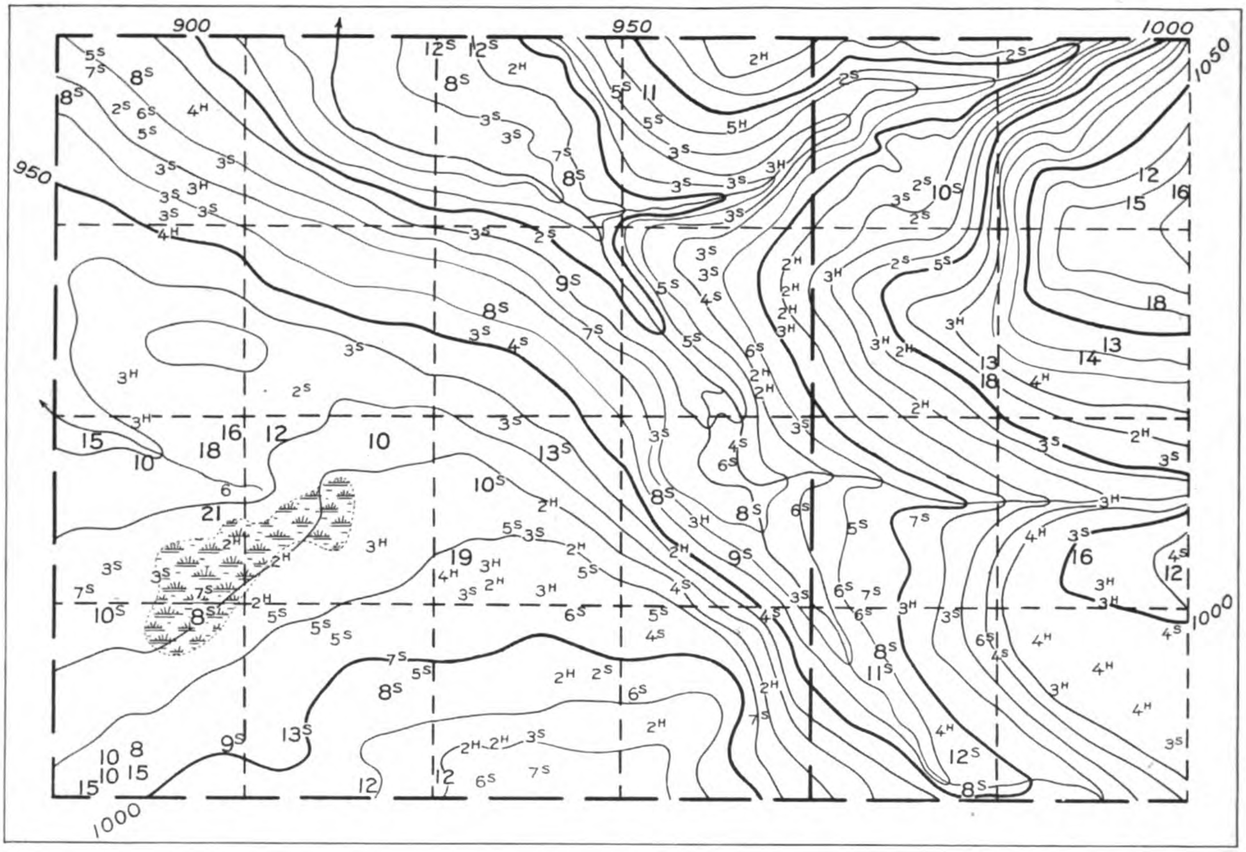


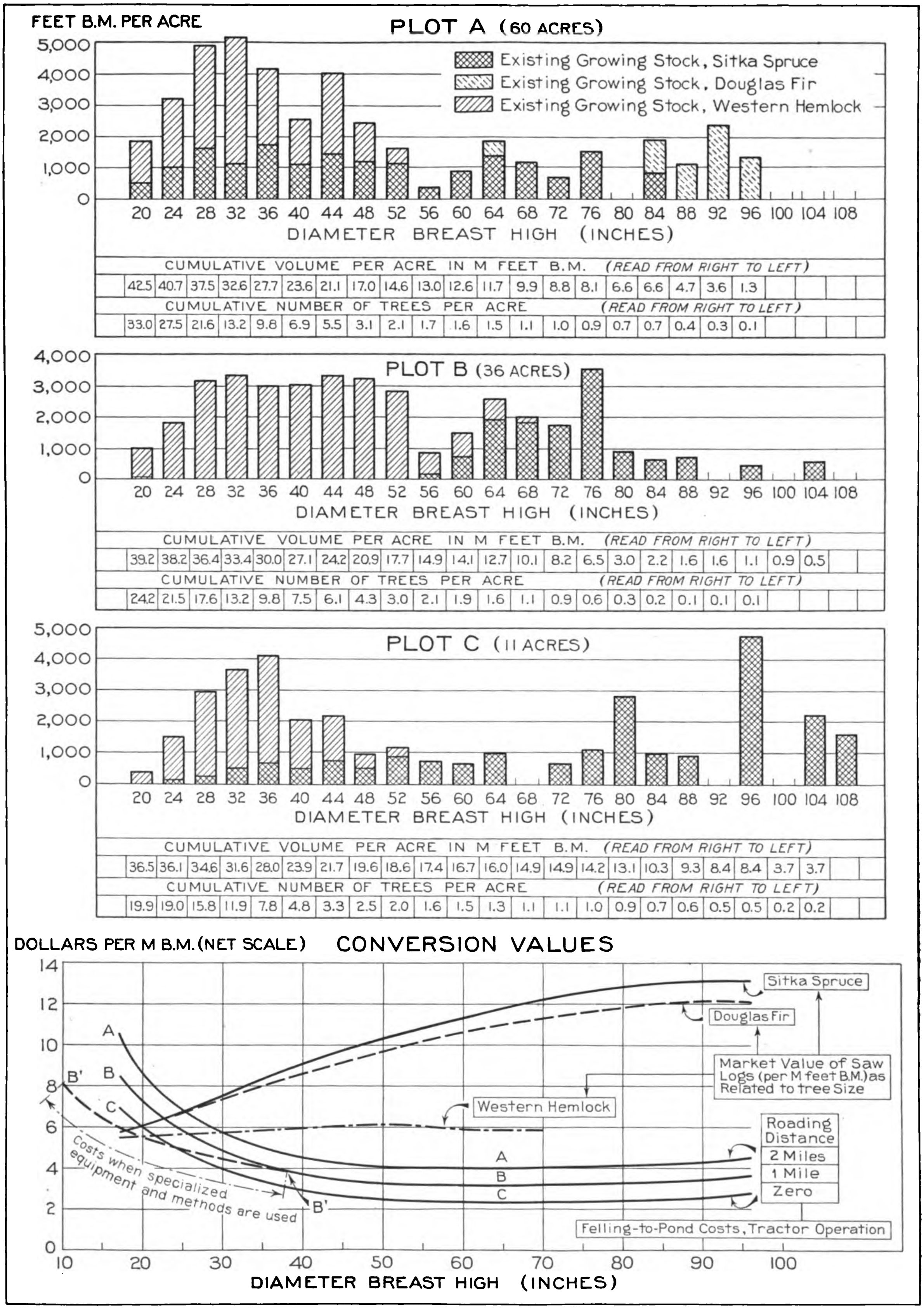
FIG. 6-PLOT A, 60-ACRE AREA, TYPICAL IN TOPOGRAPHY AND IN DISTRIBUTION OF TIMBER

Numbers represent volume in M feet b m of all trees more than 44" in diameter and indicate actual location of trees; suffix letter "S" indicates spruce, "H" indicates hemlock, and numbers lacking a suffix indicate Douglas Fir. Marginal figures indicate elevations of 50 foot contours

that the unmanaged forest is in equilibrium, growth balancing decay. In the intensively managed forest, on the other hand, losses from decay would be minimized by removing the old defective trees at a relatively faster rate at the beginning, and losses from windfall, etc., would be reduced by going over the area for cuttings and salvage every few years. At the same time, growth in the residual stand would be stimulated by frequent systematic cuttings. As is shown in table 18, chapter VI, release cuttings in the intermediate and suppressed crown classes may cause a pronounced increase in rate of growth, about doubling the rates in the examples cited in that chapter.

10. Determination of stumpage conversion values.—Logging costs, market values, and stumpage conversion values for the species and diameter classes occurring on Plots A, B, and C are shown in the conversion-value chart at the bottom of figure 7, which is drawn to the same horizontal scale as the stand-structure diagrams in that figure. Logging costs, in this case, unlike the costs dealt with in chapter II, represent a selective system of logging, that is to say, trees of widely differing size classes were removed in separate cuts (as discussed in chapter XXI of the logging cost report *(7)*. It will be seen from a comparison with those cases that the relative rise in the cost of logging small trees is not nearly so great.

Felling-to-pond costs (logging costs other than road-construction and similar per-acre costs) are represented by curve A-A for a roading distance of 2 miles, by curve B-B for 1 mile, and by curve C-C for 0 distance. According to tractor-roading results obtained in this operation in 1933, a weighted average roading distance of about 1 mile gives the lowest combined cost of tractor roading and railroad construction, maintenance, and operation when the stand is clear cut. In the following discussion, therefore, curve B-B will be considered to represent average felling-to-pond costs, except that curve B′ B′ will be considered to represent these costs for trees less than 36 inches in diameter. Curve B′-B′ shows the reduced costs of logging small trees with specialized logging equipment and methods such as staked cars and bunching of small logs. (The possibility of cost reduction through these methods was discussed in detail in chapter XX of the logging cost report.) This curve shows that all size classes and species of trees represented in the stand-structure diagrams fall in the plus-value class. Therefore, in the following analysis the selection has to do not with elimination of minus-value trees but only with order of selection.



Plot A (60 acres)

Diameter breast high (inches)	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108
Cumulative volume per acre in M feet B.M. (read from right to left)	42.5	40.7	37.5	32.6	27.7	23.6	21.1	17.0	14.6	13.0	12.6	11.7	9.9	8.8	8.1	6.6	6.6	4.7	3.6	1.3			
Cumulative number of trees per acre (read from right to left)	33.0	27.5	21.6	13.2	9.8	6.9	5.5	3.1	2.1	1.7	1.6	1.5	1.1	1.0	0.9	0.7	0.7	0.4	0.3	0.1			

Plot B (36 acres)

Diameter breast high (inches)	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108
Cumulative volume per acre in M feet B.M. (read from right to left)	39.2	38.2	36.4	33.4	30.0	27.1	24.2	20.9	17.7	14.9	14.1	12.7	10.1	8.2	6.5	3.0	2.2	1.6	1.6	1.1	0.9	0.5	
Cumulative number of trees per acre (read from right to left)	24.2	21.5	17.6	13.2	9.8	7.5	6.1	4.3	3.0	2.1	1.9	1.6	1.1	0.9	0.6	0.3	0.2	0.1	0.1	0.1			

Plot C (11 acres)

Diameter breast high (inches)	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108
Cumulative volume per acre in M feet B.M. (read from right to left)	36.5	36.1	34.6	31.6	28.0	23.9	21.7	19.6	18.6	17.4	16.7	16.0	14.9	14.9	14.2	13.1	10.3	9.3	8.4	8.4	3.7	3.7	
Cumulative number of trees per acre (read from right to left)	19.9	19.0	15.8	11.9	7.8	4.8	3.3	2.5	2.0	1.6	1.5	1.3	1.1	1.1	1.0	0.9	0.7	0.6	0.5	0.5	0.2	0.2	

Fig. 7 – Stand Structure on Plots A, B, and C and Conversion Values of Trees of Different Diameter Classes and Species
(Costs and Values as of the Summer of 1932)

TABLE 3.—*Comparison of load volumes, 1932 and 1933 experiments*

Logs per load	Average volume per load, gross log scale	
	60 h.p. gasoline tractor[1]	75 to 80 h.p. Diesel tractor[2]
Number	*Board feet*	*Board feet*
1	3,900	4,870
2	2,220	4,512
3	2,290	4,300
4	1,920	4,126
5	....	4,281
Weighted average	2,800	4,330

[1] Data taken in 1932.
[2] Data taken in 1933.

Improvements in tractor logging in 1933.—Results ot tractor logging experiments made on this operation in 1932 and reported in the logging cost report *(7)* indicated that efficiency in negotiating steep or slightly adverse grades and in handling large timber might be increased through use of more powerful tractors and through more careful attention to building up large load volumes. Introduction of 75-80 h.p. Diesel tractors and other recent developments in tractor logging have since confirmed these findings. Large scale studies were made on the same operation in 1933 by John E. Liersch *(18)*, whose findings are summarized below:

(a) The slope on which a 60 h.p. gasoline tractor-arch outfit required least time for hauling and return trip over a given distance was found to be 8 per cent. For the 75 to 80 h.p. Diesel tractor, the corresponding slope was 15 per cent.

(b) The grade on which the speed of round-trip travel was the same as on the level, for any distance, was 26 per cent for the Diesel outfit, but only 16 per cent for the 60 h.p. outfit.

(c) The grade indicated as the maximum that could be negotiated was about 30 per cent for the 60 h.p. outfit, and about 40 per cent for the Diesel outfit.

(d) Slight adverse grades (grades against the load) can be negotiated more easily with the 75 to 80 h.p. Diesel outfit.

(Thus, changing from a 60 h.p. gasoline tractor to a 75 to 80 h. p. Diesel tractor greatly extends the opportunities for successful tractor logging in typical rough country of the Douglas fire region.)

(e) The cost of operation (machine rate) is less for the 75-80 h.p. Diesel outfit owing chiefly to fuel economy.

(f) Cost can be reduced through the building up of large loads, made possible by the use of more powerful tractors, as is shown in table 3.

(The increase in average load volume from 2,800 feet in 1932 to 4,300 feet in 1933 was accomplished without increasing disproportionately the time required for hooking and unhooking the load. The maximum load volume handled in 1932 was 6,500 feet; the maximum handled in 1933 was 8,800 feet.)

In table 4 are shown tractor-hauling costs for various distances for logs averaging 1,400 board feet in volume. These cost data furnish the basis of tractor logging costs used in this and following chapters.

TABLE 4.—*Tractor-hauling costs[1] for various distances*

Distance of haul (miles)	Cost per M feet	
	Gross scale	Net scale
0	$0.22	$0.25
½	.56	.64
1	.90	1.02
2	1.59	1.80
3	2.28	2.59

[1] Based on machine rate of $33.00 per 8-hour day; to compute outputs, divide $33.00 by costs listed.

11. Basis of analysis of financial returns under various management plans.—Study of the cost and value curves in figure 7 brings to attention the fact, already demonstrated (in chapter II) for other old-growth stands, that the source of net returns in logging consists mainly in the larger trees, represented in this case by overmature spruce and Douglas fir veterans. Spruce and Douglas fir trees 60 to 100 inches in diameter yield from $6 to more than $10 per M feet, according to diameter and to distance of haul within the 2-mile tractor-roading zone represented by the space between curves A-A and C-C. A still wider value spread would be shown if the trees were segregated by quality classes, so that, for example, rough-boled versus clear-boled trees, or sound versus defective trees, were represented by separate value curves. In contrast with these high-value trees the hemlock stand which includes most of the timber less than 50 inches in diameter, shows a return averaging only about $1.50 per M feet. Intermediate between these two general groups are spruce trees, which fall in the same general size and age classification as the hemlock but of which the largest exceed the hemlocks in value per M feet by as much as $4.00.

The wide spread in stumpage conversion values becomes most significant from a timber-management point of view when time is brought into the management equation. In the case at hand the timber owner is in no position, even if he so desires, to liquidate all his timber holdings in a year's or a few years' time. As in the case of many other tracts in this region with its large merchantable timber supply, many years would elapse before the last stick of timber on this tract could be cut no matter what plan of cutting were followed. Even if this owner should decide to liquidate all his timber at the maximum practicable rate of speed, he would have to figure on a period of 20 or—more probably—30 years, because of market limitations and other restrictions arising from general business considerations. In short, this timber property would by practical necessity, if not by the owner's choice, become a comparatively long-term operation under any feasible plan of logging, including the cut-out-and-get-out plan.

The question as to which trees should be cut first and which should be cut last or not at all becomes more important the longer the operating period. Efforts to find an answer to this question are here based on the following premises:

(1) The property comprises roughly 75,000 acres of timber with a total stand of 3 billion feet.

(2) Under a cut-out-and-get-out policy of operation the annual volume of production would be 100 million board feet and the operating period 30 years.

(3) Per-acre costs (not accounted for in figure 7) amount to $0.60 per M on the basis of clear cutting.[2] This item of cost will vary with the degree of selection practiced.

(4) A debt here assumed at $3,000,000 drawing 6 per cent interest has been incurred in acquiring and holding the property and in initially opening up the tract. The existence of this debt makes it mandatory in all preliminary comparisons of financial results to use a 6 per cent rate in discounting deferred income to its present worth. After the debt is retired, which may occur at one time under one plan of management and at another time under some other plan, calculations may be revised and operating plans recast to fit any interest rate on which the owner may choose to base his subsequent operating policy. In the preliminary comparisons presented in sections 12 and 13 the servicing and retirement of this debt will not be segregated from stumpage conversion value, of which they are a part, but in the final comparison they will be so segregated (table 6).

(5) Taxes on the standing timber are assumed at 2 cents per M per annum. This item, like debt servicing and retirement, is treated as a part of stumpage conversion value, and will not be segregated except in the final comparison (table 6).

(6) In the preliminary analysis the value of the timber will be assumed as fixed throughout the 30-year period, and no attention will be given to questions of growth, decay, and changing market demands, etc. Later, the influence of these factors upon the final management plan will be considered.

12. Logging for maximum present worth of the first cut only.—From the premises set down, it is possible to make a step-by-step analysis of the financial aspects of selective timber management as they apply in particular to this property and in general to any old-growth timber property under long-term management. The first step in this direction is to determine how much of the timber should be cut to obtain the greatest possible returns in terms of present net worth, assuming at first that only one cut would be taken. In discounting deferred income to determine present net worth, the present and future value of the timber not included in this cut will at first be entirely disregarded. The first steps of such an analysis, based on Plot A, are presented in tables 5A and 5B.

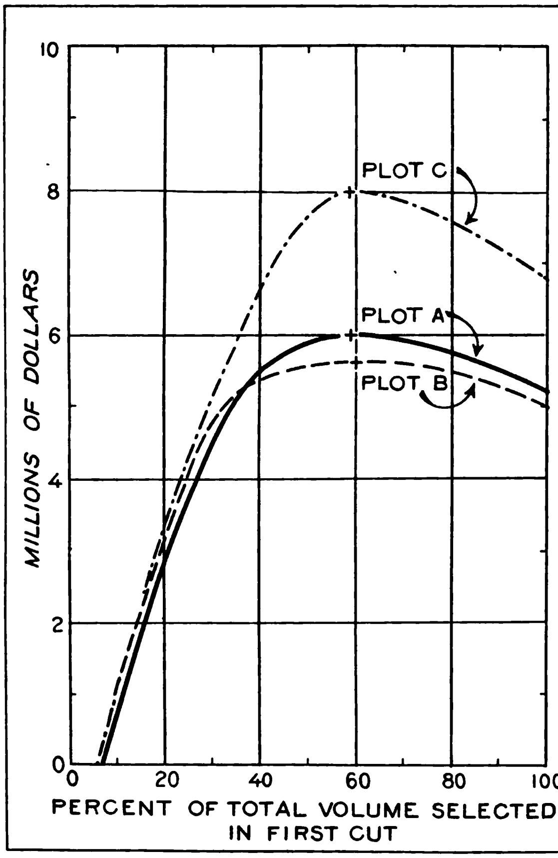


Fig. 8 - Present Net Worth of First Cuts of Various Intensities

Table 5A serves as the foundation of table 5B. The method followed in setting up table 5A was as follows:

The stand of Plot A (figure 7) was divided into 10 value classes each comprising 4,250 board feet, or 10 per cent of the total net merchantable volume. The conversion-value chart and the stand-structure diagram show that the 10 per cent portion (4,250 board feet) of the total per-acre volume that will yield the highest gross stumpage conversion value contains only spruce trees 66 inches or more in diameter breast high. For this class of trees, as is shown in table 5A, the average felling-to-pond logging cost is $3.25, the log value $12.50, and the gross stumpage conversion value, consequently, $9.25. Similarly they show that the second highest value class consists entirely of Douglas fir 86 inches or more in diameter. The third class, on the other hand, takes in both Douglas fir and spruce of different diameter classes and volumes; in this case the data on logging cost, log value, and conversion value entered in the table represent weighted averages for the two species and size classes. The tenth and lowest value class comprises 480 feet of spruce in the 20-inch diameter class and 3,770 feet of hemlock in the 20- and 24-inch classes.

Table 5B, instead of dealing separately with each of the 10 value classes, shows logging cost, log value, and stumpage conversion value as they would be affected by 10 degrees of cutting intensity each of which differs from the next by 10 per cent of the total original stand volume. If, for example, the

[2] This includes for railroad spur construction, mapping and cruising, etc. $0.25; for snag felling, $0.10; and for tractor-trail construction, $0.25. The low cost quoted for spur construction is due to skeletonizing the spur system on the basis of a 1-mile average tractor haul. The $0.60 per M (per-acre costs) does not include the cost of main-line construction outside the operating area proper, the cost of establishing camps, and any other lump-sum costs incurred in initially opening up the tract as a whole. Those preliminary lump-sum costs would be exactly the same under any of the plans discussed, and their recovery is treated in this study as a part of stumpage conversion value. On the basis on which financial results of various logging plans are to be set up here the conclusion reached would be the same no matter whether these costs amounted, for example, to $1,000 or to $1,000,000.

initial cut were 10 per cent, logging cost, log value, and gross stumpage conversion value would be as listed for the highest 10 per cent class in table 5A; if a 20 per cent initial cut were taken, the first and second of the original value classes would be included and costs and returns per M feet would be the average of those shown in table 5A for value classes 1 and 2; and so on down to the tenth plan of selection, which assumes an initial cut of 100 per cent, and the costs and returns of which represent the average of the 10 original value classes.

To obtain net stumpage conversion values, the cost of building roads and tractor-trails and other costs incurred against the area logged must be deducted. In the foregoing, costs under the clear-cutting system for the area discussed are estimated at $0.60 per M feet. The cost per M under partial cutting is shown in table 5B to decrease in the same degree as the percentage of timber removed increases, on the assumption that irrespective of the percentage of timber to be removed, the road requirement for the first cut would in all cases be exactly the same for a 100 per cent removal.

TABLE 5-A.—*Stumpage conversion values per M board feet of different value classes of timber for Plot A.*

Value class No.	Diameter class: Sitka spruce	Diameter class: Douglas fir	Diameter class: Western hemlock	Costs and returns per M feet b. m.: Logging costs[1]	Log value	Stumpage conversion value[2]	Volume in board feet per acre: Sitka spruce	Douglas fir	Western hemlock	Total	Trees per acre
	Inches	*Inches*	*Inches*	*Dollars*	*Dollars*	*Dollars*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Number*
1	66 and up	...	...	3.25	12.50	9.25	4,250	...	...	4,250	0.6
2	...	86 and up	...	3.50	12.15	8.65	...	4,250	...	4,250	0.5
3	56 to 66	68 to 86	...	3.28	11.52	8.24	2,380	1,870	...	4,250	0.6
4	40 to 56	...	...	3.40	10.00	6.60	4,250	...	...	4,250	2.0
5	30 to 40	...	48 and up	3.95	7.77	3.82	3,470	...	780	4,250	2.7
6	...	...	40 to 48	3.50	6.00	2.50	...	...	4,250	4,250	2.2
7	24 to 30	...	36 to 40	4.40	6.45	2.05	2,125	...	2,125	4,250	3.9
8	...	...	30 to 36	4.35	5.75	1.40	...	...	4,250	4,250	3.0
9	22 to 24	...	26 to 30	4.69	5.74	1.05	560	...	3,690	4,250	7.4
10	18 to 22	...	20 to 26	5.28	5.62	.34	480	...	3,770	4,250	10.1
Totals and averages				3.96	8.35	4.39	17,515	6,120	18,865	42,500	33.0

[1] Felling-to-pond costs only, as read from stumpage conversion value chart, Fig. 7.
[2] Road construction and other per-acre costs not deducted.

TABLE 5-B.—*Stumpage conversion values per M board feet and present net worth of initial cuts of various degrees of intensity for Plot A.*

Portion[1] of volume included in initial cut	Total volume cut per acre	Number of trees cut per acre	Diameter cutting limit for: Sitka spruce	Douglas fir	Western hemlock	Costs of and returns from initial cut per M feet b. m.: Logging[2] costs	Log value	Gross stumpage conversion value[3]	Cost of road construction, etc.	Net stumpage conversion value[4]	Annual income from 100 million board feet cut	Duration of initial cut	Present net worth of initial cut (discount rate 6 per cent)
Per cent	*Bd. ft.*	*Number*	*Inches*	*Inches*	*Inches*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Years*	*Dollars*
10	4,250	0.6	66 & up	...	...	3.25	12.50	9.25	6.00	3.25	325,000	3	869,725
20	8,500	1.1	...	86 & up	...	3.38	12.33	8.95	3.00	5.95	595,000	6	2,925,794
30	12,750	1.7	56 & up	68 & up	...	3.34	12.05	8.71	2.00	6.71	671,000	9	4,563,940
40	17,000	3.7	40 & up	68 & up	...	3.35	11.54	8.19	1.50	6.69	669,000	12	5,608,762
50	21,250	6.4	30 & up	68 & up	48 & up	3.48	10.79	7.31	1.20	6.11	611,000	15	5,934,154
60	25,500	8.6	30 & up	68 & up	40 & up	3.48	9.99	6.51	1.00	5.51	551,000	18	5,966,007
70	29,750	12.5	24 & up	68 & up	36 & up	3.61	9.48	5.87	.86	5.01	501,000	21	5,893,814
80	34,000	15.5	24 & up	68 & up	30 & up	3.70	9.03	5.33	.75	4.58	458,000	24	5,748,083
90	38,250	22.9	22 & up	68 & up	26 & up	3.81	8.65	4.84	.67	4.17	417,000	27	5,508,779
100	42,500	33.0	18 & up	68 & up	20 & up	3.96	8.35	4.39	.60	3.79	379,000	30	5,216,859

[1] 10 per cent of volume includes value class No. 1 in Table 5-A; 20 per cent value classes 1 and 2, etc., up to 100 per cent which includes all 10 value classes shown in Table 5-B.
[2] Felling-to-pond costs only.
[3] Road construction and other per-acre costs not deducted.
[4] Including taxes on standing timber and interest on debts.

The value of the initial cut depends not only upon current annual income but also upon the number of years required to complete the operation and the consequent discounting of deferred incomes. The present value of a series of fixed annual incomes of which the first is to come after an interval of one year is determined by the formula

$$C_0 = \frac{a(1.0p^n - 1)}{(1.0p - 1)\ 1.0p^n}$$

in which C_0=present value of a series of fixed annual incomes

a=annual income

n=number of years during which the income is to be received

p=percentage rate of interest (discount rate)

The results obtained by applying this formula to the annual incomes and operating periods listed in table 5B, using a discount rate of 6 per cent, are shown for Plot A in the last column of the table and in graphic form for Plots A, B, and C in figure 8. It is shown that present value of initial cut, instead of increasing continuously with percentage of volume removed, reaches its peak at approximately 60 per cent removal and then gradually drops off. The peak of the curve is almost exactly the same for plots A, B, and C, despite the fact that in position and form the three curves differ considerably.

The immediate conclusion to be drawn from the foregoing findings is that if the owner of this property should want to cut out and get out of the timber business and for some reason if he were prevented from making more than one cut, then the correct financial procedure would be to remove about 60 per cent of the total volume of the stand. If Plot A is taken as representative of the whole property this would mean that on the average only spruce more than 26 inches and hemlock more than 40 inches in diameter breast high should be logged. For Plot B the cutting limit for hemlock would be 42 inches, and for Plot C it would be 44 inches. To cut trees below these sizes leads to a loss even though they are in the plus-value class. The loss results from deferring cutting of large trees. In this long-term operation, in which most obviously it is impossible to liquidate all the trees on the same day or in the same year, this point is very important indeed. To obtain the best financial results a cutting program is needed that through selection gives a short discount period to timber of high immediate value.

The foregoing analysis represents only the first of a series of steps designed to throw light on the question of what plan of management will best fit this property. In drawing conclusions from the answer given above it is necessary to bear clearly in mind the premises on which the analysis is made: That both annual output and value of timber remain fixed throughout the 30-year period; that neither growth nor decay operates to modify the plan of selection; and that the owner is interested only in the returns obtainable from the first cut. As the premises change the answer to the problem changes.

Influence of interest rate and length of operating period on result.—The extent to which differences in interest rate affect the results is shown by the upper row of diagrams in figure 9. The curves representing a 6 per cent rate as applied to Plots A, B, and C are identical with those shown in figure 8. The curves labeled "no discount" simply represent the building up of the aggregate 30-year income obtained in logging all plus-value trees.

Obviously, as the interest rate is lowered the present net worth of the property increases and the percentage of total volume that would have to be logged in order to obtain the maximum net value of the first cut also increases. As has been pointed out, when the rate of interest is 6 per cent the value curve reaches its peak at a 60 per cent cut; as is shown in figure 9, the curve based on a 4 per cent interest rate reaches its peak approximately at 70 per cent, and that based on a 2 per cent rate reaches its peak at 80 per cent. In case deferred incomes are not discounted at all, the peak, of course, occurs at 100 per cent.

The three lower diagrams in figure 9 show for Plot A the extent to which variation in the length of the operating period affects the results on the basis of 6, 4, and 2 per cent interest. Length of operating period, designated on the diagrams as 60 years, 30 years, etc., represents in each case the number of years required to clear-cut the tract. Under a selective program the life of the operation is, of course, shortened, so far as the first cut is concerned, in direct proportion to the percentage of volume removed.

The curves clearly show the increase in the potency of discount as the interest rate increases from 0 to 6 per cent and as the life of a clear-cutting operation is extended from 0 to 60 years.

In examining these diagrams, attention should be given not only to the precise location of the peaks of the curves but also to the general form of the portion of each curve that lies to the left of its peak. The curves, it will be noticed, rise very rapidly as the initial cut approaches 30 or 40 per cent of total volume, but flatten out markedly nearer to the peak. In other words, relatively little is added to the present net worth of the stand by including in the initial cut the timber represented by the portion of the curve that lies immediately to the left of the peak. This fact has an important bearing on the decision as to how much of the timber the initial cut should include if it is to be followed by a second cut or a series of cuts.

Adjustment of tractor-trail plans facilitates taking a lighter initial cut.—In the foregoing analysis the assumption was made that road-construction cost and other per-acre costs are all incurred in taking out the first cut and are fixed in total amount irrespective of how light an initial cut is taken in order to avoid confusion as to method and to remove all doubt as to the sufficiency of the allowance made for increased road costs under a partial-cutting program. The question will now be considered as to what adjustment of this item can and

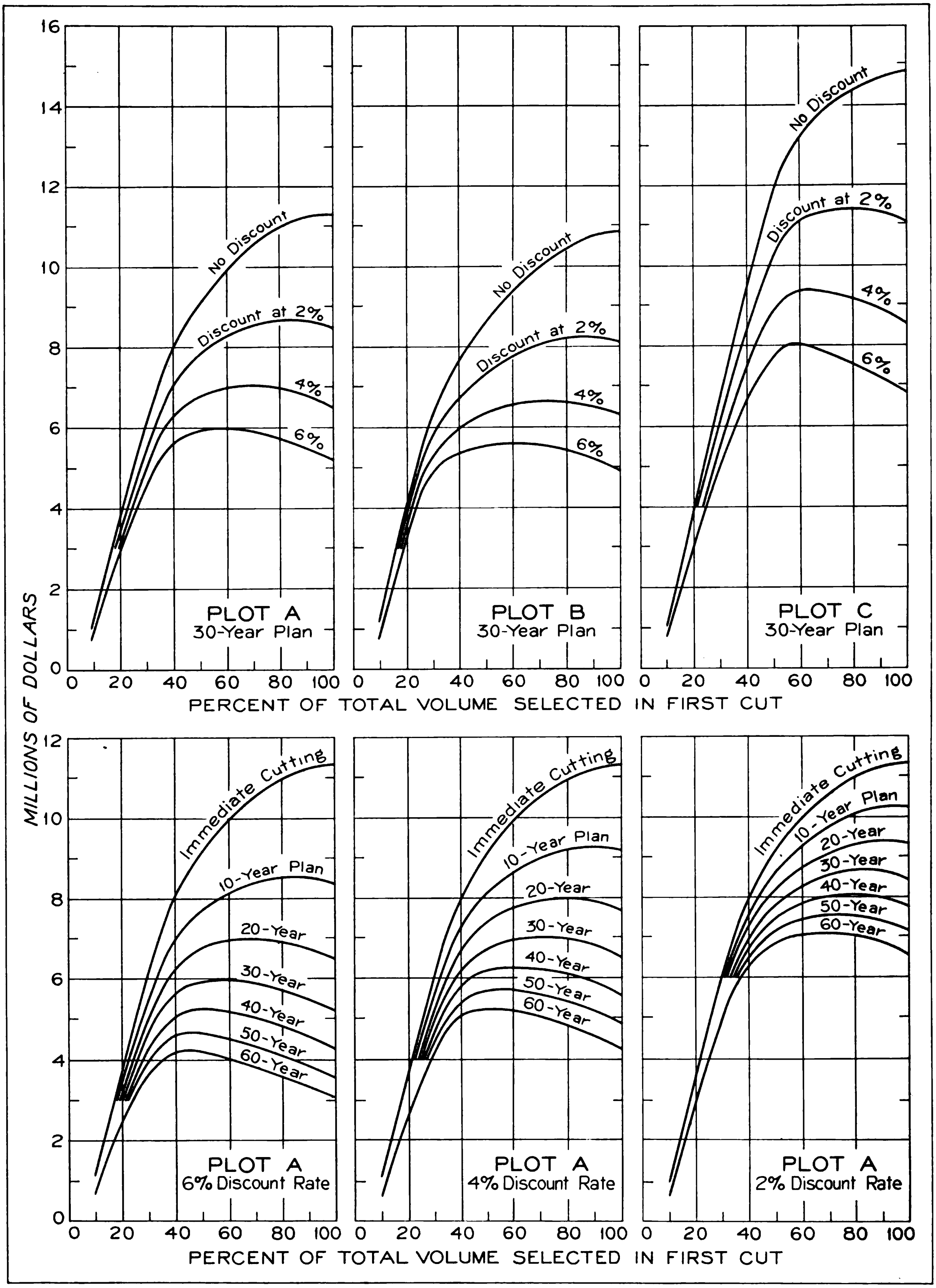


Fig.9-Present Net Worth of First Cut as Influenced by Various Rates of Discount, Various Lengths of Operating Periods, and Various Degrees of Partial Cutting

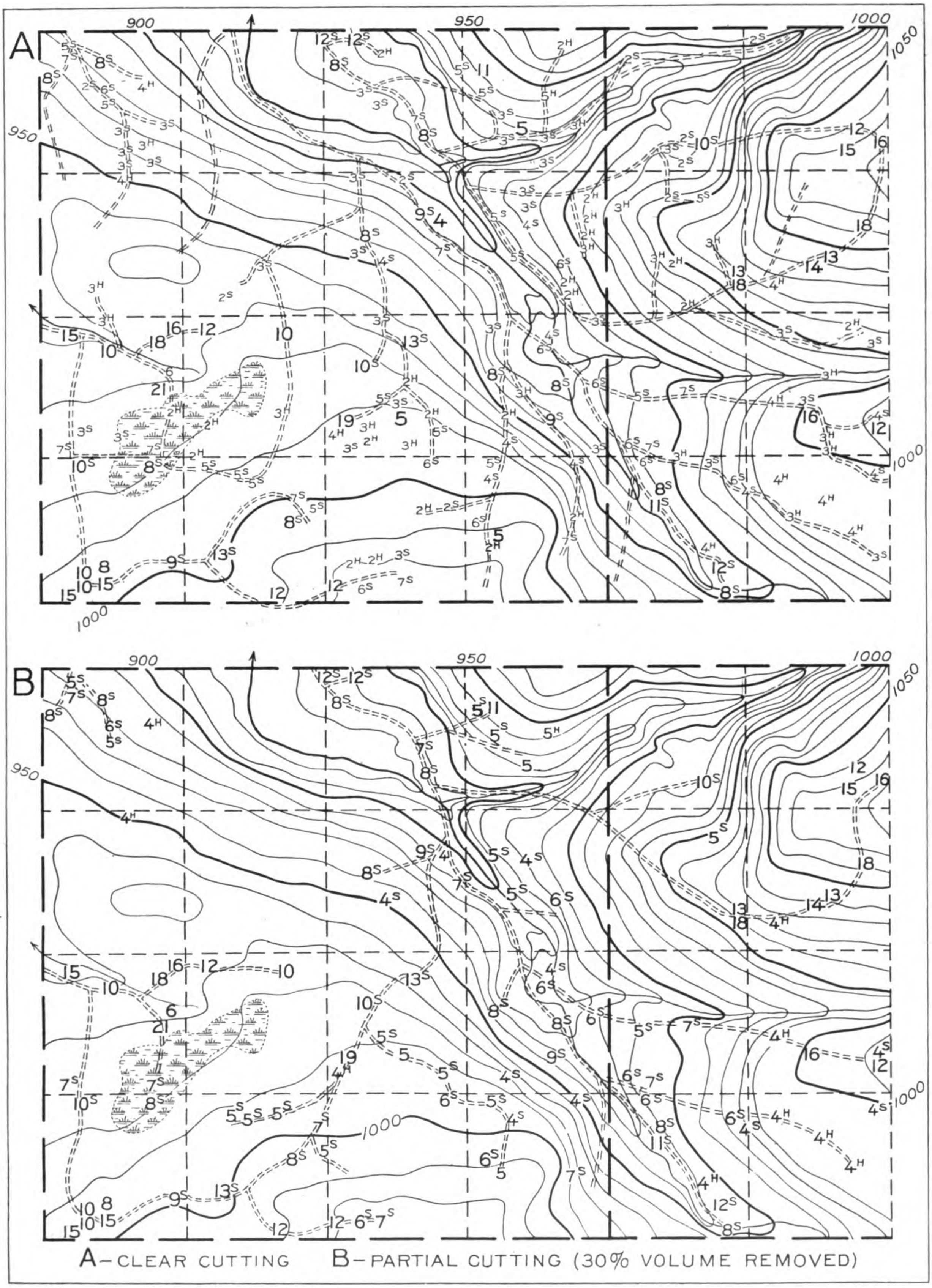


FIG. 10 TRACTOR-TRAIL SYSTEMS REQUIRED (A) UNDER CLEAR CUTTING AND (B) UNDER 30 PERCENT SELECTIVE CUTTING

should be made in order to facilitate taking a still lighter initial cut, it being evident that

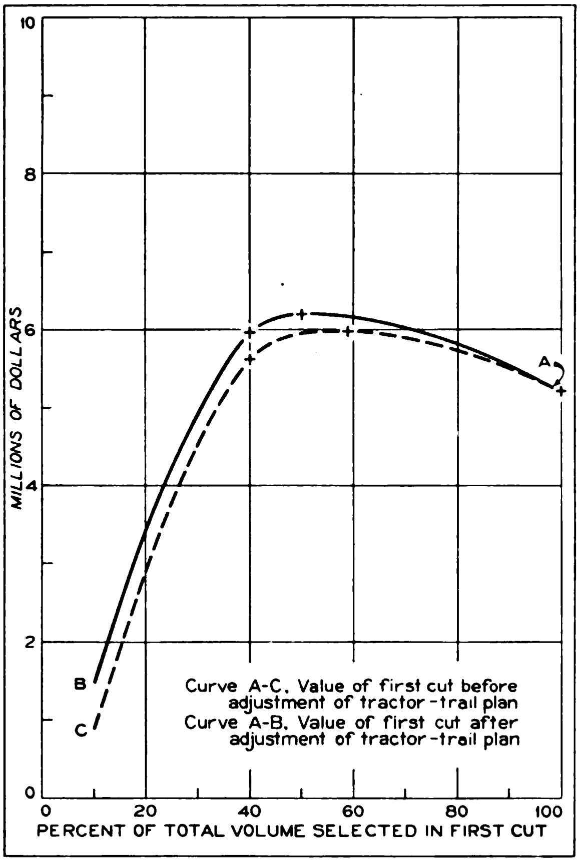


Fig. 11 - Present Net Worth of First Cut as Affected by Plan of Tractor-Trail Construction

mounting outgo for road construction is the only obstacle to taking a much lighter initial cut and a series of light return cuts. By such a procedure the present net worth of the property would be increased, since the discount period for the highest value classes would be shortened.

The degree to which the tractor-trail program can be adjusted to fit the plan of selective operation is demonstrated in figure 10, two maps representing Plot A. The upper map shows the tractor-trail system as it might be planned for a 100-per cent removal, and the location and volume of trees more than 44 inches in diameter. The lower map shows the tractor trails required for equally efficient removal of a 30-per cent initial cut comprising only spruce and fir trees 56 inches or more in diameter. Obviously, in preparation for the second cut or succeeding cuts more tractor trails would ultimately have to be built and in the end the total mileage of trails might equal that shown in figure 10A. But the money need not be spent until the trails are actually needed for logging.

According to the assumption made in setting up table 5B the increase in tractor-trail costs in going from a 100 to 30 per cent initial cut would be from $0.25 to $0.83 per M. As exemplified by figure 10, however, the corresponding increase proves to be from $0.25 to only $0.34. Experience with light selection both in this and in other types of old-growth timber has shown that on the whole the tractor-trail plan can be adapted to the amount of timber to be removed in a somewhat similar degree as shown here.

An adjustment of the railroad-construction cost may be expected, also, in going from a 100-per cent to a 30-per cent cut, but this point will not be stressed here. The cost of railroad-spur construction will be assumed as a fixed amount incurred in full against the initial cut. The error involved in this assumption will be considered to be balanced by that involved in assuming that the cost of the tractor-road construction will remain $0.25 per M irrespective of how small a percentage of timber is removed in the first cut.

No adjustment will be made for the snag felling, since all snags should be felled on the cutting areas irrespective of how light a cut is taken.

Revision of the results shown in table 5B is now in order. The cost per M for road construction, etc., will be split into two items: One covering snag felling and railroad construction (and related minor items) and varying from $0.35 per M feet for a 100-per cent removal to $3.50 per M for a 100-per cent removal; and one covering tractor-trail construction, which remains fixed at $0.25 per M for any degree of removal from 10 to 100 per cent.

In figure 11, the dotted curve A-C represents the present net worth of the initial cut on Plot A plotted directly from the last column of table 5B and identical with the Plot A curve in figure 8; the solid curve A-B represents the corresponding results corrected as stated above.

The most interesting point in a comparison of these two curves is that curve A-B not only surmounts curve A-C for any degree of removal except 100 per cent but also reaches its highest point considerably to the left of that of curve A-C. According to curve A-C the maximum present worth of the stand (if only one cut is to be made) is $5,966,000, obtainable by removing 60 per cent of the total volume; according to curve A-B this value is $6,177,000, obtainable through removal of only 50 per cent. In other words, more than $200,000 is added to present net worth by adjusting the tractor-trail program to fit the selective scheme, and at the same time an additional 300 million feet of timber (represented by value class 6 in table 5A) is saved for the future. This timber, while it detracts from the liquidation value of the tract when included in the initial cut, is shown in table 5A to have a stumpage value of $2.50 per M when considered by itself.

A similar situation is found on Plots B and C, where the maximum net present worth is increased by $185,000 and $250,000, respectively. In both cases the value curves reach their peaks approximately at a 55-per cent initial cut. Obviously, the same tendency to shift upward and to the left would apply in varying degree to all the curves shown in figure 9.

13. Cutting for highest liquidation value through a series of light cuts.—Under the assumption, so far adhered to, that logging should aim at highest returns (present net worth) from a single cut, obviously every tree capable of contributing any amount to the liquidation value of the tract should be included in that cut. The results arrived at above clearly indicate that zero-margin cutting fails utterly to accomplish this even though all the timber has a fairly substantial current value. Thus it has been found that half the timber—1½ billion feet—would contribute nothing to the liquidation value of the tract when discounted to present net worth but instead would detract from it by close to $1,000,000. All this timber, however, is in the plus-value class when considered by itself, its value per M ranging from $0.34 to $2.50 for Plot A, from $0.30 to $2.70 for Plot B, and from $0.45 to $3.36 for Plot C. A second cut therefore becomes a practical certainty and can, if desired, follow immediately upon completion of the first cut.

With a second cut or a series of return cuts in prospect a question arises as to whether some of the timber so far indicated for inclusion in the 50 per cent initial cut might not be better shifted to the second cut, and if so how much. When this has been decided, the next problem is how much of the timber allocated to the second cut should be transferred to a third cut, how much of the third cut to a fourth cut, and so on. Obviously, the financial principle that, as shown above, operates to throw half the total original volume of timber out of the immediate liquidation scheme even if no return cut is considered, operates in the same manner to shape the liquidation plan for the remaining timber.

Working against financial and other forces that, as will be shown, pull very strongly for short cutting cycles, i.e., for light cuts at short intervals, is the cost incurred in relaying track to permit return cuts on spurs lacking permanent track. In this respect it will be assumed for the moment that the same mileage of both permanent and "relay" track would be used under a selective plan of operation as under a clear-cutting plan. Investment in rails and ties, and cost of track maintenance and upkeep, would not be affected then by changing from long to short cutting cycles; with a fixed total mileage of track in use, just so many ties and so much steel would be used per million feet of output and just so much timber would be hauled over just so many miles of road. On this basis, however, the cost of relaying track would increase in proportion to the number of return cuts taken. Assuming that 60 miles of logging spurs (out of a total of 75 estimated to be required on this operation) lack permanent track and that the cost of relaying track is $1,250.00 per mile, it would cost $75,000 for each cutting cycle after the first; the cost per M feet for each relay, based on an annual output of 100,000 M would be 5 cents for a cutting cycle of 15 years, 6¼ cents for 12 years, 8⅓ cents for 9 years, 12½ cents for 6 years and 25 cents for 3 years. These costs, as shown below, must be taken into account in figuring the extent to which the effect of discount tends to force the adoption of a short cutting cycle.

Financial aspects of short cutting cycles.—The first and most important decision affecting the length of the cutting cycle is that as to how much timber shall be included in the initial cut.

Curve A-B in figure 11, it will be recalled, shows that on the basis of taking only one cut the maximum present worth of the stand, $6,177,000, is attained with an initial cut of 50 per cent. For an initial cut of 40 per cent the curve shows a value of $5,927,000. The difference between these two amounts, $250,000, is equivalent to $0.83 per M for the 300 million feet of timber involved. By referring to table 5A, it will be found that this timber is value class 5, which when considered by itself has a gross stumpage conversion value of $3.82[8] per M. If the initial cut is reduced to 40 per cent the initial cutting cycle becomes 12 years instead of 15 years, permitting a return for value class 5 during the 13th, 14th, and 15th years with all per-acre costs, except those for tractor-trail construction and track relaying, already written off against the initial cut. Under the assumption that stumpage values remain fixed throughout the 30-year period, the current gross stumpage conversion value per M would then be $3.82 and the net conversion value per M left by the deduction of $0.25 for tractor-trail construction and $0.25 for relaying of track, would be $3.32. The present net worth of an annual income of $3.32 per M coming during the 13th to 15th years, inclusive, discounted at 6 per cent to the present time, is $1.47. This is $0.64 per M more than the present net worth ($0.83)[8] contributed by the same timber if it is logged during the 1st to 15th years as a part of the 50-per cent initial cut.

Applying the same test to value class 4 shows that as a part of the initial cut this 300 million board feet of timber has a present net worth per M of $3.23, that if it is taken during the 10th to 12th years, inclusive, as a separate cut its value, discounted to the present, amounts to $3.22 per M. As a borderline case compared purely on the basis of the discounting process, value class 4 should be excluded from the initial cut for reasons discussed below.

Under the same test value class 3 contributes to present net worth at the rate of $5.13 per M if included in the first cut, compared with $4.86 if treated as a separate cut during the 7th to 9th years, inclusive. For value class 2 the corresponding figures are $6.49 and $6.10, respectively. Both these value classes should therefore be joined with value class 1 to form a 30-per cent initial cut, requiring 9 years to complete. Justification for further shortening of the initial cut, however, would arise through opportunity to make a close selection of trees within the first three value classes. Here it must be recognized that in each value class of timber as represented by a given diameter class individual trees vary widely from the class average both in logging costs and in log values. The plan of selection should therefore proceed to resegregate the first three classes into two new value groups; one comprising trees (those of higher than average value, or of lower than average logging cost, or both) that should be taken in the initial cut, and the other those to be left until the second or a succeeding cut. Through this procedure two-thirds of this timber, it is here estimated, would have a stumpage value averaging $1 higher than the previous average, and the remaining one-third, comprising low-value or high-cost trees, would consequently show a value $2 per M less than the previous average. The resultant spread of $3 per M is sufficiently wide to justify splitting the first three value classes into two cuts. The initial cut would constitute a 6-year cycle.

Turning attention next to the second and succeeding cutting cycles, it will be found that, disregarding the fine point of interpolating for periods shorter than 3 years, the cutting program would resolve itself into a series of 6-year cycles.

[8] The reason why the contribution to present net worth from class 5 drops from $3.82 to $0.83 per M is in large part that through the inclusion of this class in the initial cut the discount period for the first four value classes is lengthened and their present net worth consequently lowered.

TABLE 6.—*Present net worth to timber owner under five different 30-year operating plans.*[1]

Logging period[2]	Output	Stumpage conversion value per M b.m.	Total stumpage return	Taxes on standing timber at $0.02 per M feet b.m. per annum	Retirement of $3,000,000 debt including interest at 6 per cent	Net current return to owner	Net return to owner discounted to 1933 value (present net worth) at interest rates		
							6%	4%	2%
	Million ft. b.m.	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
			PLAN 1.—*Clear cutting* (*cable logging*).						
1935	300	2.85	855,000	180,000	675,000				
1938	300	2.85	855,000	162,000	693,000				
1941	300	2.85	855,000	144,000	711,000				
1944	300	2.85	855,000	126,000	729,000				
1947	300	2.85	855,000	108,000	747,000				
1950	300	2.85	855,000	90,000	765,000				
1953	300	2.85	855,000	72,000	783,000				
1956	300	2.85	855,000	54,000	801,000				
1959	300	2.85	855,000	36,000	233,824	585,176	128,622	211,073	349,701
1961	81	2.85	230,850	18,000		212,850	39,292	68,261	119,856
Totals and averages	[3]2,781	2.85	7,925,850	990,000	6,137,824	798,026	167,914	279,334	469,557
			PLAN 2.—*Zero-margin selection* (*tractors*).						
1935	300	3.79	1,137,000	180,000	957,000				
1938	300	3.79	1,137,000	162,000	975,000				
1941	300	3.79	1,137,000	144,000	993,000				
1944	300	3.79	1,137,000	126,000	1,011,000				
1947	300	3.79	1,137,000	108,000	830,273	198,727	87,897	114,765	150,615
1950	300	3.79	1,137,000	90,000		1,047,000	388,856	537,530	747,767
1953	300	3.79	1,137,000	72,000		1,065,000	332,067	486,066	716,745
1956	300	3.79	1,137,000	54,000		1,083,000	283,529	439,373	686,839
1959	300	3.79	1,137,000	36,000		1,101,000	242,000	397,131	657,958
1962	300	3.79	1,137,000	18,000		1,119,000	206,567	358,863	630,109
Totals and averages	3,000	3.79	11,370,000	990,000	4,766,273	5,613,727	1,540,916	2,333,728	3,590,033
			PLAN 3.—*2-cycle selection* (*tractors*).						
1935	300	6.00	1,800,000	180,000	1,620,000				
1938	300	6.00	1,800,000	162,000	1,638,000				
1941	300	6.00	1,800,000	144,000	740,568	915,432	524,342	668,906	781,321
1944	300	6.00	1,800,000	126,000		1,674,000	881,863	1,087,430	1,346,398
1947	300	6.00	1,800,000	108,000		1,692,000	748,372	977,130	1,282,367
1950	300	1.07	321,000	90,000		231,000	85,793	118,595	164,980
1953	300	1.07	321,000	72,000		249,000	77,638	113,644	167,577
1956	300	1.07	321,000	54,000		267,000	69,901	108,322	169,331
1959	300	1.07	321,000	36,000		285,000	62,643	102,800	170,316
1962	300	1.07	321,000	18,000		303,000	55,934	97,172	170,619
Totals and averages	3,000	3.535	10,605,000	990,000	3,998,568	5,616,432	2,556,486	3,273,999	4,252,909
			PLAN 4.—*5-cycle selection* (*tractors*).						
1935	300	8.24	2,472,000	180,000	2,292,000				
1938	300	8.24	2,472,000	162,000	1,472,640	837,360	625,759	688,226	758,313
1941	300	5.645	1,693,500	144,000		1,549,500	972,156	1,132,220	1,322,498
1944	300	5.645	1,693,500	126,000		1,567,500	825,759	1,018,248	1,260,740
1947	300	2.74	822,000	108,000		714,000	315,802	412,335	541,141
1950	300	2.74	822,000	90,000		732,000	271,865	375,809	522,794
1953	300	1.30	390,000	72,000		318,000	99,152	145,135	214,014
1956	300	1.30	390,000	54,000		336,000	87,965	136,315	213,091
1959	300	.27	81,000	36,000		45,000	9,891	16,232	26,892
1962	300	.27	81,000	18,000		63,000	11,630	20,204	35,475
Totals and averages	3,000	3.6390	10,917,000	990,000	3,764,640	6,162,360	3,219,979	3,944,724	4,894,958
			PLAN 5.—*5-cycle selection* (*tractors*) *leading to sustained yield.*						
1935	300	8.24	2,472,000	180,000	2,292,000				
1938	300	8.24	2,472,000	162,000	1,472,640	837,360	625,759	688,226	758,313
1941	300	5.645	1,693,500	144,000		1,549,500	972,156	1,132,220	1,322,498
1944	300	5.645	1,693,500	126,000		1,567,500	825,759	1,018,248	1,260,740
1947	150	2.48	372,000	108,000		264,000	116,767	152,460	200,086
1950	150	2.48	372,000	90,000		282,000	104,735	144,779	201,404
1953	150	2.48	372,000	72,000		300,000	93,540	136,920	201,900
1956	150	2.48	372,000	54,000		318,000	83,252	129,013	201,676
1959	150	1.04	156,000	36,000		120,000	26,376	43,284	71,712
1962	150	1.04	156,000	18,000		138,000	25,475	44,257	77,708
Totals and averages	[4]2,100	4.82	10,131,000	990,000	3,764,640	5,376,360	2,873,819	[4]3,489,407	[4]4,296,037

[1] Plans 1 to 4 represent complete liquidation within 30 years: plan 5 represents sustained yield operation (after second cycle).

[2] Each 3-year logging is represented here by the middle year: 1935 for example, represents the 3-year period 1934–36. In discounting the owner's net income to its 1933 value a discount period of two years has been applied for the 1935 period, 5 years for the 1938 period, etc. In figuring interest on the $3,000,000 debt the 1935 period is charged with 3 years' simple interest, or 18 per cent, and likewise with 18 per cent on the new balance of debt for each additional 3-year period.

[3] Decrease from 3,000 million feet caused by loss through excess breakage.

[4] Decrease in 30-year income and output caused by saving 900 million feet of growing stock for future sustained yield cut.

Short cutting cycle leads to permanent roads and continuous selective control of the timber.—With so short a cutting cycle repeated relaying of track, at an estimated cost of $1,250 per mile, would not on the whole be the best solution of the transportation problem. On spurs over which timber would be hauled for perhaps 2 or 3 years or more during each 6-year cycle, it might thus be as cheap or cheaper to provide permanent track. Then, too, substitution of motor truck roads for railroad spurs offers a practical solution of this problem in many parts and divisions of this property where topography and other logging factors combine to favor this mode of transportation.

The answer to these questions depends as a matter of fact on many considerations other than a direct comparison of transportation costs. By providing permanent rail and truck roads the entire 75,000-acre area can be kept open for logging at all times. With mobile yarding and loading machinery, with a vast amount of storage space for logs along the rail- and truck-roads, and with 1,000 miles or so of tractor-trails constantly accessible, the set-up for efficiency in logging and management becomes far more favorable than if the operation were confined to a small area. Here yarding can be carried on independent of loading, and each tractor-yarding unit can, if desired, be worked entirely by itself; difficulties of tractor-roading during the rainy season, which are very serious in this locality, can be reduced to some extent by shifting the operations to the most favorable areas, and by constant shifting from tractor-trail to tractor-trail and from landing to landing; and could be further offset in part by relying to quite an extent on keeping a reserve of logs along the roads (as well as by proper planning of subsidiary work, such as drum-unit yarding and sky-line swinging, etc.). Here, too, market selection can be practiced to the *n*th degree without interfering with efficiency. Salvage of windblown, fire-killed, or otherwise damaged timber can likewise be brought about in quick order. Maintenance of tractor-trails (which obviously would be quite an important problem under a long-cycle cutting plan) would also become a relatively simple problem, because as a result of frequent shifting of operations they would, for the most part, be maintained through frequent use. Incidentally, of course, these roads and tractor-trails, which are thus kept ready for use for logging purposes, would also be an important factor in fire protection. In brief, a permanent road system provides the means for intensive selective control of the timber growing stock and by exercising this control the best results in managing the property can be attained.

14. Comparison of results from five different cutting plans.—As indicated in the foregoing paragraph once a permanent road system is made available the working procedure in liquidating the property would for numerous reasons tend to resolve itself into very frequent shifting of logging operations back and forth over the operating areas. A regular cutting cycle of 5 or 6 years may, however, still be recognized as the guidepost for administrative planning and control since irregular shifting and distribution of the cut within the cycle is primarily a matter of additional flexibility in adjusting operations to constantly changing operating conditions and market demands.

This completes the step-by-step evolution from clear cutting to short cycle selective management with respect to liquidation of this property within a 30-year period. In tracing this step-by-step evolution, five distinct, principal plans of management have been studied, including clear cutting with donkeys (cable yarding), a plan that so far has not been discussed in this report but that represents the system in use on this operation preceding the adoption of selective logging with tractors. A comparison of the returns obtained under the different plans during the 30-year period is presented in table 6. The table shows what portions of the income go to pay taxes on the standing timber and interest and retirement of the assumed $3,000,000 debt, and finally what portion represents net returns to the owner—both current returns and their present net value when discounted on the basis of 6, 4, and 2 per cent interest rates.

Explanation of Table 6.—Plan 1 (clear cutting, cable yarding) represents clear cutting with donkeys (all the succeeding plans represent some form of selective logging with tractors). The average log value is $8.35, the same as for Plan 2, and the average logging cost $5.50, leaving a net return of $2.85. Logging costs do not include capital charges on the yarding equipment, whereas under the tractor plans (Plans 2-6) such capital charges are included. Only 2,781 million feet, instead of 3,000 million feet, would be cut under this plan, the shortage of 219 million feet being caused by excess breakage (estimated on the basis of experience on this operation).

Plan 2 (zero-margin selection) represents selective logging with tractors when all trees in the plus-value class are removed in one 30-year cutting cycle. The aim under this plan is to remove the greatest value per acre. Under this plan the operator opens up one portion of the property at a time, logging each portion selectively down to the 18-inch limit over a period of a few months or a few years. The stumpage conversion value shown is taken from table 5B (100 per cent initial cut).

Plan 3 (2-cycle selection) represents making one 50 per cent cut for maximum present worth, by the same logging methods as under Plan 2. While this plan realizes the greatest present net worth that can be realized from the stand if only one cut is taken, with 50 per cent of the plus-value timber remaining a return cut is indicated, constituting a second 15-year cycle.

The stumpage conversion value of the initial cut is taken from table 5B (50 per cent initial cut) while the value of the lowest cut is computed from data on value classes 6 to 10 inclusive, as given in table 5A. Both values have been adjusted by making proper allowances for the revised tractor-trail plan (on the basis discussed in section 12) and for relaying of railroad track on the basis stated in section 13. A deduction of $0.36 per M has been made from the value of the initial cut to cover (a) extra slash disposal cost for the heavy partial cut here made and (b) maintenance of tractor trails during the long cutting cycle (15 years) here involved. (Ordinary fire protection costs common to all plans and snag felling costs are accounted for in tables 5A and 5B.)

Plan 4 (5-cycle selection) represents a series of 6-year cutting cycles. Adjustments of tractor-trail construction costs and relaying of track are again on the basis stated in sections 12 and 13. An extra allowance of $0.05 is made in this case to cover slash disposal cost. The first 6-year cut under this plan is obtained by selecting 600 million board feet out of the 900 million representing a 30 per cent initial cut, for which table 5B shows a stumpage value of $6.71. In table 6 this has been raised to $8.24. The difference between the two amounts comes from adjustment of tractor-trail construction costs and also from an increase of $1.00 through selection within the first three value classes.

The second cut takes in the 300 million left over from the first three value classes and all of value class 4. The third cut takes in value classes 5 and 6; the fourth cut, classes 7 and 8; and the fifth cut, classes 9 and 10. In practice, exchanges from one class to another would occur the same as in the first cut, but the effect of this on returns would probably be offset by the necessity of taking out many trees ahead of schedule because they happened to be in the way of timber taken according to plan.

In its final form, plan 4, as already discussed, would be based on permanent roads. However, no definite base exists for setting up a comparison of results under this plan. For this reason, the set-up here used still assumes the use of temporary railroad track.

Plan 5 (5-cycle sustained yield plan) is recorded here for the sake of continuity. Its significance is discussed in section 15. For the first two 6-year cuts the basis of the results shown for this plan is identical with Plan 4. For the next two 6-year cuts the basis is the same as for the third cut of Plan 4, except that, owing to decreased output, deductions to cover the cost of relaying track are twice as high. (A further deduction of $0.14 per M has been made to cover certain portions of track maintenance cost that would here rise in terms of cost per M owing to decrease in output.) On the basis of permanent roads track relaying would be eliminated, but here again no definite basis exists for setting up a complete comparison of costs.

In all of the foregoing plans taxes on the standing timber are assumed to be equal. They are computed only on the basis of the zero-margin plan (Plan 2). Technically, they should be recomputed to fit the other four plans. For the cable yarding (clear cutting) plan they should be reduced, in view of the more rapid rate of depletion of the timber supply resulting from excess breakage. For the 2-cycle and 5-cycle selective cutting plans a fairly strong reason for adjustment exists in that *ad valorem* property taxes are supposedly based on the fair appraisal value of the property, and, consequently, when through selection the high-value timber is removed at the beginning of the operating period the value on the remaining timber drops correspondingly. The tax question, however, has entirely too many angles to it to justify any definite assumption other than that some adjustments in appraisal might well be obtained that would further strengthen the results obtained under the 2-cycle and 5-cycle plans and also under the cable-yarding plan.

Summary and comparison.—One of the most striking points to be noted in comparing the results of the foregoing plans is the quick work accomplished by the short-cycle system in retiring the initial debt. Under the cable-yarding plan the debt hangs on for 25 years, with the interest charges and taxes eating up the owner's equity, so that the debt is not finally paid until the timber is practically gone. In contrast the same debt is retired within 15 years under the zero-margin plan, within 8 years under the 2-cycle plan, and in less than 5 years under the 5-cycle plan.

The capitalized value of the owner's equity shows a striking increase as between the clear cutting and the 5-cycle selection plan. This is summarized in table 7, which shows the present net worth of the owner's equity on the basis of discount rates of 6, 4, and 2 per cent and also the aggregate of the current returns (in the column headed "0 per cent").

On the basis of permanent roads and consequent continuous selective control of the timber, the possibilities for a further increase in returns under plan 4 are very great indeed; increased operating efficiency, elimination of track relaying costs and wider opportunities for market selection are among the factors to consider here. These possibilities, however, cannot be evaluated in a definite manner.

TABLE 7.—*Present net worth of owner's equity*[1] *under plans 1 to 4, on basis of different discount rates*

Plan	Present worth[2] on basis of discount rates indicated			
	6% *Thousands of dollars*	4% *Thousands of dollars*	2% *Thousands of dollars*	0% *Thousands of dollars*
(1) Cable-yarding	168	279	470	798
(2) Zero-margin	1,541	2,334	3,590	5,614
(3) 2-cycles	2,556	3,274	4,253	5,616
(4) 5-cycles	3,220	3,945	4,895	6,162

[1] To compute the full value of the property, each of the amounts listed should be increased by $3,000,000, the amount of the assumed initial debt.

[2] Figures were rounded off to the nearest $1,000.

15. Basis for changing from liquidation to sustained yield management.—The foregoing comparison deals with the financial aspects of long-term liquidation on the assumption that quantities, values, and outputs would remain fixed throughout the 30-year period. The forest and its values, however, are not static; they change continuously. Growth and decay, the rise and fall of costs and values, changing standards of utilization, and other factors are constantly creating new values or wiping out existing ones. This introduces many questions, which, as they are followed up, lead to further important changes in the management plan.

First to be considered is the question of how volume increment affects the results of the five plans. It is still assumed for the moment that values otherwise remain fixed, and that logging is to be carried on at the rate of 100 million feet per year.

For the cable-yarding plan increment may for purposes of comparison be set at zero. Increment and mortality balance each other until the various portions of the stand are cut, and when cutting takes place all premerchantable growing stock is wrecked.

Under the zero-margin plan the premerchantable growing stock, trees 12 to 18 inches in diameter representing a present aggregate volume of about 150 million feet (2,000 feet per acre) and in addition many trees less than 12 inches in diameter, would be left, and if they survived, would increase substantially in volume during the 30-year period.

Under the 2-cycle selective plan (plan 3) net increment would occur not only on premerchantable trees but also on merchantable trees represented by the second cut.

Under the 5-cycle plan (plan 4) a still larger net increment would accrue on merchantable trees owing to quicker removal of decadent veterans. Under this plan, at the end of the 30-year period the volume of timber more than 12 inches in diameter would probably amount to 600 or 700 million board feet, assuming that all trees of this size survive.

Step by step, then, the volume increment (as well as the unit value of that increment) would increase in going from plan 1 to plan 4. At the same time the chance for survival of this timber would naturally become better. In the latter respect it is probable that fire and wind would practically wipe out the scattered trees left under the zero-margin plan owing to the severe disturbance of natural forest conditions created by taking so heavy a cut. Under the 5-cycle plan losses from this source would tend to be relatively smaller, but, even so, the residual stand would probably suffer particularly after the third cutting cycle. Troubles would here arise because cutting is carried on at too fast a pace for the forest to adjust itself to changing conditions. For this reason the possibilities for a large increase in volume under this plan must be discounted rather heavily.

Substitution of the sustained yield plan, or plan 5 (the cost basis of which was detailed in conjunction with the other five plans), would help to correct this situation. The aim under this plan is to give growth a better chance to maintain the growing stock and the capital value of the forest. (The advantages of motor truck roads in place of "relay track" would naturally be very great under this plan owing to the lighter output, but as in the case of plan 4 these cannot be evaluated here.)

The sustained yield plan (plan 5) differs from plan 4 mainly in that it does not continue the liquidation program beyond the second cycle at the rate of 100 million feet per year. In identically the same way as plan 4, it strikes out at the outset for quick liquidation of the overmature, high-value veterans; but when the second 6-year cutting cycle is completed the annual output is dropped to 50 million board feet. As a result, 900 million feet of merchantable timber (comprising value classes 8, 9, and 10) as well as 150 million feet of premerchantable timber is left untouched during the 30-year period.

During the 30-year period the volume of this 1,050 million feet of growing stock would be augmented from three sources, viz.:

(a) Increment on the 150 million feet that is reserved;

(b) Increment on 900 million feet cut during the 13th to 30th years; and

(c) Recruitment and growth of new premerchantable growing stock from trees less than 12 inches in diameter. (In addition to these sources of volume increment it is probable that a rise in utilization standards, presently very low for small timber of the species and diameter here involved, would occur during the 30-year period.) The total stand at the end of the 30-year period, taking in all trees more than 12 inches in diameter, is estimated at roughly 1,800 million and its annual increment at about 40 million board feet.

Financial earnings exceed growth rates.—The 1,800 million feet of growing stock shows a fairly wide spread in values. The net conversion value of all diameter classes and species —the value of premerchantable trees being placed at zero—averages, however, only $0.60 per M. The aggregate net conversion value of the residual stand as a whole is therefore only $1,080,000. Under selective management, however, the current income would be derived not from average values but from selected values. After the year 1963, the larger portion of the current cut consisting of comparatively high-value timber, the average current net return should approximate $2.00 per M, and if the value base remained fixed, would continue to do so. The growing stock would no longer be depleted in volume or over-cut in the larger size classes, but would be maintained continuously as the smaller trees advanced from one diameter to another and successively replaced the large trees removed.

This then is something to remember, because it is the very core of the advantage of selective sustained yield management: All the timber contributes to growth, in fact the premerchantable timber contributes proportionately the most; but the higher-value timber is the chief contributor to the current cut, which removes the growth. As a result the average value of the current cut is far in excess of the average conversion value of the growing stock that supports it, and this means that current earnings on the realizable capital are far in excess of the current growth rate. Thus the current annual income from a cut of 40 million board feet, under the assumptions used here, would amount to $80,000 equivalent to about 7½ per cent on the realizable capital ($1,080,000), and the net earnings after deduction of a yield tax of 12½ per cent would amount roughly to 6½ per cent, or nearly three times the current growth rate. An annual return of 6½ per cent on the realizable growing stock capital is extremely high, in view of the investment character of a going sustained yield timber property—particularly in this region where the value base is still low. In Europe, after long years of experience, sustained yield timber properties have come to be looked upon as so high grade a field for long-term capital investment that they have generally become capitalized at a rate of 2 to 3 per cent, and this in spite of the fact that there the value base is generally so high that further value increment is relatively not nearly so important a factor in fixing the capitalization rate as it naturally would be in the Douglas fir region.

On the basis of a 3 per cent capitalization rate the investment value of this property as of the year 1963 is $2,333,333, and on the basis of a 2 per cent rate it is $3,500,000, both amounts being far in excess of the property's conversion value of $1,080,000 (an amount which, as a matter of fact, is not realizable since immediate conversion of so large a quantity of timber would be impractical). Here, then, lies the reason for turning from unrestrained liquidation to sustained yield management for a large portion of the existing growing stock: The contribution of this portion of the growing stock to the income value of a selectively managed sustained yield property is far in excess of its immediate liquidation value; for as a result of maintaining continuity of production and permanent transportation facilities the residual stand as a whole is worth far more in terms of sustained annual income than it would be in terms of quick returns.

16. Further evolution of the sustained yield plan.—Sustained yield management as represented by plan 5 would be brought about simply by adjusting the rate of cut to fit the productive capacity of the residual stand, without changing the previous liquidation plan so far as order of cutting is concerned. Liquidation would begin with removal of the highest value class and would proceed step by step toward the lowest—a plan based in the first place on the assumption that the values in the forest remain fixed, unaffected by growth, market conditions, or other factors. When these factors are taken into account many important changes must be made in the plan as to order of cutting, in order to obtain the highest returns from the property both at present and in the future. In this respect plan 5 is only the first crude step toward the final plan, but an exceedingly important one since it swings the basic objective away from liquidation to sustained yield forestry.

The first step toward revision of plan 5 would affect the veterans in value classes 1, 2, and 3 (table 5A) in a relatively slight degree. They would remain at the head of the list, although many of them—mainly sound trees in relatively inaccessible locations—may well be held back for a cutting cycle or two as speculative capital designed to absorb possible benefits of unusual value fluctuations.

In regard to value class 4, composed principally of spruce 40 to 54 inches in diameter and less than 200 years in age, reasons for holding a substantial percentage of them would be predicated on their ability to earn through volume, quality, and price increment. As discussed in chapter VI, variations in increment between individual trees of the same size, age, and species, growing on the same site, are very great. This variation in combination with variations in quality of the trees and in their degree of accessibility (logging cost) would govern in the selection of trees to be held.

For spruce trees from 24 to 40 inches in diameter, and generally 100 to 150 years in age, for which plan 5 proposes complete liquidation during the third to fifth cutting cycles, the revised plan might be to remove during the

30-year period mainly the rougher and least thrifty trees or trees injured in the process of logging, and to hold the remainder. These trees, as is shown in the conversion-value chart (fig. 7), rise relatively fast in value per M feet in passing from one diameter class to the next, because of the combined effect of quality increment and reduction of logging cost (through size increase). Good, clear trees would, of course, show an even faster rate of increase than that indicated in figure 7 (compare fig. 5). Those that are making a satisfactory volume increment (1½ to 3 per cent) are now passing through a highly profitable period in their development.

As spruce of these value classes is withdrawn from the immediate liquidation scheme, opportunity arises for earlier removal of trees of other value classes. Hemlock trees 40 inches or more in diameter (value class 6) will qualify best for this promotion, because these trees, as is shown in the conversion-value chart, show practically no increase in value from quality increment, and practically none from decrease in logging costs through increase in size. Many of these trees have reached, or are approaching, physical maturity, and some of them are defective. All things considered, a large percentage of them are second only to the fir and spruce veterans in degree of financial maturity, and these should be moved up to the second cycle, and some of them perhaps to the first.

Next to be advanced in the cutting program would be such hemlock trees of value classes 7, 8, and 9 as are hampering the development of surrounding trees. The degree of financial maturity in this case is based not on the status of the tree itself but on its effect on its neighbors.

The foregoing indicated changes in order of cutting would be based primarily on differences in increment rate (taking into account volume, quality, and other factors of increment) between various tree classes. Since increment rates attainable under selective management are not known, definite conclusions on how they would affect the order of cutting cannot be reached. The important point to recognize, however, is that insofar as the initial cuttings are concerned the order of cutting based on the discount principle would not conflict in an important degree with considerations relating to increment, because the high value timber scheduled for early removal is both physically and financially overmature. Since it would require about 10 years to remove this timber ample time would be available to investigate the increment factor so that a sound program of selection can be continued in dealing with the remaining productive portion of the growing stock. By that time this factor would become highly important not only because of wide variations in increment but also because the initial 6 per cent debt would then have been discharged and the interest rate consequently lowered. Owing to these changes in the basic set-up the discount factor would become relatively less significant; in fact, it would be overshadowed by increment as to degree of importance in determining the order of cutting.

Market limitations and demands cause further shifting in order of removal and in rate of cutting.—Changes in market conditions would cause frequent shifting in the foregoing order of selection. Insofar as these changes are merely temporary fluctuations which in the long run may cancel each other they would have no important bearing on the long term plan. Here cuttings might be concentrated for a short time on Douglas fir, then on spruce, then on hemlock, etc. As long as there are large surpluses of unproductive growing stock of all species market selection can, of course, be carried on without much restraint. The permanent road system which provides continuous selective control of the growing stock would here prove its worth. Later on, with the management program centered on maintaining a stand having a balanced representation of the various species and size classes, relatively less freedom would be had in market selection.

A somewhat different aspect of the market question, which is of particular importance during the initial liquidation period, is the problem of maintaining a workable market balance over a period of several years. Lack of balance might bring a decrease in the relative market value of old-growth spruce and an increase in the value of second-growth hemlock. If so, increased production of hemlock would be obtained from those particular classes of hemlock (thinnings and physically mature trees) that, as already discussed in connection with growth, come the closest to the old-growth spruce in the order of financial maturity; with these classes to draw from together with the hemlock that would unavoidably have to be taken anyway on account of the exigencies of logging salvage operations, etc., a workable production balance might be attained without any serious upset of the selective plan.

Another measure looking toward better market balance might be to plan for a somewhat smaller cut than the 100 million feet originally scheduled on the basis of the clear-cutting plan. It is not nearly so urgent to force liquidation under the selective plan as under the original clear-cutting plan for after all there is only approximately 1 billion out of the 3 billion feet of growing stock that is unquestionably overripe for the market; the balance requires marketing only at the rate of sustained yield capacity. Whether it takes 10 years or 12 to 15 years to liquidate the 1 billion feet of financially overmature timber is not so important an issue that chances have to be taken on overproduction and ruined markets.

Group selection supplements tree selection for effective regeneration.—Hemlock and spruce which constitute the bulk of the stand on this property are shade-enduring species which reproduce quite well under shelter as provided under individual tree selection. Better results, however, would be obtained by small-group cutting, whereby dense, even-aged groups of regeneration would become established which in time would develop into high-quality stands of timber.

Group selection for this purpose need not entail any significant departure from the tree selection plan as regards the immediate economic effectiveness of different forms of selection. It would ordinarily be undertaken as the final step following a series of individual tree selection cuttings whereby the selectivity of the residual stand would be reduced to the point where further tree selection is unwarranted. In many typical timber groups on this property this would mean that scattered old-growth spruce and Douglas fir veterans as well as selected understory trees might be removed in the course of one or more tree selection cuttings, leaving a stand of relatively low quality hemlock of uniform value. The next cutting in such a stand would be by groups rather than by individual trees.

On this property there are many stands in which the understory hemlock is of extremely low quality. They would be the stands in which to start systematic group cuttings, since the earning power of low quality trees, as shown in figure 7, is relatively much lower than that of high quality trees. In stands where the understory is composed of trees of generally fair or good quality, or where tree selection brings on satisfactory regeneration, group cuttings might be deferred for many decades; in fact, a century might elapse before as much as one-half the total area of the property has been clear cut in this group-by-group fashion, continuous tree selection being carried on in the meantime over the whole area.

More rapid progress toward group regeneration may be effected through early reclamation of "blanks" or openings in the stand. There are numerous areas, generally less than two acres in extent, which are entirely or almost entirely devoid of coniferous tree growth but covered with a dense jungle growth of brush and weeds; in the aggregate these make up a substantial portion of the total area. These areas, it is here believed, would in most cases restock quite readily if thoroughly burned over. With this in mind cuttings conducted around the margins of the blanks should be designed to throw as much slash as possible within them so as to provide fuel for a broadcast slash fire hot enough to consume the brush.

Systematic group cuttings and concurrent regeneration of existing blanks would in time result in a substantial increase in production. It is quite within reason to expect that this 75,000-acre property will produce 60 million board feet per year or more provided that most of the blanks are eliminated and the entire productive area kept well stocked with growing timber.

Wide-spaced planting and intensive stand management for diversified high-value production. —Regeneration by small groups would probably in many cases tend to result in almost pure stands of hemlock. Hemlock produced under these conditions as contrasted with suppressed understory hemlock in unmanaged forests, might well prove just as valuable as any other species. Nevertheless, it would be desirable from several points of view to obtain more adequate representation of other species. To accomplish this, wide-spaced planting (15 x 15 or 20 x 20 foot spacing) of spruce, Douglas fir, and Port Orford cedar might be considered with overabundant natural regeneration of hemlock to fill in the spaces.

The cost of such planting would be about $2 to $4 per acre as compared with $10 to $15 for ordinary 6 x 6 planting. There would be no land rental to charge since the land is there for whatever use can be made of it. No added protection or administration costs would be incurred. Even taxes would remain unaffected at least until the planted trees became of merchantable size. In brief, the initial cost of planting would here be the only item to figure with. For this 75,000-acre property, on which group cutting would progress perhaps at the rate of about 300 acres per year, an annual allowance of $500, equivalent to 1¼ cents per M board feet of annual cut, might well prove adequate for the purpose in view, since spruce would surely come in with hemlock on many of the regenerating areas. The planting policy might well be to set aside a definite and reasonable allowance to go as far as it may toward planting in areas that need it the most, and that are most suitable for the various species proposed.

In the skillful management of the regeneration groups lies the key to the ultimate development of the selective plan. Here stand management could probably begin as soon as the young stands reach an age of 40 to 50 years (bearing in mind that a permanent road system is available at all times). Hemlock, which constitutes the bulk of the stand would be taken out for pulpwood and this might go on for several decades. Gradually the stand would be composed more and more of species other than hemlock. Selected trees, including many hemlock trees, might be carried on to an age of 150 to 200 years. High-value timber production, derived from a sufficient variety of species always to make the best of constantly changing market conditions, is thus within the scope of the plan.

Progress along this line can be made also through skillful management of existing stands of both merchantable and premerchantable growing stock. There are numerous areas of dense even-aged second-growth stands, both pure and mixed, which are or will soon be ready for the same type of intensive stand management as discussed above. The same thing, too, can be accomplished more or less perfectly with the existing many-aged understory timber, except in stands where this timber is of unusually poor quality. In brief, high-value production, through intensive stand management, will be on its way long before the time when new growth obtained through group cuttings comes into the picture.

Fire protection.—This property is located within the so-called "fog belt" which constitutes a zone of specially low fire hazard. Adequate fire protection under selective timber management can therefore be provided at low cost.

Among the most essential requirements for attaining a high degree of fire safety are: (a) Continuous maintenance of a heavy growing stock to preserve the forest climate, which as noted in chapter VII is the key to low fire hazard; (b) continuous maintenance of roads and tractor-trails to provide quick and easy access to all parts of the property; (c) felling of snags; (d) careful planning of the cutting operations; and (e) proper organization and equipment for suppression of fires. Fulfillment of the first two requirements, the importance of which is more fully discussed in chapter VII, is part and parcel of the selective program regardless of fire protection. Snag felling is to a large extent a requirement under any form of cutting but, as already noted, should be greatly hastened under a program of light selection. Intelligent planning of the cutting operations includes leaving during any given cut certain strategically located strips of timber within which no cuttings take place, as well as training the fallers to avoid creation of bad slash hazards in the felling operations; as a rule trees can be felled in several directions and the direction chosen will oftentimes make a big difference in the ensuing slash hazard. Occasionally tops from felled trees, which may have lodged against other trees or stubs, will have to be yanked away to safer locations with the tractor outfit.

Windthrow is a special hazard in this locality and is closely related to the fire hazard. This is a special reason why light selection under sustained yield management is far superior to heavy selection. Heavy selection leads to serious disturbance of forest conditions and consequent heavy losses from windthrow; and long cutting cycles preclude salvage of the windfall. In contrast to this, light and practically continuous selection with constant maintenance of a heavy growing stock gives a relatively windfirm stand, and provides for practically immediate salvage of such windfall as may occur. In brief, successful solution of both the windthrow and fire protection problem appears to center very largely on continuous maintenance of a heavy growing stock, which in any event is the central theme of the selective management program outlined above. Overcutting is indeed the bane of forestry, from every point of view.

17. Summary and conclusion.—The foregoing study touches on three different phases of the economics of selective timber management. The first of these deals with liquidation of financially overmature timber; the second with maintenance of productive timber capital on a sustained yield basis; the third with building up the forest property for high-value production. All three aim at the same goal, namely to obtain the greatest net economic returns from the forest property.

Most attention in the study has been devoted to the first phase, centering on a study of the purely financial aspects of selective liquidation of a 30-year supply of virgin timber. Here five distinct plans of management have been studied in considerable detail: Results from management based on clear cutting; zero margin selection; liquidation in two 15-year cutting cycles; and, finally, liquidation in five 6-year cycles (which in practice would lead to permanent roads with even shorter cutting cycles and continuous selective control of the timber) have been compared by discounting deferred incomes to their present net worth. Step by step, in the order mentioned, these plans supersede one another on the financial ladder leaving the short-cycle plan based on permanent roads as the obviously most efficient one for liquidation of the investment.

The second phase of the study brings into consideration a few general facts pertaining to growth. Here the significant point is that by reducing the cut so as to save sufficient productive growing stock, a profitable sustained yield operation would be established within a rather short period. Under intensive selective management a relatively high financial return can be supported by a rather low growth rate owing to the fact that the average unit value of the growing stock is considerably less than the average value of the current cut. In this situation lies the reason for sustained yield operation as a substitute for complete liquidation.

The third phase of the study touches on the principles of and points out the possibilities for building up high-value sustained yield production, indicating that intensive selective management when placed on a profitable basis would naturally lead toward a more and more intensive and profitable use of the forest land.

The foregoing three phases of selection are complementary to each other under a truly economic system of selective management, which aims to remove from the forest in the order of their maturity the trees that are financially mature, to conserve for maturity those now financially immature, and to build up the future productivity of the forest to the fullest practicable extent and so obtain the highest capital value for the property as a whole.

It should be remarked that the financial analysis made in this study was based on stumpage conversion values as of the summer of 1932. Other values would apply to other years. It is significant, however, that such changes though of obvious importance in case, for example, the property were to be sold, have no important bearing on the management plan. Stumpage conversion values have changed and the size of the zero-margin tree has shifted considerably but the order and the relative importance of selection remain substantially the same. Adjustments in the order of selection if needed to meet such changes or to meet fluctuating market demands are, furthermore, an easy matter under an operating plan based on permanent roads and continuous selective control of the growing stock.

It should be remarked also that the use of a 6 per cent interest rate in computing the results under the five management plans is not the sole explanation for the conclusions here reached with regard to the need for intensive selection. It is the sole controlling factor only on the basis assumed in the preliminary analysis, namely, that neither growth nor decay nor other value changes occur during the 30-year period. Interest may as a matter of fact be entirely disregarded without thereby altering the general conclusions here reached as to the intensity of selection.

The keynote of the management methods here discussed is selective control of the growing stock as made possible through a permanent road system and flexible logging methods. Given selective control of a growing stock as variable as to value, physical condition, growth, species, etc., as found on this property there is indeed no escape from the conclusion that intensive selection must be practiced. The need for constant shifting over the operating area as a matter of operating economy and for maintenance of tractor trails through frequent use is in itself of considerable importance in laying the foundation for this intensive system of management. The need for continuous control of the growing stock for effective salvage as well as for market selection is likewise of great importance. Finally, the function of intensive selection in the long-term management of the growing stock capital on the basis of growth and discount must be considered.

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 noncommercial 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*

	Cut in million feet b.m., by decades							
Block	*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 feet.

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 2½ 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 main-line 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 of 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 following 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 of 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 set-up 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 of 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 loading 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 is 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.

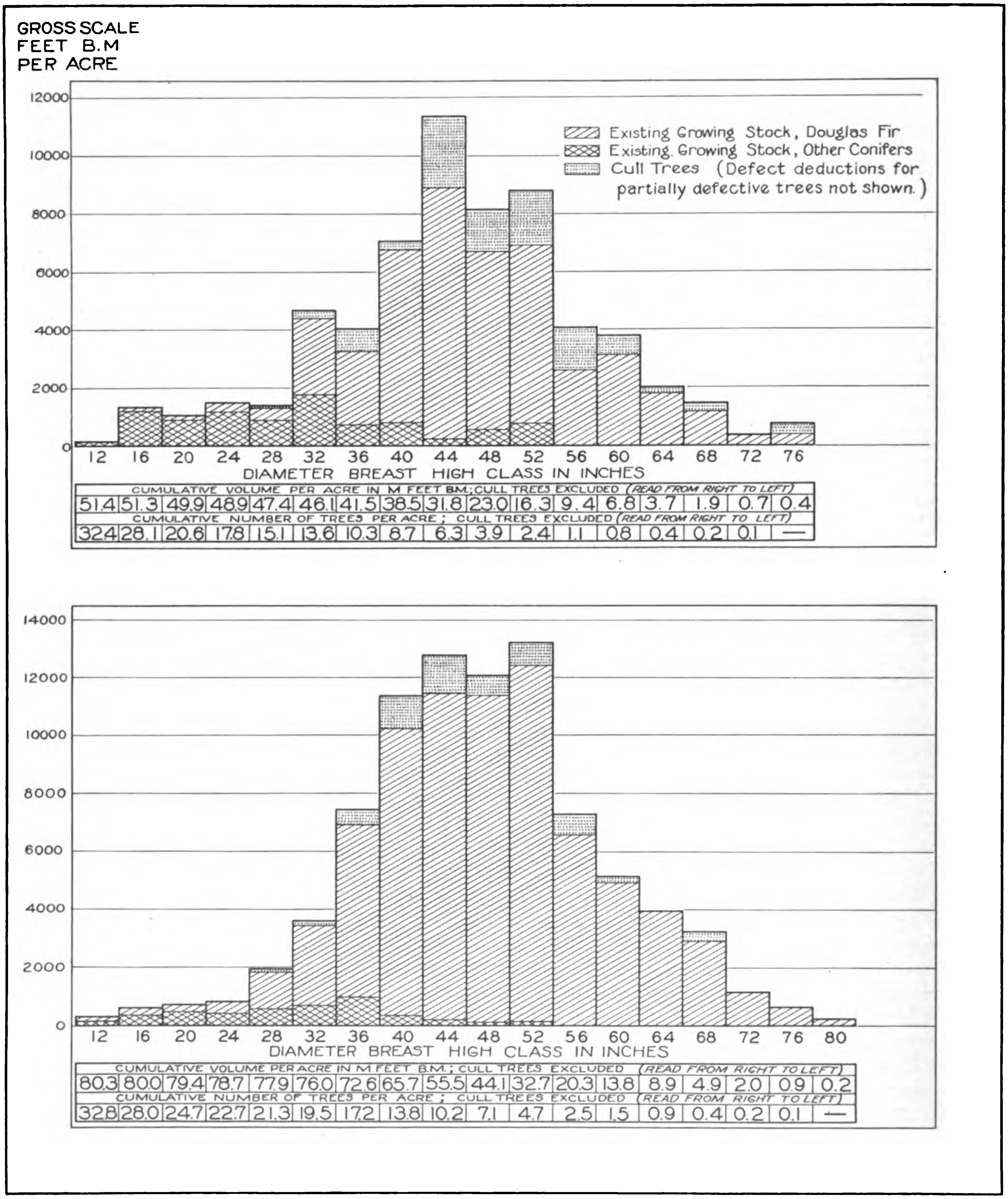


Fig. 12 – Stand Structure Diagrams of Block 2. Chap. IV

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 $11 for 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 clear-cutting 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 of 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.[6] 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.

[6] 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 forthcoming 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 losses, 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 3,000 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 1/4 per cent, as compared with 1/2 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 carry on 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 full 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 stocked predominant-

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

Block No.	Douglas fir 40 in.+	Douglas fir 20–40 in.	Western hemlock 20 in.+	Western red cedar 24 in.+	Immature conifers 6–20 in.	Young conifers 6 in.−	Total productive	Noncommercial[1]	Total area
	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.

ly 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 transporation. 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	Douglas fir over 40 inches D. B. H.: Others	Douglas fir 20 to 40 inches D. B. H.: Douglas fir	Douglas fir 20 to 40 inches D. B. H.: Others	Western hemlock[2] over 20 inches D. B. H.: Douglas fir	Western hemlock[2] over 20 inches D. B. H.: Others	Western red cedar[3] over 24 inches D. B. H.: Douglas fir	Western red cedar[3] over 24 inches D. B. H.: Others	Immature coniferous timber 6 to 20 inches D. B. H.: Douglas fir	Immature coniferous timber 6 to 20 inches D. B. H.: Others	Young coniferous types under 6 inches D. B. H.: Douglas fir	Young coniferous types under 6 inches D. B. H.: Others	Total volume by tracts: Douglas fir	Total volume by tracts: Others	Total volume by tracts: 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 tra.ls. 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 thrify 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 cyles. 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 pre-

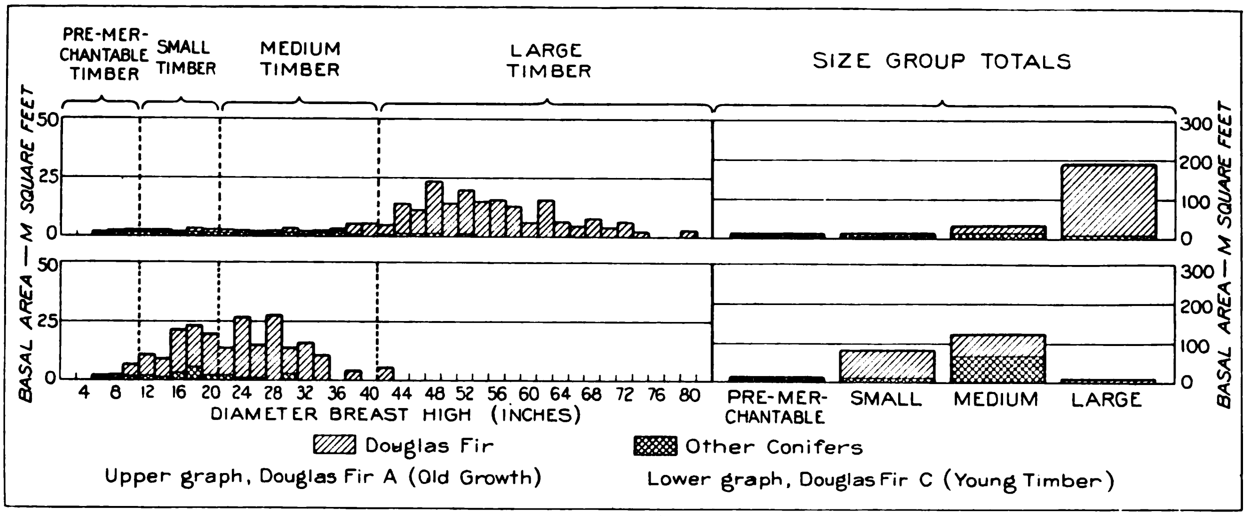


Fig. 13 - Stand Structure Diagrams of Block 2
(Chap.V)

merchantable (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 carry on 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 any one 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 areas 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 cu.[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	%[2]		M bd. ft.	Sq. feet	%[2]		M bd. ft.	%[2]	Sq. feet	%[2]
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		....	1,286	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		....	1,278	3,007		....	12,422	14.8	115,475	21.4
59,859	53,055	248,322		4,024	20,294	53,090		716,245	96,858		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	88,839		611,270	
....	5,602	25,951		....	1,146	2,980		....	15,299	17.8	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		....	26,819	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	

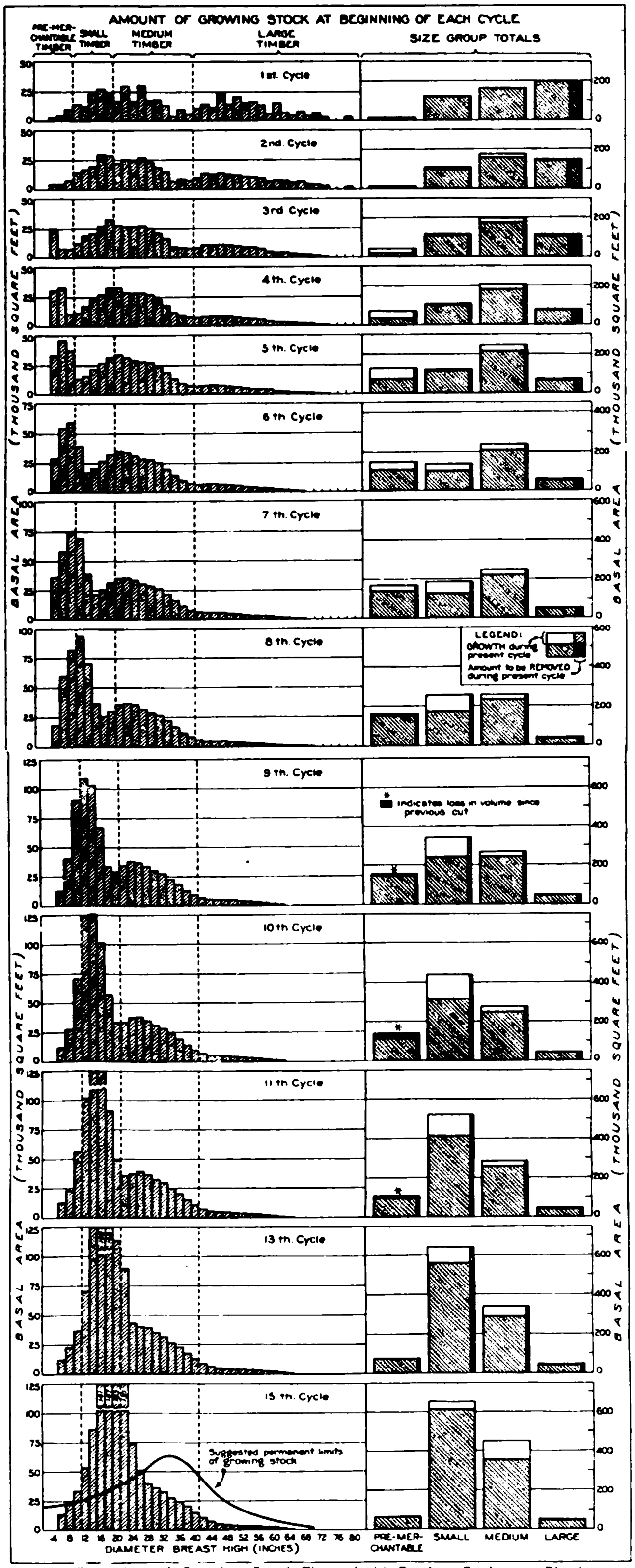


Fig. 14—Evolution of Growing Stock Through 14 Cutting Cycles on Block I

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.

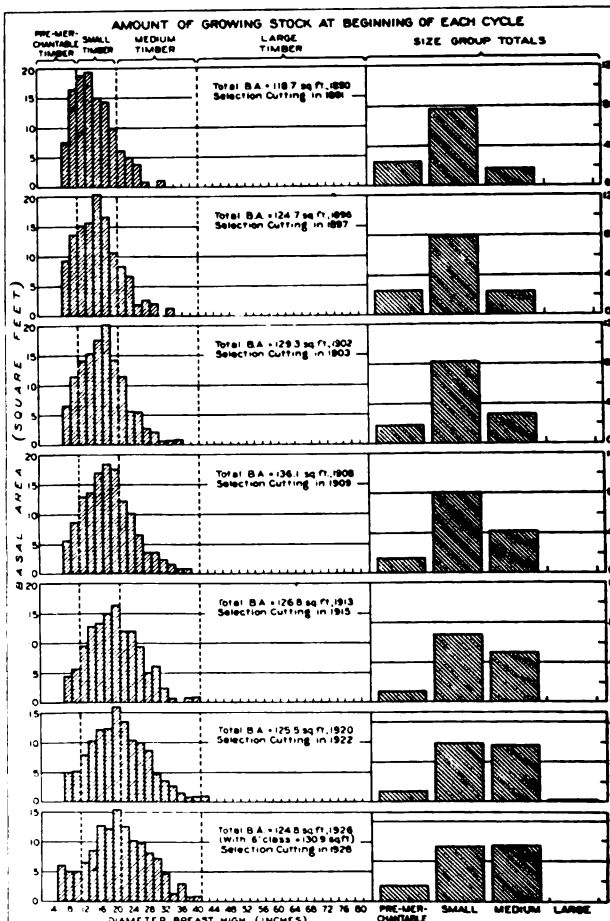


Fig. 15—Evolution of the Growing Stock from 1890 to 1927 on average acre, Division 14 of the Communal Forest of Couvet, Switzerland; Based on inventories Recorded, Prior to Cutting, Each Six-Year Cycle as Noted Above.

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 oversized 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 *Inches*	Time required for 2 in.d.b.h. growth *Years*	Trees moving into next d.b.h. class in 5-year cycle *Per Cent*	Gross volume per tree *Bd. ft.*	Basal area per tree *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 a 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

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

Item	1st cycle	2nd cycle	3rd cycle	4th cycle
	Costs per thousand feet board measure			
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.

conditions will best be met by selecting groups 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. (Pl. 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 the 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 per cent 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 required to maintain the forest in profitable pro-

TABLE 15.—*Probable distribution of the cyclic cut and growing stock to timber groups after restoration of the growing stock* (*block 1*).

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	22,000[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.

duction. 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 1⅛ 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 overmature 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 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 cordwood 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 overmature 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 clear-cut 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 are 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.

CHAPTER VI

THE INFLUENCE OF PHYSICAL CHANGE AND TIME ON STAND CONDITIONS AND STUMPAGE VALUES

32. Changes in value of trees and stands.—It is a curious fact in the history of American timber ownership that at the same time that forest owners in older forest regions have been willing to invest in timber of regions thousands of miles distant, for the sake of reaping the profits from increasing stumpage prices, they have ignored the possibility of management methods which provide equally favorable price movements in continuity on their operating properties. Since this itinerant investment or speculative procedure has now extended over all forest regions, investment opportunities now narrow down to the value movements within existing properties. As a matter of cold fact, the itinerant investment method overreached itself both through overextension of the field with relation to the financial resources available and through the enormous waste inherent in the unnecessary liquidation, region by region, of the natural productive capacity of the forest and the large capital investment in operating facilities. Sound investment fields have become so restricted in recent years that these methods are no longer tolerable from either the individual or the public standpoint.

Perhaps the most difficult mental attainment for the manager of a forest property is the realization that he is not dealing with fixed qualities or values in any respect, but that prices, costs, timber volumes and values are undergoing constant change. In this chapter attention is centered on the factors creating and changing stumpage values as they affect continuous earning possibilities of individual forest properties in the Pacific Northwest.

Changes in value of trees and stands and of unit stumpage values, due to physical and economic factors over a period of time, may theoretically be grouped under the following classification:

A. Volume increment (growth in volume).
B. Quality increment (growth in quality).
C. Price increment (growth in price).

Value increases resulting from reduction in logging costs through improving technic, etc., also have the same effect as quality or price increment. In practice it is very difficult to make a clear-cut separation of these and owing to space limitations volume and quality increments will be considered together in the following pages. Price increment is a large subject in itself and a somewhat imponderable factor which is not relied upon for any of the conclusions herein.

Only a few of the myriad physical and economic factors that influence each of the above classes of increment will be discussed. Systems of measuring trees, logs and manufactured products; standards of utilization changing with time; changing demand for various forest products; inflation and deflation of money and credit; all these and many other factors have varying influence on one or the other of the ways in which increment may occur. It is also to be noted that each form of increment may at times be negative. In view of these facts skilled forest property management depends on flexible procedures designed to take from the forest warehouse during any given period whatever forest raw materials are in high enough demand to bring a peak in the particular values concerned. Selective timber management with short cutting cycles, permanent road systems, and continuous intensive control of the growing stock is best adapted to meet these requirements.

33. Growth in volume and quality.—Growth, as a source of value increase, was neglected so long as ample supplies of matured timber were found in all the forest regions. Owing to habit and lack of knowledge concerning growth, this neglect has continued long after justification for it ceased. Probably the chief reason for continued neglect lay in the erroneous belief that volume growth is solely a matter of starting with young stands and waiting for their development over a period up to a century or more. Such misconception causes growth to be ignored as a factor in private timber management. It overlooks completely the millions of trees which have been growing in our forests for many years and have already reached merchantable or nearly merchantable size. Growth is the factor which for enormous numbers of such trees lifts them from unmerchantable to merchantable sizes in 5 to 20 years, periods well within the length of time for which stumpage investments are customarily made. Even more important in its effect on earnings, it lifts merchantable sizes from diameter class to diameter class, and simultaneously makes available earnings from increment in volume, quality, and price.

Logging methods are now available in the Douglas fir region, as well as elsewhere, which permit the preservation of most trees which will earn satisfactorily if held for a future cut. It is only through the establishment of an adequate permanent growing stock that growth can be regularly translated into an active contribution to current financial returns during either short or long terms of years. Such a growing stock can be preserved largely without cost on any forest property still having stocks of timber which are large in proportion to the annual cut and to the size of the property concerned. The method of establishment simply involves saving trees and immature stands which have not reached a high value for immediate conversion.

In general it may be said that to persons accustomed to think of the forest as an aggregate of static or nearly static elements growth seems a negligible factor. As compared with changes which take place in a matter of days, it is a slow acting force, but in terms of the life of soundly managed enterprises which support communities and states it may be rapid. On large forest properties the gains from growth can attain massive proportions. A property so managed under extensive clear-cutting methods that these gains can only be realized as deferred income at long periods may not benefit financially from this growth, no matter how large, because accumulated expenses may eat up returns. The present discussion is, however, confined chiefly to selective methods and intensive stand management which permit immediate utilization of the equivalent of current growth without the heavy losses from fire, insects, and disease which occur in forests cut over only at long intervals.

In view of the fact that forest management capable of yielding high grade forest raw materials and maintaining a favorable relation between capital investment and income must concern itself primarily with the continued economic production of large timber, the means of speeding production of such timber deserves special investigation. Since the rate of production of large trees depends on the rate of movement of trees from diameter class to diameter class the current rate of growth of trees of various sizes is of fundamental importance.

34. **The current rate of diameter growth in unmanaged stands.**—Current growth is most easily investigated by dealing first with diameter growth. The rate of diameter growth determines the time required for trees of one diameter class to move into the next class. From the standpoint of selective cutting, information available is very inadequate. Such as is available for the Douglas fir region deals with averages in unmanaged stands and does not show rates of growth attainable in stands under good management where mature, defective, ill-shapen and poorly crowned trees are removed at short intervals and the productive capacity of the soil thrown to the better trees.

Average growth in young even-aged Douglas fir stands has been quite exhaustively investigated by Richard E. McArdle and Walter H. Meyer *(20)*. Their work is relied upon for most of the data concerning early growth of even-aged stands resulting from past fires and from clear cutting, as well as for even-aged groups originating from group selection as discussed in this report. In table 16 (column 3) are listed the average diameters at various ages on Site class II of trees from 40 to 160 years of age. (Site class II is cited because areas which average nearly of this quality are most suitable for intensive private management.) Since averages include (particularly in the younger age classes) hundreds of small trees that will never grow to utilizable size, for any markets now in sight, they greatly understate the diameters of trees that will actually be dealt with in the later cutting operations.

The selective management methods apply both in principle and in practice to management of so-called "even-aged stands", in the same way as to many-aged stands, particularly within groups originated under group selection. Although such groups may be even-aged, these methods deal with individual trees according to size and such other characteristics as vigor and quality of the tree rather than with age classes. Even precisely even-aged planted stands show great variation in these respects among individual trees.

Douglas fir stand tables compiled in connection with the yield study cited *(20)* throw some light on these differences in development. Average diameters and rates of growth of the

20 largest trees in the stand from ages 40 to 160, computed separately, are given in columns 6, 7, and 8 of table 16. It is to be noted that the average rate of growth in the 20 largest trees (column 7) is much more rapid than the parallel rates for average trees (column 4) and continues so until the large trees reach an average diameter 8 to 10 inches greater than that of the average trees. Data cited later from Lewis County suggest that the falling off in growth at 34 to 36 inches is due more to overdensity of the stand than to age.

In contrast to the development of the largest trees from 40 to 160 years, the 20 smaller trees show average sizes at ages 40 to 160 years as in columns 9 and 10. The average rate of growth cannot be determined from the data available for these trees on account of the rapid rate at which they are dying and dropping out of the stand. Under good management, these trees would be removed whenever a market exists for this class of material, provided a sufficient degree of natural pruning has been completed on the remaining main-crop trees. These trees lag 20 inches behind the largest trees at the end of the period covered in the table.

Diameter growth on permanent sample plots by crown classes.—More precise information on differentiation in growth rates between different crown classes and tree sizes in young Douglas fir stands has recently been provided through analysis by Dr. Meyer of data from permanent sample plots measured periodically by the Pacific Northwest Forest Experiment Station. Figure 16 is based on partially weighted average 5-year rates of diameter growth on suppressed, intermediate, codominant, and dominant trees in unmanaged stands 50 to 60 years of age. It can be observed at a glance that the suppressed trees are growing practically not at all, the smaller intermediate at a slow rate, the larger intermediate with fair rapidity and the codominant and dominant quite rapidly. On the whole the growth on individual trees is slow possibly on account of the heavy stocking in these plots. When market conditions permit, the slower growing trees in such stands should be removed from the stand. However, as repeatedly noted, this should not be done until natural pruning has proceeded to a height of 35 to 50 feet.

Diameter growth on larger trees.—Data for growth of trees of sizes larger than those covered in Technical Bulletin 201 *(20)*, or those included in permanent sample plots, have been derived from growth measurements taken in connection with the Timber Survey of Lewis County, Washington, on sample trees within plots distributed throughout the Douglas fir type in the 20- to 40-inch size classes (young timber) and in the 40-inch and larger classes (old timber). These plots were classified by site classes and by density classes as shown in

TABLE 16.—*Diameter growth of Douglas fir of various ages, sizes, and tree classes, on Site Class II.*

Age	Averages of entire stand[1]				Averages of 20 largest trees[2]			Averages of 20 smallest trees[3]	
	Trees per acre	Diameter of average tree	Average diameter growth each 20-year period	Time required to grow 2 inches	Diameter of average tree	Average diameter growth in each 20-year period	Time required to grow 2 inches	Diameter of average tree	Difference in average diameter in each 20-year period
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Years	*Number*	*Inches*	*Inches*	*Years*	*Inches*	*Inches*	*Years*	*Inches*	*Inches*
40	385	9.4			14.4			3.7	
			4.6	8.7		6.7	6.0		3.0
60	218	14.0			21.1			6.7	
			3.9	10.2		4.8	8.7		2.7
80	157	17.9			25.9			9.4	
			3.3	12.1		3.9	10.2		2.5
100	123	21.2			29.8			11.9	
			2.8	14.3		3.1	12.9		2.4
120	101	24.0			32.9			14.3	
			2.5	16.0		2.3	17.4		2.1
140	88	26.5			35.2			16.4	
			2.4	16.7		2.9	13.8		2.0
160	79	28.9			38.1			18.4	

[1] Data from Table 2, U. S. Dept. Agr. Tech. Bull. 201. *(20)*
[2] Data from Table 11, U. S. Dept. Agr. Tech. Bull. 201. *(20)*
[3] The growth rate cannot be ascertained from Bulletin 201 because the 20 smallest trees of each age group up to 120-year group have mostly dropped out of the stand. There is practically no growth in the smallest trees, as is confirmed by sample-plot data cited on pp. 66 and 67.

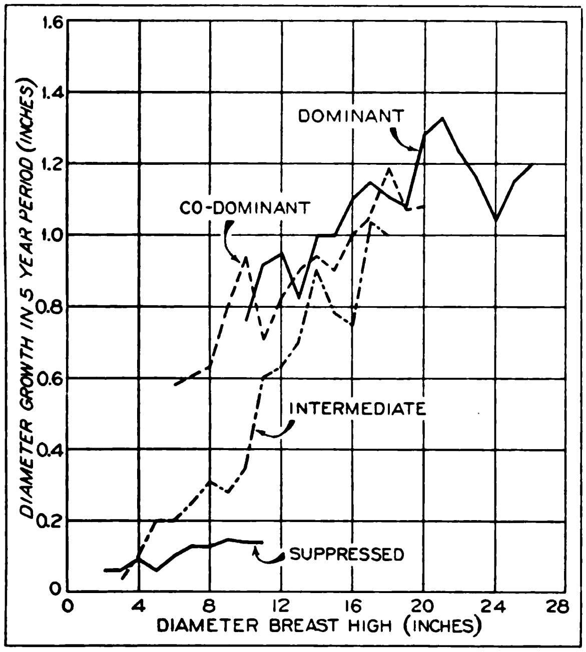


Fig.16 - Diameter Growth of Even-aged Douglas Fir, 50-60 Years Old, by Crown Classes. Site Class II

table 17 and figure 17. It is readily observable from the original data that there is a marked variation in rates of growth between different trees in the same diameter group. Analysis of the data from several aspects justifies the following conclusions:

(a) Diameter growth varies greatly with the density (volume per acre) of the stand (fig. 17).

(b) For trees more than 34 inches in diameter on a given site quality the rate of diameter growth varies only moderately with the size of the tree.

(c) On a given site, age of the tree has relatively a lesser influence on growth than does environment, expressed in terms of density.

These data indicate that, on a given site, density of stand is a controlling factor in diameter growth. The significance of this fact when applied to stand management varies with tree size. For the smaller trees (12 to 32 inches d.b.h.) which have been cleaned of branches, thinnings are indicated which will throw the growth capacity of the site to fewer tree stems and thus produce the acreage growth on a smaller tree capital but at a faster rate in relation to the capital. For large trees, removal of dense groups is indicated to the extent of about 0.5 per cent of the total area annually. If the dense stands exceed this percentage of the area, tree selection may be carried on to reduce density where needful.

The measurements (table 17) were made without correlation with crown conditions or other tree characteristics. Well-known facts as to the influence of size of crown and other factors on growth confirm the belief that in selective cuttings the slower-growing trees can readily be identified and eliminated from the stand when desired and that, where this is done, the weighted average rate of growth on trees remaining will be larger.

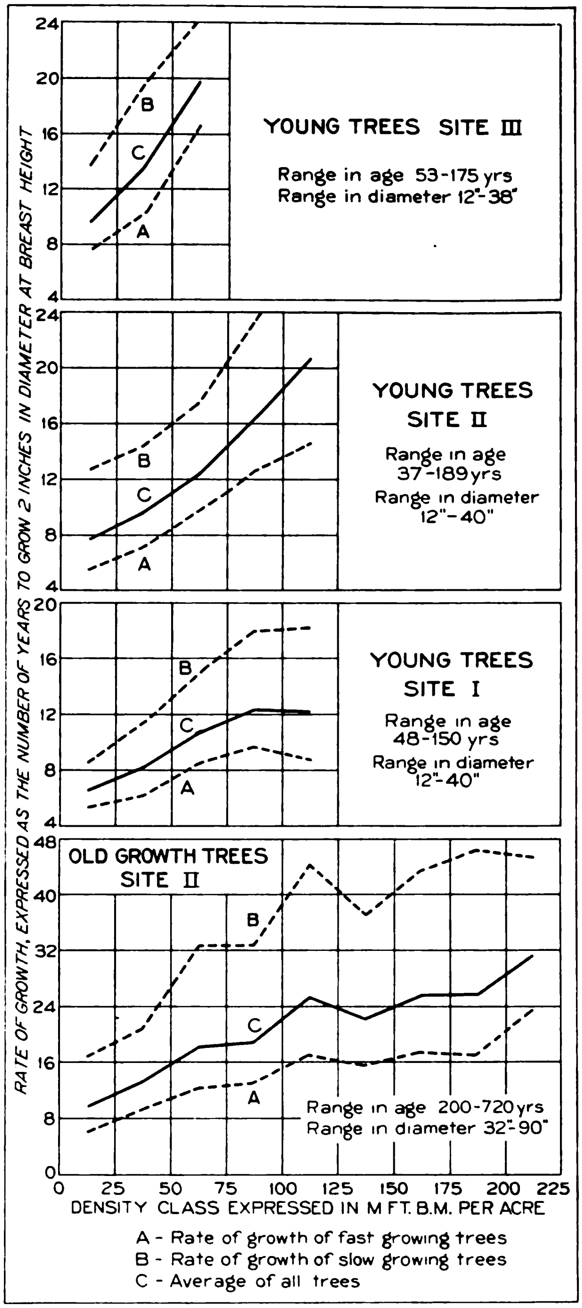


Fig.17 - Influence of Stand Density and Site Quality on the Rate of Diameter Growth in Douglas Fir

Table 17.—*Rate of growth[1] of Douglas fir in stands of different densities by site qualities.*

Diameter breast-high class	Density class expressed in thousand board feet, net log scale, per acre: 0–25					26–50					51–75					76–100					101–125				
	No. of trees basis	Average age of trees	Average number of years required to grow two inches in diameter at breast height: Fast[2] growing trees	Slow[3] growing trees	Weighted average of all trees	No. of trees basis	Average age of trees	Average number of years required to grow two inches in diameter at breast height: Fast[2] growing trees	Slow[3] growing trees	Weighted average of all trees	No. of trees basis	Average age of trees	Average number of years required to grow two inches in diameter at breast height: Fast[2] growing trees	Slow[3] growing trees	Weighted average of all trees	No. of trees basis	Average age of trees	Average number of years required to grow two inches in diameter at breast height: Fast[2] growing trees	Slow[3] growing trees	Weighted average of all trees	No. of trees basis	Average age of trees	Average number of years required to grow two inches in diameter at breast height: Fast[2] growing trees	Slow[3] growing trees	Weighted average of all trees
Young Douglas fir under 40 inches D. B. H.—Site I.																									
12"–20"	4	56	6.3	9.0	7.4	5	63	10.9	13.7	11.3	4	73	10.1	23.5	14.2	...	...	...	...	...	...	...	...	...	...
21"–30"	4	69	5.0	9.9	6.6	12	72	6.1	10.0	7.5	19	81	7.8	13.2	9.7	7	105	10.6	20.0	13.3	3	109	6.4	24.4	12.7
31"–40"	2	60	4.9	6.1	5.4	4	96	4.6	12.8	6.8	4	123	11.1	18.2	13.8	8	119	8.9	16.7	11.6	10	119	9.6	16.5	12.1
Wt. average	...	62	5.4	8.5	6.6	...	74	6.2	11.4	8.2	...	86	8.5	14.9	10.7	...	112	9.7	18.0	12.3	...	116	8.8	18.2	12.2
Young Douglas fir under 40 inches D. B. H.—Site II.																									
12"–20"	14	62	6.8	13.5	9.0	17	74	9.2	17.1	12.2	7	74	10.5	20.8	13.3	...	...	...	...	...	...	...	...	...	...
21"–30"	34	70	5.3	12.5	7.5	50	85	7.1	13.8	9.4	30	93	9.9	16.1	12.3	14	105	11.8	22.5	15.5	5	120	11.8	31.7	19.0
31"–40"	8	103	4.9	11.6	6.8	23	122	6.3	13.8	8.8	9	136	9.2	22.7	12.4	4	156	16.5	28.2	20.6	8	148	16.7	31.3	21.7
Wt. average	...	72	5.5	12.7	7.7	...	93	7.2	14.4	9.7	...	99	9.8	17.5	12.4	...	117	12.6	23.5	16.4	...	137	14.6	31.4	20.6
Young Douglas fir under 40 inches D. B. H.—Site III.																									
12"–20"	6	63	7.3	13.5	9.5	5	70	12.9	20.2	16.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21"–30"	9	103	7.6	13.7	9.5	15	94	9.6	18.3	12.8	10	124	16.5	24.4	19.8	2	141	8.6	25.3	12.8	2	132	14.1	32.2	19.6
Wt. average	...	89	7.5	13.6	9.5	...	88	10.2	19.6	13.6	...	124	16.5	24.4	19.8	...	141	8.6	25.3	12.8	...	132	14.1	32.2	19.6
Old growth Douglas fir over 40 inches D. B. H.—Site II.																									
31"–40"	...	...	...	...	...	4	295	11.8	21.7	15.3	4	200	13.6	42.6	20.6	6	282	14.0	30.3	19.2	4	350	18.0	101.1	30.8
41"–50"	5	267	6.0	16.8	9.7	11	253	8.8	22.2	13.1	10	245	10.4	22.0	14.1	12	304	12.4	40.0	19.1	10	338	18.7	44.4	26.3
51"–60"	...	...	...	...	...	8	299	8.5	23.8	12.6	13	381	13.0	50.0	21.5	7	389	15.0	29.4	20.8	9	356	17.9	41.7	26.3
61"–70"	...	...	...	...	...	3	367	10.6	33.3	13.7	6	383	13.0	30.3	18.2	6	442	16.7	39.2	23.5	14	425	18.5	41.7	25.7
71"–80"	...	...	...	...	...	...	...	...	...	...	4	413	15.5	29.8	20.4	5	475	19.0	40.8	28.2	5	417	10.2	34.5	17.7
81"–90"	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	475	8.5	19.4	11.0	2	575	19.8	87.0	32.3
Wt. average	...	267	6.0	16.8	9.7	...	287	9.3	22.8	13.2	...	328	12.4	32.8	18.2	...	377	13.1	32.8	20.8	...	390	17.1	44.4	25.3

Old growth Douglas fir over 40 inches D. B. H.—Site II (Continued).

Diameter breast-high class	126–150					151–175					176–200					201 and over									
41"–50"	14	310	16.0	38.5	22.7	12	306	23.5	50.0	31.8	7	280	17.0	37.7	22.2	14	330	27.0	52.6	35.7	...	...	...	...	...
51"–60"	12	396	15.2	32.3	20.6	10	438	23.5	45.5	31.3	5	420	19.6	50.0	30.8	12	404	25.7	42.6	32.3	...	...	...	...	...
61"–70"	8	460	14.8	48.5	22.0	13	494	18.0	40.0	20.4	5	480	15.4	55.6	27.0	14	525	22.2	50.0	30.8	...	...	...	...	...
71"–80"	7	461	16.7	37.0	24.4	5	485	13.1	37.7	21.5	...	...	...	...	...	4	558	33.3	66.7	44.4	...	...	...	...	...
81"–90"	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	540	13.2	30.3	20.0	...	...	...	...	...
Wt. average	...	390	15.6	37.0	22.2	...	423	17.5	43.5	25.6	...	380	17.1	46.5	25.7	...	440	23.5	45.5	31.3	...	...	...	...	...

[1] Rate of growth is expressed as the "number of years to grow two inches in diameter at breast height." The basic growth data were obtained from increment borings and the "number of years to grow two inches" has been calculated.

[2] By the term "fast-growing trees" is meant the fastest growing 50 per cent of the total number of trees in the group.

[3] By the term "slow-growing trees" is meant the slowest growing 50 per cent of the total number of trees in the group.

When growth is sustained until the tree reaches a large size, this growth is at a relatively low percentage rate. The rate of about two inches in 10 or 12 years is very desirable to maintain, and selection of trees for holding into the large-size classes should, therefore, be confined to the most vigorous and well-formed individuals. Occasional determination of the rate of diameter growth is easily made on the ground by means of an increment borer. The number of rings in the last inch of radius reveals how many years have been required to grow two inches in diameter. For the rate of volume change, it is well to set up a volume table based on local utilization practice, tree form, and height or utilized log length.

In view of the wide variation in diameter growth, in both young and old stands, it is apparent that the skilled technician, desiring to raise the earnings of a forest property, can influence average rates of growth within fairly wide limits, merely through removal of slower growing trees from the stand. Selection with this objective alone, however, is often undesirable. Another aspect of the problem of accelerating rates of growth is discussed in the next section.

35. Acceleration of the average rate of diameter growth when competition has been reduced in the stand.—The effect of release from competition within the stand has not been systematically investigated in the Douglas fir region, but all of the species are of the type which responds readily to release. This is especially true of the shade-enduring spruce, hemlock, cedars, and balsam firs. Under shade all of these tend to hold a full crown and in a very short time will increase their rate of growth in response to increased light and space. Although Douglas fir does not hold foliage under dense shade there are in most Douglas fir stands, especially those averaging under 40 inches in diameter, numerous trees falling somewhat behind in competition with dominant trees but with full crowns and well able to take advantage of removal of the larger trees.

Fragmentary data on increased growth following release, based on borings of some 30 spruce and hemlock trees released by selective cuttings in 1917 and 1918 in the lower Columbia River region, are shown in table 18.

The data are insufficient to indicate the effect of different degrees of release or to draw any detailed conclusions. They indicate, however, that on good sites the increase of growth on released trees is immediate and is maintained for some years. The response of suppressed spruce to release is remarkable. Before release the average time taken to grow 2 inches in diameter was 9 years, after release it was 3 years. This indicates, however, that the cuttings were too heavy. Uniform quality of the wood is favored by light and frequent cuttings rather than by heavy and infrequent cuttings.

36. Growth in managed stands consists of progression of trees through lower diameter classes to valuable large sizes.—Selective timber management does not depend on average trees either for current cutting operations or for continued growth. To do so is to obtain mediocre results in both growth and income. Selective cuttings, to get the best results, must have two aims. First, when cutting in a heavy stand the high-value, financially mature trees or groups are selected to the extent of perhaps 15 to 30 per cent of the stand volume. This insures a high stumpage return on the major product from the forest. Second, if industries such as pulp and paper mills are ready to absorb smaller sized trees or lower grade materials, surplus and defective trees are taken out. When, as under present conditions, these desirable cuttings of inferior or surplus trees often cannot be made, the growing stock may in part have to consist temporarily of undesirable larger trees and less valuable species. However, in time a constant though somewhat restricted market for this poorer material can probably

TABLE 18.—*Average growth at breast height of western hemlock and Sitka spruce trees, before and after a partial cutting of the stand*

Species and crown class	Average diameter[1] 15 years before release	Average diameter[1] at time of release	Average diameter[1] 15 years after release	Average diameter growth in 15 years		Average time required to grow 2 inches	
				Before release	After release	Before release	After release
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Years*	*Years*
Western hemlock:							
Intermediate	17.1	20.3	26.1	3.2	5.8	9	5
Suppressed	18.1	19.4	21.8	1.3	2.4	23	12
Sitka Spruce:							
Intermediate	15.7	20.4	29.4	4.7	9.0	6	3
Suppressed	14.0	17.5	26.5	3.5	9.0	9	3

[1] Average diameter computed from average basal area.

be counted on, so that it should be possible to clean up those stands within a few cutting cycles if the forest owners are alert to take advantage of such outlets as are available. The present market for this material is largely filled by timber that should not have been cut and the legitimate outlets are thus restricted.

The remaining stand, if undesirable trees are removed, will consist, so far as larger merchantable trees are concerned, only of those specially reserved on account of clear trunks, freedom from defect, and prospective vigorous growth rates. These trees will exceed average trees in growth rate and will earn heavily on the investment which they represent. The rest of the area will be occupied by smaller merchantable and premerchantable trees.

In dealing with the merchantable size classes from 12 inches up, which in selectively operated properties compose 80 per cent or more of the investment value, the continuous and reasonably rapid passage of trees from diameter class to diameter class and finally to large high-quality timber is essential if high yields and good earnings are to be obtained from the forest. It has been pointed out repeatedly in the logging cost report *(7)* and in previous chapters of this report that low extraction costs and high average quality and value are almost invariably associated with large size. It has already been stated that, owing to the method of dealing with averages of the entire stand in yield studies, little is known as to the rate of progression of the better trees through to the larger sizes in unmanaged stands and still less in managed stands.

Douglas fir yield tables *(20, table 2)* indicate that the average tree on Site II passes from 12 inches diameter at about 50 years to 29 inches at about 160 years. There is, however, a wide dispersion of diameters from 12 inches to 45 inches *(20, table 11)* in 160-year unmanaged stands of Site Class II. Effective stand management should take advantage of this natural dispersion of diameters as the stand develops and endeavor to encourage dispersion beyond the upper limits by favoring full crowned trees which have established a satisfactory clear length of 35 to 50 feet (at least one 32-foot log length). This problem is somewhat supplementary to the simpler problem of raising the weighted average growth rate by frequent light cuttings which aim at each cutting to remove a quota of less thrifty and slower-growing trees. The aim is to accomplish this without loss of growth per acre but this will often be impossible. Increasing the growth rate of individual trees, or arresting their decline in growth, involves more definite care in selecting trees for cutting. Such encouragement of individual trees should involve not only release from competition but also avoidance of injury in logging and in too sudden or excessive exposure.

Space does not permit nor does this report aim at detailed discussion of the silvicultural factors to be considered in selective cutting to promote growth in the residual stand. During the first few cutting cycles economic and operating factors must control, since disregard of these will set back for an indefinite period the time when more intensive silviculture can be practiced. The main objectives reasonably to be expected within 4 to 10 cycles of effective selective management may be summarized as follows:

(a) Selective cutting of dense groups and large trees, which on account of stag-headedness or other factors have poor crowns, should leave a stand in which the weighted average rate of growth is faster than in the unmanaged stand.

(b) Since the large trees contain much of the fungus infection, which with losses by windfall and insects approximately offsets growth in older stands, their removal together with windfalls and other salvage should eliminate most losses by decay and make the growth almost wholly a net gain in volume.

(c) Attention in cuttings to the space requirements of trees that remain standing will free them of competition and should maintain their growth at a higher rate or in some cases restore a higher rate than that of the same trees in an unmanaged stand.

(d) Finally, when markets available to any particular property permit the systematic removal of portions of the growing stock which are inferior from the standpoint of species or individual tree form, or which contribute to overdensity of the stand, then the quality of the growth laid on by the stand should be improved.

Experimental data are lacking as to how much average rates of growth can be improved by these processes of selective stand management. Evidence of varying growth rates so far described, and experience with stand management in other regions and other countries, warrant the belief that within the 1- to 10-acre clear-cut groups on Site Class II under skilled selective management, holding density within reasonable bounds, the time required for conifers to pass through each 2-inch diameter class from 12 to 22 inches need not exceed 6 years for each class; from 22 to 32 inches, 6 to 7 years for each class; from 32 to 42 inches, 8 to 11 years for each class; and for classes 42 inches and up, 12 years. The data in table 17 justify considering the rate of growth as constant for diameter classes over 40 inches except as it is influenced by increased density of the stand. On the very limited areas of Site I the growth is more rapid than the above figures indicate, while it is slower on Site Classes III, IV, and V *(20)*. Site II is considered not far from average for the area that should receive close attention under intensive management. Site quality III will justify less intensive management than Site II, and Sites IV and V ordinarily will justify only such care as may be given incidental to care of better sites. These conclusions as to possible favorable growth rates of Douglas fir under intensive selective management have been embodied in Table 19, together with approximate board-foot volumes found under average conditions for each diameter class. Table 19 also presents for later reference, among other data, the current rate of growth in board feet for trees of each diameter, expressed as a percentage of the volume of a tree of the diameter class on which current growth is being added.

The principal difference between these rates estimated for managed stands and those in unmanaged stands is to be found in the 12- to 20-inch diameter classes, growth of which can be speeded up by anticipating natural thinnings, and in diameter classes from 42 inches up, where the slower growing trees can be removed, thus raising the weighted average growth. No increase in rates of growth due to release can be expected in the larger trees.

With trees such as hemlock originating under shelter the situation is entirely different. On these the growth may be slow for many years until the overstory is removed, when they pick up in growth rate. Slow growth in the early years has no effect on financial returns because the overstory is making constant earnings.

It may be remarked that the fact that growth falls to a rate of 1 per cent or less at about 40 inches has led many foresters (overlooking several factors) to the conclusion that trees of that size could no longer make satisfactory earnings. The overlooked factors are that such trees would make up no more than 6 to 8 per cent of the merchantable sizes in a forest division; that the greater part of their volume was built up at faster rates in earlier years; that the increment, being mostly clear

TABLE 19.—*Estimated rates of growth of Douglas fir trees of various diameters on quality II sites, and related data*

Diameter (inches) class *Pre-merchantable*	Approximate no. years to grow 2 inches in diameter	Basal area, sq. ft.	Volume in board feet (Scribner rule)	Number of board feet per square foot basal area	Rate[1] of volume growth in per cent, compound
(1)	(2)	(3)	(4)	(5)	(6)
	6	0.022			
2	6	0.087			
4	6	0.196			
6	6	0.349			
8	6	0.545			
10					
Merchantable[2]					
12	6	0.785	105	134	
14	6	1.069	175	164	8.9
16	6	1.396	265	190	7.2
18	7	1.767	350	198	4.8
20	7	2.181	440	202	3.3
22	8	2.640	584	221	4.1
24	8	3.142	750	239	3.2
26	9	3.69	940	255	2.9
28	9	4.28	1,150	269	2.3
30	10	4.91	1,379	281	2.0
32	10	5.59	1,690	302	2.0
34	11	6.30	2,040	324	1.9
36	11	7.07	2,360	334	1.3
38	11	7.88	2,759	350	1.4
40	11	8.73	3,150	361	1.2
42	12	9.62	3,516	366	1.0
44	12	10.56	3,950	374	1.0
46	12	11.54	4,413	382	0.9
48	12	12.57	4,900	390	0.9
50	12	13.64	5,388	395	0.8
52	12	14.75	5,860	397	0.7
54	12	15.90	6,360	400	0.7
56	12	17.10	6,860	401	0.6
58	12	18.35	7,475	407	0.7
60	12	19.63	8,000	408	0.6
62	12	20.97	8,600	410	0.6
64	12	22.34	9,200	412	0.6
66	12	23.76	9,700	408	0.4
68	12	25.22	10,400	412	0.6
70	12	26.73	11,300	423	0.7
72	12	28.27	12,100	428	0.6
74	12	29.87	13,000	435	0.6
76	12	31.50	13,800	438	0.5
78	12	33.18	14,700	443	0.5
80	12	34.91	15,700	447	0.5

[1] Computed as a compound interest rate for all periods of years required to grow 2 inches. The percentage opposite each diameter class expresses the rate of growth from the preceding class.

[2] Term "merchantable" is used in sense that these sizes will make merchantable products. Only special products of limited demand can at the present time be made at a profit from sizes up to 20 inches.

wood, may be worth 5 to 10 times the value of wood produced on the small timber tree class; and that only the high quality materials in the timber output of the forest can provide high income. Data are not yet available to establish rates of value increase with any accuracy. We are neither able to forecast the rate of price increment which may constitute considerable additions to such percentage rates of increase as given below nor can we accurately evaluate the effect of quality increment. For converting the volume growth relationships of table 19 to value relationships (money earnings), the following tabulation is considered, however, to represent a rough approximation to present conditions.

Merchantable timber class	Diam. classes dividing growth periods	Unweighted average rate of volume growth	Range of stumpage values per M ft. b.m.	Approximate annual earnings expressed as per cent on investment
	Inches	Per Cent	Dollars	Per Cent
Small timber	10 to 20	6.0+	.50 to 1.00	[1] 6.0+
Small medium timber	20 to 30	2.9	1.00 to 3.00	[2] 5.7
Large medium timber	30 to 40	1.5	3.00 to 5.00	[3] 2.5
Large timber	Over 40	1.0-	5.00 to 10.00	[4] 2.1

[1] Since the material produced is all low in value financial earnings coincide closely with volume growth per cent.

[2] Calculated as follows for small medium class: A 20-inch tree containing a volume of 440 board feet worth $1.00 per M feet b. m. ($0.44 for the tree) grows in 41 years to be a 30-inch tree containing 1,379 board feet worth $3.00 per M feet ($4.14 for the tree). The growth in value is equivalent to 5.7 per cent earnings compounded annually.

[3] Likewise a 30-inch tree (1,379 feet b.m.) worth $4.14 grows in 54 years to be a 40-inch tree containing 3,150 board feet worth at $5 per M feet $15.75 for the tree, which is equivalent to 2.5 per cent earnings compounded annually.

[4] A 40-inch tree (containing 3,150 feet b.m.) worth $15.75 as under footnote 3 grows in 60 years to be a 50-inch tree containing 5,388 board feet worth $10 per M feet or $53.88 for the tree, which is equivalent to 2.1 per cent earnings compounded annually.

37. Determination of stand volume growth from diameter growth and number of trees in each diameter class.—The movement of trees from diameter class to diameter class in an actual stand and their eventual appearance in the large and valuable tree sizes can be calculated as shown in table 20. These calculations may readily be made for any subdivision of the forest from records compiled in connection with the continuous inventory system discussed in chapters VIII and IX. Table 20 is based on actual conditions in a Douglas fir stand about 120 years old on Site Class II. The table covers 40 acres in which no cutting has taken place but which contains a small patch of 30-year-old trees resulting from previous fire damage.

The presence of the younger age group accounts for irregularity of growth rates in the small diameter classes of Douglas fir. The 6-, 8-, and 10-inch trees come from this patch. The young 10-inch trees are dominant and are growing at the rate of 2 inches each 3 years; the 8-inch trees are codominant and grow at the rate of 2 inches each 6 years; and the 6-inch trees are suppressed and grow only at the rate of 2 inches each 9 years.

In the older age class the trees from 12 to 20 inches are suppressed and grow 2 inches in from 18 to 35 years; trees from 22 to 26 inches are codominants and require 12 to 15 years to grow 2 inches. The fastest growth of the larger, dominant trees occurs on the 32- and 34-inch trees. Growth drops off from that point as sizes increase, owing partly to the presence of some veterans in the stand.

Cedar in the same stand shows the most rapid growth on trees from 20 to 24 inches in diameter, which grow 2 inches each 6 years. Below these sizes the cedar occurs as understory to Douglas fir and the growth falls off. Above, growth falls off as the trees increase in diameter.

TABLE 20.—*Aggregate number of trees, by diameter classes, on 40 and number, size and volume of*

Diameter breast high class	Number of trees on 40 acres before cutting (1930)			Gross volume (board feet, log scale) on 40 acres			No. of trees taken in first cut plus mortality			Gross volume (board feet, log scale) taken in first cut (includes mortality)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Inches	Douglas Fir	Western Red Cedar	Total	Douglas Fir	Western Red Cedar	Total	Douglas Fir	Western Red Cedar	Total	Douglas Fir	Western Red Cedar	Total
6	47	101	148	1,200	800	2,000	....	....	....	....	....	....
8	49	71	120	2,400	10,000	12,400	....	....	....	....	....	....
10	45	80	125	4,400	12,800	17,200	....	....	....	....	....	....
12	76	77	153	11,200	13,600	24,800	....	....	....	....	....	....
14	68	77	145	13,600	15,600	29,200	....	....	....	....	....	....
16	75	52	127	20,400	11,600	32,000	....	....	....	....	....	....
18	88	44	132	34,000	12,400	46,400	4	....	4	1,544	....	1,544
20	111	37	148	60,400	12,400	72,800	8	....	8	4,352	....	4,352
22	96	23	119	69,200	11,200	80,400	6	....	6	4,326	....	4,326
24	108	25	133	102,800	17,200	120,000	6	....	6	5,712	....	5,712
26	111	36	147	138,400	31,600	170,000	4	....	4	4,988	....	4,988
28	128	32	160	198,000	35,600	233,600	2	....	2	3,094	....	3,094
30	54	20	74	100,400	26,800	127,200	2	....	2	3,718	....	3,718
32	60	7	67	132,000	10,800	142,800	2	....	2	4,400	....	4,400
34	74	7	81	191,200	12,800	204,000	1	....	1	2,584	....	2,584
36	62	17	79	181,200	38,400	219,600	....	2	2	....	4,518	4,518
38	46	5	51	153,200	13,600	166,800	1	2	3	3,330	5,440	8,770
40	41	8	49	154,400	22,800	177,200	....	2	2	....	5,700	5,700
42	24	11	35	102,000	34,400	136,400	1	2	3	4,250	6,254	10,504
44	15	5	20	68,800	19,200	88,000	1	2	3	4,587	7,680	12,267
46	9	5	14	48,400	21,200	69,600	2	5	7	10,756	21,200	31,956
48	11	7	18	59,600	29,200	88,800	2	7	9	10,836	29,197	40,033
50	13	4	17	78,000	19,200	97,200	13	4	17	78,000	19,200	97,200
Over 50	79	22	101	871,600	180,360	1,051,960	79	22	101	871,607	180,356	1,051,963
Total	1,490	773	2,263	2,796,800	613,560	3,410,360	134	48	182	1,018,084	279,545	1,297,629
Average per acre	37.3	19.3	56.6	69,920	15,339	85,259	3.35	1.20	4.55	25,452	6,989	32,441

Growth during 5 years on "40" =2,290,520 (Col. 30) + 1,297,629 − 3,410,360 = 177,789 ft. B.M. (gross volume) on 40 acres = 4,445 ft. B.M. per acre (5 years) = 889 ft. B.M. per acre (1 year)

[1] Under selective management recruits from young developing groups will move into the 6-inch diameter class each cycle to replace trees removed in cutting.

In stands subjected to short-cycle selective management, with inventories periodically recorded as discussed in chapters VIII and IX, net utilizable growth is most easily computed by comparing successive inventories taking also into consideration timber removed in cutting. These computations are best made separately for each division of the forest. Computations in table 20 indicate how growth can be computed by these means. In this case, however, only one inventory has been taken and diameter growth was determined for each diameter class by use of an increment borer. Columns 2 to 4 show the total number of trees in 1930 from which, by means of a volume table, the total stand was computed and recorded in columns 5 to 7. The number of trees expected to be removed by cuttings and mortality are shown in columns 8 to 10 from which the volumes to be removed are computed in the same manner and recorded in columns 11 to 13.

Owing to the heavy volume of the stand used here for illustration and to the presence of a considerable number of defective veterans of more than 50 inches diameter, the first cut together with mortality for the remainder of the cutting cycle is estimated at 34,441 feet b.m. per acre gross volume. As this includes all the defective trees from 50 inches up and allows for unsalvaged losses by fire, insects, and disease, the net recovery of volume is calculated at 70 per cent of the gross cut or 22,709 ft. b.m. per acre for the "forty."

To determine the growth of the entire stand during a 5-year cutting cycle, the following simple procedure may be followed:

First, from the number of trees (columns 2 to 4) in each diameter class at the beginning of the cycle (1930) deduct the number of trees which are to be felled immediately together with the estimated mortality and further removals for the entire cycle. (Columns 8 to 10.) This will show the number of reserved trees that will be standing at the end of the cycle. (Columns 14 to 16.)

Second, by applying the percentages of trees (columns 19 and 20) that move to the next higher diameter class during the cycle to the numbers of reserved trees in each diameter class determine the number of trees that move forward one diameter class (columns 21 and 22). Add to these in each diameter class those that do not move forward (columns 23 and 24). The sum will be the number of trees in each diameter class before the next cyclic cut (1935). (Columns 25 to 27.)

Third, compute with the same volume table used for the stand at the beginning (1930) of the cycle (columns 2 to 7) the total volume of the stand at the end of the cycle (before the next cyclic cut). Volumes are shown in columns 28 to 30.

Fourth, the gross volume growth during 5 years equals the volume on hand at the end (column 30) plus the cut and mortality during the cycle (column 13) less the volume on hand at the beginning (column 7). In this case 2,290,520 (column 30) +1,297,629 (column 13)—3,410,360 (column 7)=177,789 ft. on 40 acres.

Since trees subject to the heaviest losses from defect and decay have been utilized during the first cycle a higher factor for net utilization than was used in the cyclic cut in 1930 (70 per cent) should be applied to find the net cut in the next cycle. It is estimated that utilized volume may be as high as 80 per cent of the

acres before the cyclic cut; number removed by cutting and mortality; trees on hand at end of cutting cycle.

No. of trees left on 40 acres after cutting (to survive 5 years)			No. of years to grow to next diameter class		Per cent of trees that grow to next diameter in 5-year period		No. of reserved trees that move into next diameter class[1]		Number of trees that remain in each class		Total number of trees in each diameter class 5 years after initial cut[1]			Gross volume in each diameter class 5 years after initial cut (1935)		
(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
Douglas Fir	Western Red Cedar	Total	Douglas Fir	Western Red Cedar	Douglas Fir	Western Red Cedar	Douglas Fir	Western Red Cedar	Douglas Fir	Western Red Cedar	Douglas Fir	Western Red Cedar	Total	Douglas Fir	Western Red Cedar	Total
47	101	148	9	31	55	16	26	16	21	85	21	85	106	546	680	1,226
49	71	120	6	27	83	18	41	13	8	58	34	74	108	1,666	10,434	12,100
45	80	125	3	21	100	24	45	19	0	61	41	74	115	4,018	11,840	15,858
76	77	153	35	16	14	31	11	24	65	53	110	72	182	16,170	12,744	28,914
68	77	145	31	12	16	42	11	32	57	45	68	69	137	13,600	14,007	27,607
75	52	127	27	9	18	55	14	29	61	23	72	55	127	19,584	12,265	31,849
84	44	128	22	7	23	71	19	31	65	13	79	42	121	30,494	11,844	42,338
103	37	140	18	6	28	83	29	31	74	6	93	37	130	50,592	12,395	62,987
90	23	113	15	6	33	83	30	19	60	4	89	35	124	64,169	17,045	81,214
102	25	127	13	6	38	83	39	21	63	4	93	23	116	88,536	15,824	104,360
107	36	143	12	7	42	71	45	26	62	10	101	31	132	125,947	27,218	153,165
126	32	158	10	9	50	55	63	18	63	14	108	40	148	167,076	44,480	211,556
52	20	72	10	11	50	45	26	9	26	11	89	29	118	165,451	38,860	204,311
58	7	65	9	14	55	36	32	3	26	4	52	13	65	114,400	20,059	134,459
73	7	80	9	17	55	29	40	2	33	5	65	8	73	167,960	14,632	182,592
62	15	77	10	21	50	24	31	4	31	11	71	13	84	207,533	29,567	237,100
45	3	48	11	25	45	20	20	1	25	2	56	6	62	186,480	16,320	202,800
41	6	47	12	29	42	17	17	1	24	5	44	6	50	165,704	17,100	182,804
23	9	32	12	34	42	15	10	1	13	8	30	9	39	127,500	28,143	155,643
14	3	17	13	38	38	13	5	....	9	3	19	4	23	87,158	15,360	102,518
7	0	7	15	44	33	11	2	....	5	0	10	0	10	53,780	0	53,780
9	0	9	16	49	31	10	3	....	6	0	8	0	8	48,344	0	48,344
0	0	0	17	55	29	9	0	....	0	0	3	0	3	18,000	0	18,000
0	0	0	16	55	31	9	0	....	0	0	0	0	0	0	0	0
1,356	725	2,081	....	....	....	....	559	300	797	425	1,356	725	2,081	1,919,703	370,817	2,290,520
33.9	18.1	52.0	....	....	....	....	14.0	7.5	19.9	10.6	33.9	18.1	52.2	47,993	9,270	57,263

gross volume included in the 1935 cut. As the growth is arrived at by comparing gross volumes of successive inventories it appears logical to apply the same utilization factor to the calculated gross volume growth. In this case 80 per cent of 177,789 amounts to 142,231 board feet net growth during the cycle (on the "forty") which is equivalent to 3,553 per acre for 5 years or 708 feet net per acre per annum.

It is of interest to note in passing that this heavy volume cutting, together with the accompanying felling losses and subsequent estimated mortality, removes only 182 out of 2,263 trees, an average of 4.4 trees per acre, of the slowest growing classes. More than 50 trees per acre remain and the growth capacity of the forest, of about 700 board feet per acre annually, remains practically unimpaired. No influence of release was included in these calculations.

38. **The selective system makes full use of current growth by providing an ample growing stock, including a due proportion of large diameter classes.**—Despite the insufficiency of data as to current growth and related factors that must be dealt with in effective timber management, it is possible to visualize the procedure that must be followed if stands are to be kept in a high state of productivity in terms of high-quality material. Briefly, the process involves as careful selection of trees to be held for future cutting as of timber for immediate utilization. In order to provide a continuing supply of trees of high quality a heavy growing stock, usually 25,000 to 50,000 ft. b.m. per acre in this region, is required. This will constitute, ordinarily, more than 80 per cent of the investment and will place the forest owner in position to profit currently by growth in volume, quality, and price. To maintain a favorable relationship between value of material removed at each cut and the remaining capital, special care must be taken to retain an adequate number of superior specimens of the 40- to 60-inch diameter classes.

If any other method of maintaining adequate investment returns is possible it has not yet been developed. With these methods the time required for a tree to grow to large size and quality does not have the supreme importance generally attributed to it. The aggregate growth on the merchantable size classes and the periodic removal of high-value material are the factors that spell success or failure. Total time for individual tree growth may be ignored if sufficient growing stock is maintained, and this is not an insurmountable problem in this region where a large volume of growing stock already exists.

With the exception of the depletion element in production cost the current financial results of a forest enterprise depend chiefly upon the management of the merchantable growing stock. Where the merchantable tree sizes (12 inches up in diameter) are not continuously recruited from the premerchantable sizes, it is necessary to levy a depletion charge, usually from $2.00 to $8.00, against each thousand feet of timber removed. This cost is so much greater than the cost of avoiding depletion that any timber management which incurs it through neglect must be considered as crude and ineffectual. The methods of recruiting the stand under selective management so as to avoid depletion are discussed in the next section.

39. **Development of premerchantable size classes and the recruitment and development of lower merchantable classes therefrom.**—Group and tree selection was shown to be economically feasible and in fact economically the best form of operation in the three cases described in chapters III, IV, and V. In the long run, however, the forests would suffer if such cuttings should constitute unsound silvicultural practice. Any reader familiar with the silvicultural characteristics of the species and forests of the Northwest will immediately realize that the small open spots resulting from group selective cuttings are virtually certain to regenerate abundantly to coniferous species. They provide suitable conditions for all of the species common to the region. Assuming that the clear-cut spots will constitute only about 0.5 per cent of the forest property area for each year's cut, stands on these areas, regenerating without cost, should develop through the premerchantable size classes at no cost except small acreage charges for fire protection, taxes, and administration. Under good business practice these costs would be charged to current expense; they would be incurred whether the areas restocked satisfactorily or not. Such a charge-off would impair total net income to a negligible degree at the same time that it would avoid accumulation of investment charges at compound interest.

Selective timber management with short cutting cycles will eliminate time as a paramount factor from this portion of the forest operations just as in the case of the merchantable size classes. From the financial standpoint the problem is purely one of the required size of the investment and the current expenses. The small proportion of the forest area (10 to 20 per cent) continuously occupied by premerchantable timber, the absence of merchantable timber on the cut-over spots and of costs of natural regeneration of such small clear-cut areas, will reduce the investment therein to negligible proportions. Whenever sound selective management starts with the mature forest the later investment in premerchantable areas and stands should seldom accumulate to more than 5 to 10 per cent of the total investment. The rate of earnings made by this portion of the investment can therefore have no important influence on the rate earned by the forest property as a whole.

Despite the small costs of providing recruits from the premerchantable size classes, failure to provide them will result in depletion charges (which in normal times exceed $20,000,000 annually in the Douglas fir region) against the annual cut. It is, therefore, desirable to consider in some detail the origin and development of the premerchantable stands.

Under selective operation, regeneration which will later provide recruits for the small timber class may originate under shelter of older timber as well as in small clear-cut groups. Continuous attention to maintaining density of the merchantable size classes will prevent diversion of a wastefully excessive portion of the productive capacity to regeneration and premerchantable timber and will restrict the number of recruits to the small timber class (12 to 20 inches) coming from regeneration under shelter.

To insure that there will be sufficient recruits of high quality to the small timber class in the Douglas fir region, considerable dependence must be placed on the clear-cut spots resulting from cutting of groups of trees. These group cuttings may be handled in either of two ways. The first is to cut each group independently of previous cuttings. The second (illustrated in fig. 18) follows a long-used method of group

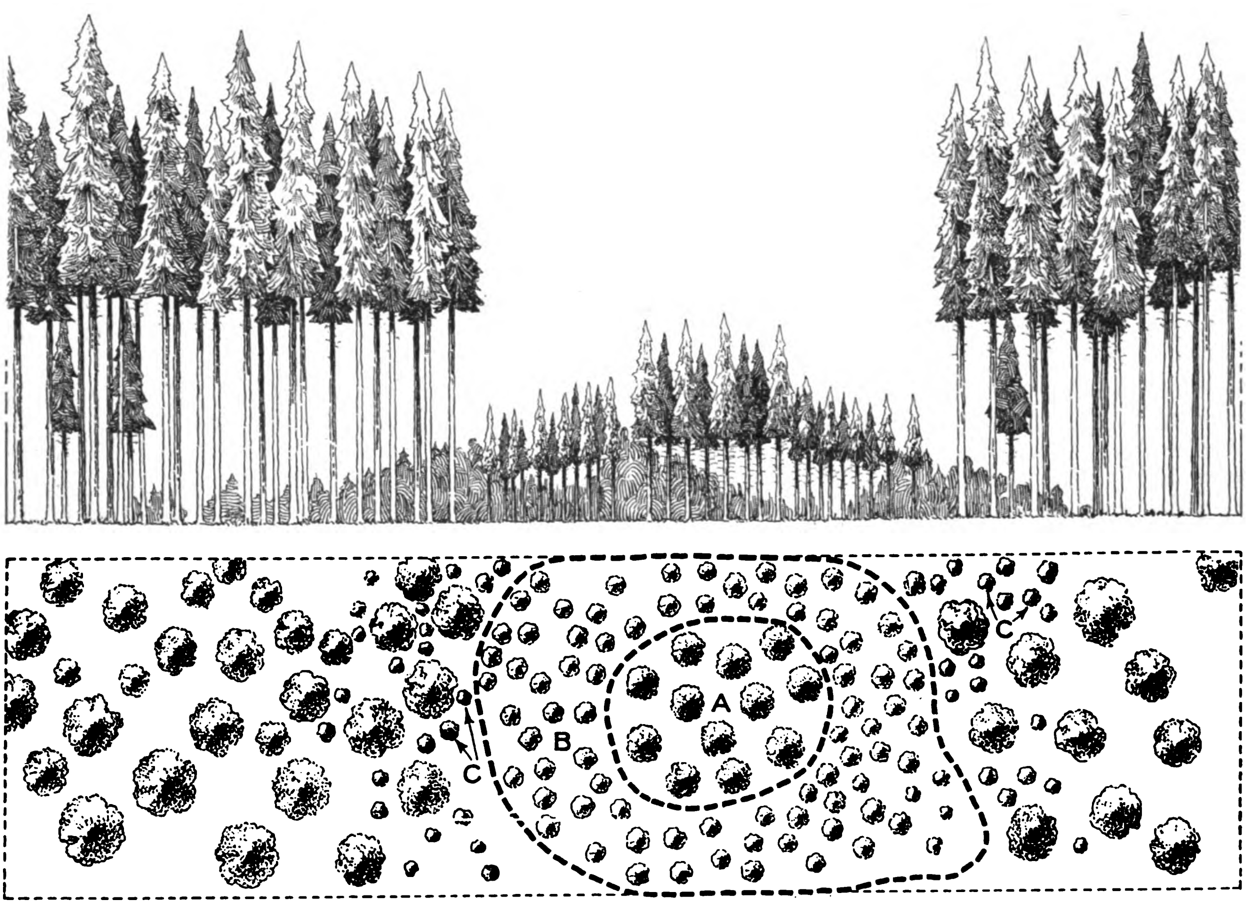


FIG. 18 – GROUP CUTTINGS ENLARGED IN SUCCESSIVE CYCLES

A-Young growth following cut of 1910
B-Young growth following cut of 1920
C-Advance growth due to presence of light from the side

cutting and consists of establishing in a given cycle a number of small nuclei which as regeneration occurs and develops are enlarged in succeeding cycles.

As a result of these methods, every coniferous species found nearby in the surrounding forest is almost certain to be represented in the young stand. This will be very advantageous for several reasons. A mixed forest is less liable to loss by insects and disease than a pure stand because many such pests attack only one species. Growth in mixed stands with species possessing complementary characteristics generally exceeds the rate in pure stands. Finally, stand management can begin earlier where some species (hemlock, true firs, spruce) are suitable for utilization in the pulp and paper industry and other industries using small trees.

It should be noted that little or nothing will have been expended for regeneration or care of the stand up to this point, except for fire protection, which will have been charged off currently against operations in the merchantable stand, together with minor amounts for taxes and administrative costs; that the area required for regeneration and premerchantable stands need be only 10 to 20 per cent of the whole; that the current earnings of the major investment are not materially reduced by charging off annually all current expense pertaining to the young stands; and that the continued addition of recruits from these stands to the merchantable classes is the sole factor which in the long run permits continued saving of the depletion charges. It should also be noted that if these productive measures are neglected and the cut-over land is held, which it must be when scattered through the property, the costs will remain the same without, however, any offset of ultimate income. It is evident therefore that no significant investment or cost need be attached to recruiting merchantable sizes and saving depletion charges under group and tree selection methods.

In a deteriorated forest lacking the more valuable species, it may sometimes be desirable after cutting to plant the clear-cut spots with strong stock of desirable species (Douglas fir, western red cedar, Sitka spruce, Port Orford cedar) widely spaced (from 12 to 20 feet each way). Species in the surrounding stand can be counted on to regenerate densely in the space between the planted trees. The cost of desirable planting of this kind on an operation cutting selectively 50,000,000 ft. b.m. annually need not exceed $500 to $2,000 per annum. This is equivalent to 1 to 4 cents per 1,000 feet current cut which can be rigidly budgeted because no definitely predictable harm will result if some spots are left entirely to the local species. The contrasting conditions on large clear-cut areas are well described in articles by Isaacs on seed flight *(15)* and seedling mortality *(16)*.

The desideratum in group regeneration is ample density. This will cause some retardation in individual tree development but will insure killing of side branches at about lead pencil size or slightly larger, before formation of branch heartwood. This will favor early decay of side branches and clearing of the trunks. These dense young stands should remain undisturbed until side branches are dead on the lower 35 to 50 feet of trunk at a probable age of 40 to 60 years. By this time on Sites I and II, 100 to 125 trees per acre should have reached or surpassed the 12-inch diameter class —or enough to establish the future stand.

As the trees in these groups attain sufficient trunk length clear of live branches and move into the small merchantable class, it becomes desirable to thin the stands and prevent further loss of basal branches of the crown. As the trunk cannot be actually cleared to a height much above 50 feet by death and early decay of the side branches it is better that the upper branches remain alive and form sound knots than that they die and form black and oftentimes loose knots. If the stand consists of a well-distributed mixture including the better pulp species (spruce, hemlock, or true firs), pole and post species (cedar), and lumber species (Douglas fir and large trees of the foregoing), stand management can begin as soon as natural pruning is sufficiently advanced. The possibility of thinnings depends on market conditions. If the smaller trees cannot be marketed as poles, posts, pulpwood, etc., it may be desirable to reduce density by taking out a portion of the dominant trees 12 inches d.b.h. and over for poles, piling timber, and common lumber, thus allowing the codominant trees to develop into the permanent stand. This practice would tend to favor development of timber with thinner annual rings toward the heart of the tree (as preferred for structural timber) but would somewhat retard the development of large tree sizes. These operations should be carried on at the time of the regular cyclic cut. The small timber should usually be skidded by horses or small tractors or cut into cordwood and hauled out over the permanent forest roads.

Each cutting should aim to favor trees which will grow in value if left standing. This being less true for such pulpwood species as hemlock and true firs, early cuttings may consist largely of these together with less promising individuals of other species if any market is available. Later, small saw-timber trees of the major species may be cut in order to speed development of the main-crop trees. These cuttings should be at frequent intervals and not too heavy, so that continuous development of high quality material with uniform grain will be going on in the reserved trees, and so that the fire hazard from slash will be kept at a minimum.

Investigation of stocking in large areas of even-aged stands proves that it seldom averages over 80 per cent of yield-table standards *(21)*. There is no practical way under the extensive clear-cutting system to build up to higher standards. Under group and tree selective methods frequent attention to each part of the stand provides better opportunity to improve density. The objective in developing groups should be to maintain spacing which will utilize the full productive capacity of the site and build up a volume of 100 thousand feet or more per acre by the time the group is ready for another final cutting as a group. In this manner high yields will be maintained.

It is obvious that if the cost for the permanent roads established and charged-off in connection with selective removal of the virgin timber had to be charged against the thinnings these would be loaded with construction charges which would in most cases prohibit early cuttings. The result would be indeterminate losses of trees crowded out of the stand and retardation of growth on those that remained. When, therefore, selective management of young stands is combined with similar treatment of mature stands the cut of fully matured saw timber, together with the salvage of trees killed by fire, insects, and disease, the avoidance of losses in natural crowding, and the saving of merchantable growth through restriction of regenerating areas will all sum up to a much greater yield than can be obtained by intermittent management under the clear-cutting system.

40. The important influence of growth in volume, quality, and price on financial earnings of forest properties.—The data herein presented show, in some measure, the great variation in rates of diameter and volume growth with site conditions, character of the tree as to crown class and position in the stand, stand density, and other factors. A very important characteristic of the species of the Douglas fir region is their ability (as shown by table 17) to maintain substantial rates of growth to diameters as large as 80 inches.

The influence of volume growth on management cannot, however, be properly evaluated unless its relation to quality and price increment is recognized.

Overlooking these relations has led many foresters to the erroneous conclusion that forest properties cannot earn in excess of the percentage rate of volume growth. As annual growth of conifers in the northern United States ordinarily varies from about 0.5 per cent to 6 per cent of the existing volume of the tree or stand, it has been erroneously concluded that the capital invested in forest property, when management costs are deducted, must earn at an even lower rate *(26, 28)*. Such a conclusion holds only for poorly managed forests where the average value per unit of the timber cut annually is approximately equal to the average value per unit of the growing stock. This is a condition which the competent forest manager should constantly strive to avoid by keeping an ample growing stock of well-distributed sizes and values so that the annual cut can include the largest possible proportion of timber with values exceeding the average value of the growing stock.

The effect of a desirable distribution of values can be readily visualized by considering any one of numerous forest tracts of the better site quality in the Douglas fir region within 50 miles of tidewater. In these, about 30,000 board feet per acre of properly selected merchantable growing stock, plus an adequate representation of premerchantable sizes, is capable of producing about 600 board feet of growth annually and hence allows an annual cut of that amount. This growth includes the volume of trees recruited annually from the premerchantable into the merchantable size classes (12 inches diameter and larger) and is at the rate of 2 per cent annually on the merchantable growing stock. (This is about two-thirds of the rate in European forests of similar character under selective management.) As the saw-timber growing stock includes all sizes down to 12 inches diameter and is in part below zero conversion value, its value averages about $1.50 per M or $45.00 per acre, to which may be added $1.50 for land investment and $3.50 for investment in forest improvements, bringing the total to $50.00. This under competent management may be considered a fairly stable permanent investment value, based mainly on conversion values of various elements of the growing stock.

By selecting annually at least 50 per cent of the cut from the highest values which are available in the forest (i.e., from trees more than 40 inches in diameter) the stumpage conversion value of that portion of the cut should not be less than $8.00 per M board feet under present conditions. The other half of the cut can be thought of as coming from thinnings and salvage selected for the benefit of the stand among the lower diameter classes and inferior species from 12 inches up, and valued at about the average value of the entire growing stock ($1.50 per M board feet). With this distribution between the two classes the weighted average value of the annual cut is $4.75 per M. Since the assumed annual cut is 600 board feet per acre, $2.85 is the annual return per acre. This annual return on a total investment of $50.00 constitutes a gross percentage return of 5.7 per cent, which is nearly three times the gross rate of growth. From this must be deducted from 2 to 2.5 per cent to cover expenses for taxes, fire protection, and administration, leaving a net return of from 3.7 to 3.2 per cent on the total investment. Such a rate of earning is possible only where a reasonable proportion of the stand is grown to sufficiently large sizes to reap the full returns from increment in volume, quality, and price. Under liquidation the premerchantable sizes and negative value merchantable sizes will be destroyed and all future returns from this source will be sacrificed.

If on the other hand the timber to be cut is carelessly selected so that its unit value only equals the average unit value of the stand, as often happens under clear cutting, the gross percentage return on the investment in growing stock, soil, and forest improvements will be only 1.8 per cent. As before, from this must be deducted from 2 to 2.5 per cent for management expenses (possibly a little less owing to cruder management methods), leaving a negative return on the investment. This less effective type of management coincides with the conclusions of the authorities cited *(26, 28)*. Furthermore, if continuous stand management is neglected the rate of growth will soon fall off.

In the foregoing example the standing timber (growing stock) is valued at its net conversion value under present market conditions; the soil is given a nominal value corresponding closely to present sale value of areas stripped of timber; and the forest improvements are valued as if mostly written off against past use in timber extraction. These are all definitely known values for the chief elements involved, which in the aggregate constitute a sound appraisal of the forest investment according to present knowledge. They are ostensibly the values at which the property thus correctly appraised could be immediately liquidated. In actual practice the attempt thus to liquidate many speculatively held properties has proved impossible, owing to the inability of the market to absorb more than a small fraction of the offerings. It was through this liquidating process that the wreckage of timber values was well advanced even prior to the depression which started in 1929.

With the progress of sound continuous yield management of any forest property a different method of determining investment value is almost certain gradually to take effect. This consists of "capitalization" of the net income, using a rate of interest commensurate with the stability and assured permanence of the income. Thus a property with net income of $10,000 per year at present, but of somewhat uncertain future, might be capitalized on a 10 per cent basis, in which case:

$$\text{Capitalized value} = \frac{10{,}000}{.10} = \$100{,}000.$$

If the income is very stable under present and expected future conditions the capitalization rate may be 5 per cent, in which case, the

$$\text{capitalized value} = \frac{10{,}000}{.05} = \$200{,}000.$$

If the income is not only stable and assured but if the type of business possesses other attractive features such as the satisfactions usually associated with land ownership, the probability of future price increment, etc., the capitalization rate may be as low as 2 to 3 per cent. At 3 per cent the capitalized value becomes $333,333.33.

In Europe forest properties are usually capitalized at an interest rate of 2 to 3 per cent. A recent observer states that in Germany "under conditions of prosperity these forests (privately owned) only return between 2 and 3 per cent on the investment" *(26)*. This situation is the source of a curious misconception not infrequently expressed by forest owners and even by foresters. According to this idea "the earnings of forest property are low." Those who hold this view overlook that earnings are the basis of capitalized value and that where capitalization is at a low rate of interest it is an expression of desirability of that class of property. Owners will not sell unless they receive a price on which the property is earning only 2 to 3 per cent. Likewise, buyers bid properties up to high price levels based on income capitalized at a low rate under the same conditions. If the properties were less desirable buyers would bid less and owners would sell more cheaply. Capital flows from undesirable investments to safe and desirable ones even though the earnings are low.

Reverting now to the example cited, where in well-managed stands about 30,000 feet of growing stock per acre can be expected to produce 600 board feet of annual cut per acre worth about three times the average value of the growing stock, the net earnings of about 3.7 per cent under selective operation with value as stated may be expected to increase investment values somewhat beyond the present level of $50.00 per acre. On the other hand poor management, cutting timber of only average value and yielding a very low percentage on the investment must be expected to reduce value well below $50.00 per acre.

In order to produce high-value timber, which must be available if the high-earning type of management is to be used, from 2 to 5 per cent of the number of trees on the forest property must be carried until they reach large size, attainable at an age of 125 to 200 years. This is illustrated by table 12, chapter V. It can readily be ascertained by consulting any standard book on forest finance that the cost of producing large timber by carrying extensive even-aged stands from seed to a maturity as late as 200 years, without material intermediate returns but with expenses of originating and annual care of the stand accumulated for the whole period, is excessive. Even for shorter rotations the defects of the method consist, among others, of devoting too much expense to regeneration; too much space to premerchantable size classes; too much growth laid on small trees, of which 75 per cent or more never reach utilizable size; and, most disadvantageous of all, depending upon average growth in stands containing many slow-growing trees.

In contrast, selective management aims to hold regeneration down to the quantity actually necessary; to favor the best formed and most vigorous trees in order to obtain rapid growth; and continuously to devote productivity of the soil so far as possible to increment on merchantable size classes, including many trees on which growth contributes much clear wood. In forests thus managed selectively on short cutting cycles, expenses are charged off currently and net income can be accurately gauged. Time affects returns only through requiring an adequate investment in growing stock. In the Pacific Northwest the time involved in the production of growing stock lies in the past and the investments already exist. The growing stock is present in ample volume except where it has been removed on large clear-cut areas. Only the relatively simple problems of physical preservation and management to maintain productivity and capital value have to be solved. Under these conditions the continued production of valuable large sizes should be perfectly feasible, as is brought out in the examples cited in chapters III, IV, and V.

Price increment.—In the foregoing examples the differences in value between small and large trees are due to quality increment. The favorable earnings depend on this factor and not on price increment, which, under conditions of the last 50 years, has been almost continuously adding to timber values in the Douglas fir region and hence to earnings of the timber investment. Price increment is in many cases an "unearned increment" but in virgin timber, involving care of a forest property for many years before prices reach a profitable operating level, it is in part earned. From now on price increment is not necessary to the successful management of most forest properties in the Douglas fir region. Nevertheless it will probably continue to contribute to earnings and therefore to higher capitalized values of forest properties. In spite of its general importance it is of subsidiary importance in the present discussion, and is not dealt with in this report. The past record of log prices (which are the basis of stumpage prices) in the Puget Sound market is given in a recent article in the Timberman *(23)*.

41. The effect of removal order of different timber values and of the order of making forest improvements on forest earnings and financial maturity.—The somewhat voluminous data so far considered in this report are sufficient to show that a forest stand and a forest property comprehend many diverse and dynamic values, and that the successful forest manager must be alert to select and utilize these values at the proper time. This is a matter of controlling income.

In like manner the control of expense may be accomplished through holding costs to a level that will permit complete annual charge-off or, if that is impossible, the least possible charge to capital account with subsequent annual capital charges. These factors can in considerable degree be controlled through the order of cutting. Taking these several matters into consideration there are three principal ways in which the net income available under good management, as discussed in section 38, can be kept at a maximum.

(a) Avoid losses involved in holding timber of stationary or declining value.

(b) Avoid losses due to premature construction of forest improvements.

(c) Conduct operations in a maner to avoid capital investment which will result in continued capital charges against operations over a term of years. These three management measures will be briefly discussed.

Avoiding losses by holding timber of stationary or declining value.—The heavy losses certain to be incurred through wrong order of selection in large long-term properties are forcibly illustrated in the example discussed in chapter III. Only brief reference to this factor is therefore necessary at this point. Table 21 shows the losses suffered by holding each dollar of stationary value for several periods of years at different discount rates. Complete interest and discount tables are to be found in standard works on forest finance and valuation of which four may be cited *(8, 9, 25, 27)*.

TABLE 21.—*Discounted (present) values of $1 of income due at various future times*

Discount period	Interest rate 3%	5%	8%	10%
Years	*Dollars*	*Dollars*	*Dollars*	*Dollars*
5	0.86	0.78	0.68	0.62
10	.74	.61	.46	.38
15	.64	.48	.32	.24
20	.55	.38	.21	.15
25	.48	.29	.15	.09

The meaning of these discount factors in practice is that losses will occur on all elements of the stand which do not increase in value proportionately to the time they are held. This is because if the values were converted to cash, and the cash successfully invested, interest could be earned on the investment. Even at the rate of 3 per cent, deferment of income of $1.00 for 5 years reduces it to a present value of 86 cents. The timber values which are subject to these losses include, in general, all dead timber, timber in which decay equals growth and which is not increasing in price, and any other timber in which values are stationary or declining. It is probable that losses from these causes in the Douglas fir region exceed the net income of the operating industry. The only way to prevent them is through an intelligent continuing process of selective management which will continually remove matured values and leave standing in the forest the great mass of timber that is still making satisfactory earnings from one or another of the three forms of increment.

Avoiding loss by premature construction of improvements.—These losses are, in effect, the reverse of what occurs in the previous case. By opening up tracts or portions of tracts in the wrong order, untimely capital charges are created, involving loss of capital charges that run on until the year in which the work would have been done under better planning. The examples given in chapters IV and V show that conversion values can be immediately raised through starting and continuing cutting operations on portions of tracts where construction costs are the lowest. This is in large measure a permanent gain, little of which has to be sacrificed later. This is true because the saving of capital charges by deferment will in many cases equal the cost of later construction. In addition to this factor, the improvements (mostly roads) first constructed will continue to have sufficient utility to adjacent timber to obviate making them a charge against more remote timber which may also come out over them. Where growing stock is maintained the cost may also be spread over the timber added by growth and the unit cost further reduced.

Charging forest improvements to current expense.—The examples given in chapters III, IV, and V show that, when a proper order of cutting is followed, all local improvements can be charged directly to current operations and still maintain low logging costs and high conversion values. If charged to capital they will create capital charges, chiefly interest and depreciation, which may amount to from 20 to 50 cents per dollar of investment until charged off, and which will thus become a burden on future operations, especially at the lower point of the business cycle.

Charging these costs to current operations does not impair the utility of any improvements capable of further use. It simply means that they have been paid for in full through efficient operation and yet that they remain to contribute to earnings in the same manner as the soil and growing stock. If the enterprise continues to be efficiently handled they will become a part of the investment value arrived at by capitalizing the earnings of the property (sec. 40).

Financial maturity.—Financial maturity of a tree or group of trees is reached at the time when the sum of its earnings from volume, quality, and price increment culminates or when this no longer equals the reasonable minimum earning rate above which the forest owner aims to hold all forest property-investment elements and below which he endeavors to withdraw the realizable value and reinvest it elsewhere, either in some part of the same property or in another form of investment. The realizable value is the actual net conversion value at a given time. Under present unstable conditions of prices the precise point of financial maturity cannot be determined but careful analysis will disclose the relative earnings of different timber classes and show the correct order of liquidation. In time, when stability again returns, more precise determinations will be possible.

Recovering stationary and declining values, avoiding premature construction, and currently amortizing local improvement costs, will all tend to lift total conversion values to the highest level possible under sustained yield and thus to assure the highest net income from the property. In some instances, however, this income may be obtained at the expense of leaving too much investment in certain elements of the growing stock, unless attention is paid to removal of financially mature timber which is not earning the interest rate at which the forest owner capitalized his property.

Trees of relatively high earnings may be cut among the smaller timber when their removal will improve earnings of remaining trees, but a more conservative selection policy should govern in the case of larger timber whose removal abolishes for the time being all earnings of the immediate area it occupies.

It was pointed out in chapter III that so long as there is a major debt against a property the capitalization rate should equal the rate of interest paid. This is usually 6 or 7 per cent, but includes risks and costs to the lender which on the average of his diversified investments seldom leave him with a net rate of over 3 per cent. This conclusion is also in accord with known facts concerning net earnings of common stocks and other forms of investment, and with the fact that the accumulation of the Nation's wealth does not exceed such a rate over long periods when the losses accompanying depression periods are considered. After all debt has been discharged the relative safety of the forest investment warrants use of an interest rate not over from 2 to 3 per cent in most calculations. An even more important reason for employing a low rate of interest lies in the fact that any tree or group that is retained will share in meeting the fixed charges and will help to offset the lack of direct earnings of such portions of the investment as the soil and the forest improvements. These elements of the investment are wholly dependent on the growing stock for any earnings.

The industrial and community advantages of maintaining the millions of acres of privately owned forests in such condition that they will be capable of earning safely 3 per cent net, as compared to adding them through clear cutting to the millions of acres already stripped of forests, are beyond question. Such properties can provide continuous employment in the forests and in the forest industries for large numbers of persons.

CHAPTER VII

CHANGES IN FOREST FIRE HAZARDS AND OTHER ELEMENTS OF RISK RESULTING FROM SELECTIVE SUSTAINED YIELD MANAGEMENT

42. The fire hazard in the Douglas fir region.—The Douglas fir region, in spite of the high annual precipitation over much of its area, usually has an acute shortage of rain during the summer months. This midsummer drought dries the forest, particularly where openings or clearings expose the interior to direct sunlight and wind, to a high degree of inflammability. Wherever a large mass of combustible material has accumulated in these luxuriant forests, and becomes thoroughly dried out, any fires that start are likely to gain great momentum and be difficult to stop. Under conditions of low atmospheric humidity and high wind velocities there is danger that fires will "crown" and spread rapidly through the tops of trees killing all in their path. Any system of forest management must take into account very seriously measures for controlling fire and must provide sufficient funds to do so. Without proper provisions to abate extraordinary fire hazards and to prevent and suppress fires, there is always the possibility that considerable portions of the forest capital may be wiped out and efforts for sustained yield management be partly defeated. It is a paramount consideration, therefore, that the forest management of this region provide a method of cutting and a method of slash disposal or fire suppression that will keep the fire hazard to the minimum, and make certain the control within reasonable limits of the fire menace.

The fire danger is by no means uniform over the region. Variations in climate alone create a decided range in the hazard. In the "fog belt" of the immediate coastal strip and in many of the moist valleys of the northern Cascade Range the number of "fire days" per annum is much less than in the low-lying lands east of the Coast Range or on the foothills of the Cascade Range for example. Then, too, the nature of the forest cover has a profound effect upon the incidence of fire. Open areas exposed to the drying effect of sun and wind are more subject to the incidence and spread of fire than areas of continuous crown cover. Widespread conflagrations such as the Tillamook burn of 1933 may occur, however, even where there is continuous crown cover. The amount of inflammable debris on the ground and of dead or partly dead trees and snags also contributes largely to the fire danger. Clean-cut areas with undisposed slash are recognized as ranking highest in hazard.

The methods of management applied to a given type of stand will profoundly influence the hazards arising from these various factors. Some methods of management materially increase hazards while others operate to reduce or eliminate them. The conditions in various types of stands deserve further discussion.

Conditions in heavily stocked unmanaged stands.—The old-growth Douglas fir forests contains numerous fire hazard factors such as snags, stag-headed, moss-covered, defoliated and defective trees, and heavy ground debris. Where such hazards occur in excessive degree such as following widespread defoliation by insects, extensive windthrow, or partial damage from previous fires, a very serious conflagration hazard may exist. In its normal state this type of forest is relatively safe from fire because these elements are generally widely distributed through the forest and isolated by intervening walls of green timber, and the dead material on the ground is progressively rendered innocuous by decay, the progress of which is hastened by the humidity maintained within the forest.

The quantity of litter and debris produced naturally within the typical Douglas fir forest is far in excess of what is apparent to the casual observer; Nature, when not circumvented by fire or other adverse factors, clothes every acre with practically all the vegetation it can support. Under normal conditions from one-fourth to one-half of the total quantity of coniferous foliage falls from the trees every year. Practically every tree loses some live twig and branch material annually through the action of wind, snow, ice, and other elements. Through a great part of the life of the tree the lower branches are being killed by the deep shade of the dense stand. The dead branches are gradually weakened by decay and fall off. To the age of 100 years or more, the struggle for existence in a normally stocked stand is intense, resulting in natural thinning whereby entire trees are constantly being added to the debris on the forest floor. For example, the Douglas fir yield table for Site II (*20*) shows that from the 20th to the 40th year the average even-aged stand declines from 880 to 385 trees per acre; in other words, at this early stage of development more than half the total number of trees die out of the normal stand within a period of 20 years. Usually trees of that age are left to decay on the forest floor. This process of elimination continues as the stands grow older, though for a time its pace gradually decreases. Among trees of approximately the 20- to 50-inch diameter classes the loss in numbers is less, because natural thinnings have practically been completed and because of the vigor of trees of these sizes. Nevertheless small percentages of these trees are constantly being added to the debris through windfall and other natural causes, so that at the age of 300 to 400 years only 10 to 30 trees of the original stand will remain on the average acre; in other words, out of 100 trees that reach 40 years of age about 95 will drop out before the stand reaches 300 to 400 years. Among trees more than 50 inches in diameter the loss in numbers is not so great but generally some trees are attacked by fungi, or are defoliated by insects, or become stag-headed owing to such factors as failure of moisture to reach the tip of the crown. Such trees gradually lose large branches and tops of their crowns and eventually become windfalls or snags. Finally, all the shrubs, herbaceous plants, and other minor vegetation of the forest add their quotas to the dead material on the forest floor.

In a forest where none of the wood or other plant material is utilized or removed, the entire annual production sooner or later becomes debris. Precise data are lacking, but it is probable that within the merchantable timber classes the annual loss (usually offset by growth) over large areas ranges on the average from ½ to 2 per cent by volume; for the rest of the vegetative cover, such as herbs, shrubs, leaf fall, etc., the annual turn-over from living plant to debris is, of course, proportionately much greater. Some of the resultant litter and debris, such as that represented by the annual deposit of leaves, twigs, and needles, is produced at a fairly uniform annual rate, spread uniformly through the forest, and consumed through oxidation and decay at about the same rate as it is produced, leaving a mat of duff and surface litter of about constant depth and character. Some of it, such as that caused by windthrow, occurs at irregular intervals in the life of the stand and may at various times accumulate here and there in large amounts.

These general facts about the amount and character of debris and the presence of other extraordinary fire hazards in the unmanaged forest should be kept clearly in mind in attempting to visualize the conditions created under selective timber management.

Fire hazards under various conditions.—Some idea of the relative physical susceptibility to fire of various types of forest cover may be gained from table 22, which gives in condensed form some of the results of an exhaustive statistical study made by H. B. Shepard in 1930-34 *(29)*, in an effort to rate for forest insurance purposes the hazard of various types of cover and exposure. This study, based on the fire record of the Douglas fir region for the 10 year period 1921-30, shows that fire hazard varies to a considerable degree with class of stand and according to certain factors such as the presence or absence of slash and snags, but that fire losses in stands of merchantable size are on the whole remarkably low. Thus table 22 shows that the rate of loss (i.e., the ratio between the net volume of timber lost through fires and the total volume of timber exposed to fire) excluding major conflagrations,[7] amounts only to 0.033 per cent[8] per annum for class I[9] stands (the volume of which is mainly in trees 20 to 40 inches in diameter) and 0.049 per cent[8] per annum for class II[9] stands (old-growth stands, the volume of which is mainly in trees more than 40 inches in diameter). For immature stands on the other hand the loss rate is comparatively high; and for logged-off land that has not yet restocked, the burning ratio as stated in chapter I is exceedingly high.

Of particular significance is the high loss rate (0.921 per cent) for class V stand, which, as defined by Shepard *(29)*, consists of reproduction less than 25 feet in height. This rate of loss is approximately 20 times as great as for merchantable timber (class I and II). This is primarily because young regeneration is inherently more susceptible to damage by fires of ordinary intensity than larger trees, which have thick bark, clear trunks, and crowns far above the forest floor, and because the numerous large, continuous areas of small young growth which have followed clear-cutting or large fires enjoy a much less favorable local climate (from the standpoint of fire hazard) than stands of older timber.

It should be borne in mind that the low ratio experienced in old-growth stands may be partly due to the fact that these forests are situated in large measure away from human habitation in great unbroken tracts, where lightning fires were infrequent and man was the only possible causative agency.

General effects of management methods.—The objective of selective timber management is to maintain, or if it is absent to build up, a heavy growing stock composed largely of merchantable size classes which are the least susceptible to fire damages. Also, through short cutting cycles and light cuttings directed toward the removal of mature and declining elements of the stand selective management aims at continuous utilization of merchantable portions of the trees which in the unmanaged forest contribute, as described above, to the debris on the forest floor. In contrast to this gradual but continuous attrition of the supply of forest fire fuels, extensive clear cutting, as so far practiced in the Pacific Northwest, leaves the natural accumulation from windfalls and other sources to accumulate in the uncut forest. On the cutting areas the stand, including both merchantable and unmerchantable trees, is destroyed at one time with the consequent creation of large masses of debris which are generally removed in part by slash burning.

43. Differences in fire hazard in the forest and in the open.—Reasons for the lower fire hazard in the forest than on cut-over land have been intensively investigated in some of the forest regions of the United States as well as in Europe. The results of all these investigations bring out in a consistent manner the important influence of the forest on various local climatic factors which affect fire hazard. In the United States comprehensive studies along these lines on which published results are available have been conducted by, among others, Stickel *(30)* in the western Adirondacks and Gisborne *(11, 12)* in northern Idaho. These

[7] The so-called "Tillamook fire" of the summer of 1933 was the only "major conflagration" in the Douglas fir region in the 31 years beginning with 1903. The estimated loss of class I and II stands from the Tillamook fire when prorated over a 20-year period is about twice as great as that from all other fires combined.

[8] These are net-after-salvage figures. Corresponding rate of loss before salvage is 0.045 per cent for class I and 0.103 per cent for class II stands. For class III, IV, and V stands no salvage allowance is made.

[9] The hazard classes designated by Shepard are defined in footnotes of table 22; although roughly equivalent to, they differ in some respects from the stand classification used by the Forest Survey.

TABLE 22.—*Rate of fire loss[1] for the 10-year period 1921-30 for five forest classes in the Douglas fir region as affected by various hazards.*

(Data furnished by H. B. Shepard.)

Character of Hazard	Forest Class I[2]			Corresponding loss rates for forest classes			
	Exposed	Lost	Rate of Loss	II[3]	III[4]	IV[5]	V[6]
	M ft. b. m.	*M ft. b. m.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Fern, brush, grass	68,372,000	11,120	0.016	0.014	0.374	0.031	0.568
Recent cutovers	8,016,320	6,913	0.086	0.024	0.181	0.187	0.999
Snags	10,739,160	43,100	0.403	0.661	0.712	0.704	12.570
Slash[7]	4,008,160	17,980	0.449	1.555	0.432	1.123	11.590
No special hazard	74,003,520	15,595	0.021	0.003	0.411	0.021	0.662
Steep slopes	30,700,000	35,017	0.114	0.171	0.145	0.163	1.683
Moderate slopes	104,100,000	16,087	0.015	0.017	0.027	0.035	0.771
Level	19,600,000	504	0.003	0.006	0.076	0.058	0.525
Heavy density	69,530,000	10,760	0.015	0.076	0.044	0.053	0.321
Moderate density	63,500,000	39,090	0.062	0.041	0.066	0.066	1.550
Light density	21,370,000	1,758	0.008	0.001	0.047	0.089	0.412
Pure Douglas fir	89,868,000	44,641	0.045	0.040	....	0.060	....
21-50% hemlock	19,760,000	4,705	0.024	0.116	....	0.223	....
51-80% hemlock	10,770,000	467	0.004	0.022	....	0.059	....
Pure hemlock	14,410,000	179	0.001	....	....	....	....
21-50% cedar	4,260,000	1,405	0.033	0.513	....	0.113	....
51-80% cedar	1,986,000	....	....	....	....	0.092	....
Pure cedar	1,186,000	....	....	0.008	....	0.167	....
21-50% other	3,909,000	211	0.005	....	....	0.083	....
51-80% other	3,998,000	....	....	....	....	0.008	....
Pure other	4,253,000	....	....	....	....	....	....

[1] Excludes "major" conflagrations as explained in text.

[2] Thrifty merchantable, consisting mainly of trees 20 to 40 inches in diameter; the lowest hazard class. Details on the volume of timber exposed and the loss for each hazard are given only for this class. Total volume exposed 154,400,000 M ft. b. m.; total annual loss (net after salvage) 51,608 M ft. b. m.; average annual rate of loss, 0.033 per cent.

[3] Overmature merchantable, consisting mainly of trees more than 40 inches in diameter. Total volume exposed 157,200,000 M ft. b. m.; total annual loss (net after salvage) 77,411 M ft. b. m.; average annual rate of loss 0.049 per cent.

[4] Small poles consisting mainly of trees more than 25 feet in height and less than 6 inches in diameter. Total area exposed 784,000 acres; total annual loss 446 acres; average annual rate of loss 0.057 per cent.

[5] Large poles consisting mainly of trees 6 to 19 inches in diameter. Total area exposed, 3,542,000 acres; total annual loss 2,230 acres; average annual rate of loss, 0.063 per cent.

[6] Reproduction less than 25 feet in height. Total area exposed, 1,324,000 acres; total annual loss, 12,194 acres; average annual rate of loss 0.921 per cent.

[7] Slash exposure obtained by taking ⅓ of area cut over 1928-30. Balance into recent cut-over (weed) areas.

and other studies have shown remarkable contrasts in humidity, wind velocity, surface and air temperature, moisture content of the duff, and other fire hazard factors between forested and adjoining non-forested areas. Gisborne *(12)* has summarized his findings on differences in these factors as shown in table 23.

In the Douglas fir region this subject has not yet been investigated except in a preliminary way but some data on certain fire hazard factors were obtained during the fire season of 1933 at the Pacific Northwest Forest Experiment Station. These data are graphed as figure 19. They show surface and air temperatures, wind movements, etc., within the forest as contrasted with adjoining areas in the open. A striking similarity is found between these data and those obtained by Stickel, Gisborne, and others.

These data bring out forcefully that the well-stocked forest maintains a climate of its own characterized by the presence of much moisture in the air, in the soil, and in the material on the ground and by slower air movements and lower temperatures, both on and above the ground. The reasons for these differences are that in the forest evaporation takes place at a lower rate, air movement is retarded by the presence of the tree crowns and trunks, the tree crowns absorb the direct sunlight, and the atmospheric moisture supply is constantly augmented by transpiration from leaf surfaces.

These differences in climatic factors as influenced by the presence or absence of a forest cover are very significant. Fire protection experts have shown that such differences in relative humidity, wind velocity, etc., may frequently spell the difference between comparative safety and catastrophe, between numerous days of exceedingly high fire danger and relatively few days of moderately high fire danger; between a long fire season and a short one; between severe and moderate fire losses.

44. Changes in fire hazard as a result of cutting.—Any appreciable amount of cutting of standing trees in the Douglas fir forests will increase the fire hazard not only by opening up the canopy to wind and sun, but also by creating inflammable slash in the form of foliage, branches, and tops of the felled trees. The extent to which this will increase the fire hazard will depend in part upon the quantity of slash and the condition in which it is left, and in part upon the degree to which the stand is opened up by cutting. To cite the extreme, clear cutting over large areas and cable yarding as now customarily practiced in this region create the maximum of fire hazard, both because of the accumulation of vast quantities of fuel and because the local climate is changed to that of unshaded open land. On the latter point Gisborne *(12)*, in commenting on his findings as to the results of partial cuttings (see table 23), states:

"It is also evident in these measurements that removing half the timber canopy . . . did not result in drying out the site to a condition half-way between that of the full-timbered and clear-cut areas. This is shown by the fact that the measurements on the half-cut area resemble more closely those for the fully timbered than those for the clear-cut area. In other words, although half the crown canopy was taken out, the danger was not increased proportionally."

A similar situation is shown by the data in figure 19. On the heavy-cut area the residual stand is composed of premerchantable and unmerchantable timber which makes up approximately 30 per cent of total basal area of the original stand counting all trees above 8 inches in diameter. Even in the case of so heavy a cut it will be seen that the climate is measurably modified as compared with that of the clear-cut area.

Slash from extensive clear cutting creates a serious problem.—Under clear cutting with cable yarding, according to studies made by A. H. Hodgson *(14)*, the average quantity of slash per acre in typical Douglas fir logging operations amounts to about 43 cords (approximately 21 M feet, log scale) of sound material of cordwood size and larger plus 7 per cent of the original cubic volume of the stand in the form of unusable broken pieces, decayed material, etc. Not all this slash originates from trees that are actually utilized; much of it comes from trees below merchantable size that are torn down or shattered under the destructive cable-yarding system and from excessive breakage in the felling and yarding of merchantable trees. In addition, the logging debris includes the entire volume of twigs, foliage, and underbrush.

This vast amount of inflammable debris coupled with destruction of the forest climate sets the stage for a fire situation that is extremely difficult to cope with.

TABLE 23.—*Measurement of factors in fire danger on uncut, half-cut, and clear-cut forest land, northern Idaho, August 11-20, 1931*

(Data by H. T. Gisborne) (12)

Factor measured	Uncut area	Half-cut area	Clear-cut area
Average maximum air temperature..........°F	83.9	86.9	90.6
Average relative humidity at 5 p. m..........per cent	23.4	19.0	16.8
Average wind movement..........miles per day	2.0	24.8	49.6
Evaporation rate..........grams per period	34.7	93.4	206.7
Average maximum temperature just below surface of duff..........°F	78.8	93.6	133.3
Highest duff temperature..........°F	85.0	102.0	148.0
Average moisture content of duff..........per cent	10.5	9.9	4.6
Average moisture of 2-inch diameter dead wood..........per cent	8.3	7.2	3.8

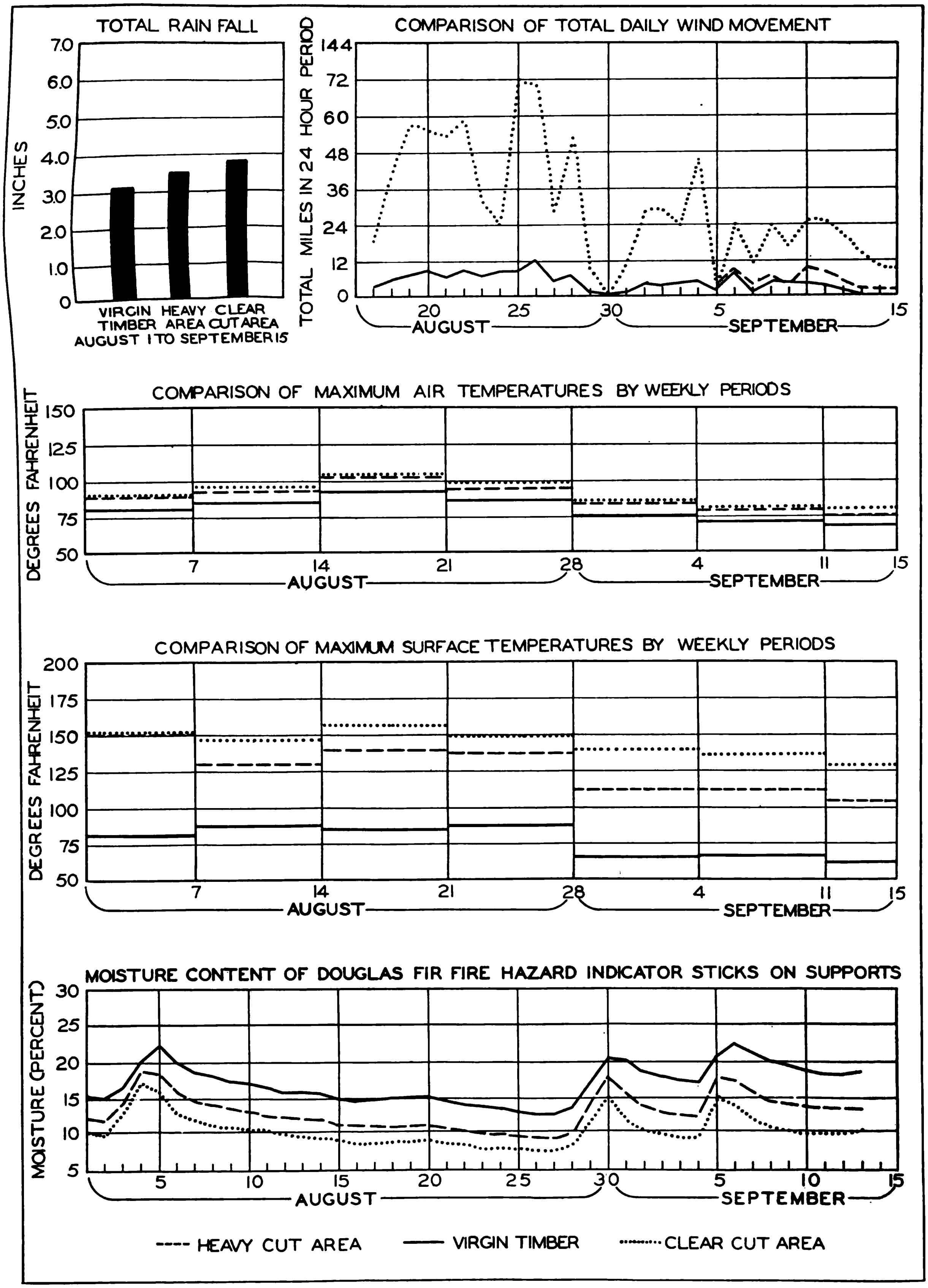


FIG. 19 — RELATIVE CLIMATIC CONDITIONS IN VIRGIN TIMBER, HEAVY CUT AREA, AND CLEAR CUT AREA

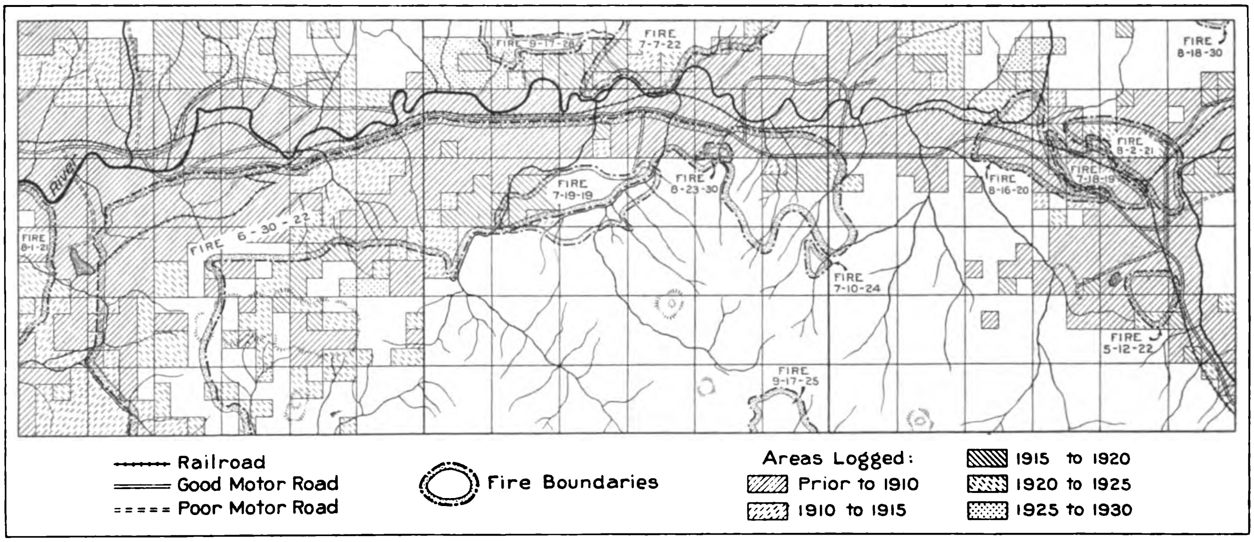


Fig. 20–Fire History (1919-1930) of Three Townships in Western Washington

Extensive clear cutting has necessitated an effort to protect the adjoining forest and the ensuing young growth against the excessive hazard created by this debris. This effort has generally taken the form of broadcast slash burning. This does not prevent later fires, but relatively frequent reburning occurs, under the incomplete protection that has up to the present time been given these lands cut under a liquidation policy. The only advantage of the slash burn is reduction of the amount of fuel available. Data collected in the Douglas fir region in connection with the Forest Survey establish that, although some cut-over land escapes recurring fires entirely, an average of 3.9 per cent of the acreage logged since 1920 has burned over annually. Illustrative of this situation are the data presented in figure 20, showing the fire history of an area of 3 townships where during the past quarter century extensive clear cutting has been practiced and where, as a result of cutting and fire, forest productivity on the cut-over areas has been virtually destroyed.

Changes in hazard from clear cutting of small areas under selective management.—On the spots (generally 1- to 10-acre areas) clear cut under selective management the quantity of slash per unit of area would be about the same as under present clear-cutting practices. Where the cutting occurs on northerly slopes or where very small areas are cut over, the forest climate might not be very greatly altered. Where the cutting occurs on slopes with southerly exposure they would be exposed directly to sun and wind and so have about the same degree of ignitibility and inflammability as large clear-cut areas. Even then, the fire hazard to the surrounding timber would be in one sense measurably less than that created by clear cutting of large areas because hazard increases with size of area; on large areas the force of the fire and the consequent difficulties of keeping it from spreading into surrounding timber become greater, owing to pick-up of momentum and increased length of "fire front." On the other hand, scattered small clear-cut areas expose more adjacent timber than an equivalent clear-cut area all in one piece. For example, although there is 16 times as much frontage around a section (640-acre square) as around a 2½-acre square, the latter has 16 times as much frontage per unit of area.

Changes in hazard from light tree-selection cutting.—In contrast with extensive clear cutting, light selective cuttings conducted along the lines discussed in chapters III, IV, and V are designed to create little slash at any given time or place and to avoid much disturbance of forest conditions. The trees removed would be chiefly the large ones and other trees in which the life processes were slowing down. The quantity of foliage and other small debris per M feet of volume utilized would be considerably less than for trees still in vigorous growth. Removal of only 5 to 20 per cent by board-foot volume, the average portion of the stand to be removed during any five-year period, would therefore create proportionally less slash than under clear cutting. Furthermore, it is generally recognized that slash under forest cover, owing to the moisture conditions existing there, will rot a good deal faster than slash on large clear-cut areas.

The slash situation created under light individual tree selection, therefore, would in most cases be quite different from that created by clear cutting, with respect to quantity of slash, distribution of slash within the stand, and moisture and other climatic conditions governing both the inflammability of slash and the rate at which it will decay. In effect this method of cutting anticipates natural removal of trees from the stand. It reduces the volume of debris on the ground below that is produced in the natural forest by windfalls in older stands and by natural thinnings in young stands, by the volume actually utilized, which is usually about 75 per cent of the total stem volume of utilized trees. Besides reducing the quantity of fuel on the forest floor, removal of the trunks facilitates fire suppression by leaving fewer obstructions to foot travel, construction of fire lines, etc.

During the period of transition from conditions in the unmanaged forest to normal sustained yield operations, the slash hazard on certain parts of the tree-selection areas oftentimes will be far greater than the ultimate hazards described in the foregoing. This will usually be the case during the initial cut and for some time thereafter. Heavy culling owing to breakage and defect in overmature timber, the felling of snags, and the presence of unmerchantable windfalls that have accumulated over long periods in the past may for a time clutter the forest floor with a great deal of large debris. Then, too, in many places the forest canopy might be opened up to a degree that would measurably modify the forest climate.

A part of this hazard from slash, however, might be offset by a reduction of hazard in the stand itself. Standing snags, for example, which should be felled in the course of the initial cut, constitute the greatest single element of hazard in the original stand. Old, loose-barked, moss-covered, stag-headed, defoliated, and defective trees which would be among those removed in the first cut, or, in any event, within a relatively short period, are also a relatively great hazard in the original stand, particularly with respect to crown fires.

"Zero-margin" selection creates an especially difficult fire problem.—Following the introduction of tractor logging a few years ago, so-called "zero-margin" selection has been practiced in several operations in this region. This form of selection has nothing in common with selective sustained yield management except as to the mechanics of cutting. It is a liquidation cutting which differs from clear cutting only in that the minus-value trees are left standing. In a few cases with low fire hazard and a very heavy residual stand this may work out all right from a fire protection point of view. In many types of timber, however, particularly in old-growth even-aged stands of Douglas fir, such cuttings lead to the opening of the stand to such a degree that the forest climate is lost or greatly modified, and to the creation of so much slash that broadcast burning must be resorted to. The result usually is that the standing trees are either killed by the fire or, if they remain alive, are blown down later; in any event, the fire situation in such cases is worse than under clear cutting.

45. Reduction of fire hazard through intensive fire protection.—Maintenance of the forest climate, as may be inferred from the foregoing discussion, is the starting point from which to build for control of fire hazard. In this respect selective management carried out along the lines discussed in chapters III, IV, and V offers an initial advantage of inestimable value. Selective timber management also provides for progressive development and continuous maintenance of a network of railroads or truck roads, amounting in the cases cited to 1 mile or so per square mile of timber, and of an intensive network of tractor-trails amounting generally to 5 to 15 miles per square mile (exclusive of short branch trails). These provide quick access to fire and when required may function as fire trails or facilitate construction thereof. Finally, it should be noted that under selective cutting, mainly of trees that will yield a wide margin of conversion value, the financial resources available for fire protection should be relatively greater than under clear cutting, as is illustrated in chapters III, IV, and V. The permanent values to be protected, also will be greater, since selective timber management with sustained yield will maintain the capital value of the forest. Under these conditions it is wholly in order to set aside whatever amount of money is necessary for effective fire prevention and suppression measures.

Irrespective of the amount of cutting it may be said that any logging with the corollary road building, has the net effect of augmenting the causative fire hazard. This hazard should be reckoned with and compensated for. The fire hazard may at times be a dominant consideration in determining the form of cutting to be employed. The circumstances of each property must be considered and not the least of these is the immunity of the property, or lack of immunity, from causative hazards originating outside the property over which the property manager has no control. If the causative hazards ordinarily much augmented by the building of roads which admit to the forest campers, fishermen, berry pickers, etc., can be controlled, a greater physical hazard of slash can be accepted than where there is a constant threat of man-caused fires.

The problems of fire-protective organization, of equipment, and of fire-fighting methods have long engaged the attention of those interested in the forests and forest industries of the Douglas fir region; personnel and fire control organizations generally recognized as outstanding within the territory of the United States have been built up; much experience and expert knowledge in handling fire problems have as a result been gained and a large volume of literature on the subject is available. It is not within the scope of this report to examine these problems in all their aspects. It is clear, however, that in making major revisions in cutting methods corresponding revisions must often be made in fire protection methods. With widespread experience in selective management as yet lacking no one is now competent to say just how the precise details of fire protection generally should be handled. This is furthermore a problem that in many of its details must be worked out for each individual forest property and that can only be worked out as practical experience under the selective methods of operation gradually accumulates. By providing for complete selective control of the growing stock and by virtue of their extreme flexibility these methods provide for a constant experimental approach to all the varying problems of fire protection in much the same manner as they do for varying problems of silviculture and other aspects of forest management.

In chapters III, IV, and V, having in mind the particular conditions met with in each of the cases studied, a few specific suggestions were made with regard to slash disposal and other fire prevention and suppression methods, that might be adopted at the beginning of operations while long-time experience is still lacking. In the contrast between the three cases studied a rough indication is given of how widely initial methods may vary to fit widely varying conditions as to character of timber and topography and varying climatic hazards in different parts of the region. As a general rule the problem in any given case is to find the right balance between what measures should be taken to prevent fire from starting and what preparations should be made for putting it out in case it does start. In attempting to visualize in a general way the initial fire protection problem it should be remembered that as the cutting area expands in the course of a light initial cut the permanent road and tractor-trail system is expanded at a like rate and maintained by continuous use. Since this makes all portions of the area accessible to trucks and tractors, adoption of new types of fire-fighting equipment is justified, as for example, tank trucks and specially constructed truck and tractor trailers equipped with water tanks, pumps, and other fire-fighting tools and equipment. Bulldozers, which are a part of the logging operations, constitute excellent equipment for the construction of fire lines. The ease with which these highly mobile types of equipment can be brought into close proximity to any fire obviously would facilitate quick suppression, which is the essence of effective fire control.

With the means of fire suppression thus vitally improved, precisely how much slash disposal it would be advisable or necessary to undertake in any given forest property could be determined only by exercise of good judgment to begin with, later modified by actual experience. In this respect it should be borne in mind that in the practical working out of selective timber management, cuttings will be of two distinct kinds, namely, (a) very light individual tree selection, (b) clear cutting by small groups. As a rule no intermediate degree of cutting (in the form of heavy tree selection cuttings) would be necessary or justifiable. The principal reason for this is that heavy tree selection cuttings as a rule are uneconomical, as repeatedly noted in this report. Exceptions to this rule may occur but wherever this leads to creation of a serious slash disposal problem it constitutes a final reason for avoiding heavy tree selection cuttings. In other words, when all factors are fully weighed the scale will usually turn either to group cuttings or to very light tree selection.

The slash disposal problem on the clear-cut spots is, of course, entirely distinct from that on the tree selection areas. On these spots broadcast slash burning would generally be necessary at least during the early stages of the plan. Good management would naturally see to it in the first place that time and place of logging and slash burning on these spots are so chosen as to limit fire hazard and the corresponding need for preparation for burning to the very minimum. It should be borne in mind that under selective sustained yield management clear cutting by small groups would proceed at a very slow rate, since an average of only about one-half per cent of the total managed area would be clear cut each year; in the case cited in chapter IV, with a sustained yield capacity of 40 million feet per annum and an operating area of 60,000 acres, clear cutting thus would proceed at the rate of about 300 acres per year. The task of careful handling of broadcast slash burning does not therefore appear to be huge in relation to the size of the current logging operations although it is a most important job that needs to be well planned and well done.

On the tree selection areas the extent to which slash disposal and other fire protection measures might be needed would naturally vary considerably according to local conditions. It is generally recognized that the disposal of slash through decomposition and return to the soil is beneficial especially in improving the moisture retaining capacity of the soil. Where this method of slash disposal involves too great fire risks, other and more costly methods have to be used. The problem can be partly solved or greatly simplified by good planning of the cutting operations. Good judgment should be exercised, for example, in choosing felling directions for the selected trees, in staggering the cutting areas, in avoiding in each cut all cuttings on certain strips of timber so as to break up the cutting areas. On operations where the truck roads are accessible to the motoring public it may also be necessary to close such roads to public travel during all or part of the fire season. Intensive patrol, fire lookouts, etc., would also be incorporated in the fire protection plan. Essentially the problem is to perfect for each property a slash control plan and fire organization that will fully meet the high standards of forest productivity and of fire safety and control, which can and should be adhered to under selective management.

46. Losses from fungi, insects, and windthrow.—Throughout the Douglas fir region heavy losses from fungi, insects, and windthrow are constantly taking place. Catastrophic losses of this nature have occurred occasionally in the past. The hemlock looper, for example, has done heavy damage in certain hemlock areas along the coast. The so-called "Olympic blowdown" of 1921 took a toll of about 4½ billion board feet of timber on an area about 75 miles long and 20 to 30 miles wide; and in the spring of 1931 and in the fall of 1934 far more widespread storms occurred which blew down large quantities of timber, estimated by some authorities to have exceeded in the aggregate the loss from the Olympic blowdown. When prorated over a long period the average annual loss from these rather spectacular occurrences probably does not amount to more than a small fraction of the total loss, the bulk of which consists in widely scattered losses from fungi, insects, and windthrow, which are occurring at all times and in all parts of the region. Such losses, it can be readily reasoned, are on the whole nearly equal to the aggregate growth of the forest. A large part of the normal loss from windfall in the old-growth unmanaged forest is probably caused by the infirmities of old age and particularly by fungi and insect attacks, which weaken the trees to the point where they fall easy prey to winds. Under selective timber management the merchantable growing stock, as finally developed, should consist of healthy, vigorous trees in well-stocked stands. Losses from fungi, insects and windthrow should as a consequence be held to a low figure, particularly since the growing stock is under continuous selective control which facilitates salvage.

The question is very properly raised as to the severity of windthrow losses during the transition period from virgin forest conditions to ultimate management conditions. It is a matter of observation that zero-margin or other forms of heavy tree selection bring about so sudden a change in forest conditions that the scattered and weakened residual stand is apt to suffer severely. There is ample evidence to show that this is the danger in heavy selection cutting, particularly with shallow-rooted species growing on areas exposed to severe windstorms. It does not necessarily follow, however, that light selective cuttings under sustained yield would lead to similar results. Light selection should as a rule allow the remaining trees to adjust themselves to such gradual changes in condition as may occur through cuttings.

It might well be remarked that windfall losses occurring in the trackless unmanaged forest generally go unnoticed with the result that little attention is attracted to their importance; few persons in fact realize that such losses are on the average far greater than losses from fire. Under intensive selective timber management, the entire growing stock would be practically under constant surveillance with the result that windfall would naturally attract far more attention than before. This might, of course, readily create the impression that selective management results in an increase in windfall even if the contrary should be the actual fact.

47. **Conclusion.**—The existence of a fire problem in the Douglas fir region under any form of management must be recognized. It will require study and experience to determine just what the fire hazards will be under the scheme recommended and to devise the proper measures to take care of them. The weight of the evidence presented in this discussion clearly indicates, however, that selective timber management, if cautiously applied, presents no insuperable difficulties to solution of the fire problem and in fact promises permanent success far beyond anything that can be hoped for under extensive clear cutting as at present practiced. Selective timber management, properly applied, tends to have certain favorable effects upon the fire danger: (1) The maintenance of a forest climate more humid than that of clear-cut areas, and (2) the continuous or periodic removal from the whole forest of dead and down trees, thus gradually reducing this form of fire menace. On the other hand, the construction of roads under the procedure may possibly increase the entry of people and causative hazards of fire, and the slash from the selectively cut trees even in small quantities is in itself some menace until it has decayed or been disposed of.

These conclusions and previous statements concerning selective management are intended to apply only to areas under selective sustained yield management accompanied by intensive fire protection. No other form of selective management has been recommended in this report. Any deviation from the sustained yield plan that would tend toward rapid depletion of the growing stock is apt to lead to serious results; and any wide departure such as that embodied in short-term liquidation may easily bring disaster. Experiences with zero-margin selection or other forms of heavy liquidation cuttings have already clearly revealed the dangers that may arise. The risks from such practices far outweigh the illusory benefits of liquidation which destroys the forest but as already noted fails to recover adequate immediate returns or to conserve the capital investment.

CHAPTER VIII

ORGANIZATION OF LOGGING AND TIMBER MANAGEMENT: FIELD AND OFFICE METHODS

48. **Introduction.**—The desirability of effective organization of selective timber management needs no emphasis. Forest organization involves, on the one hand, careful collection of accurate information and on the other hand well-reasoned use of this information in a plan of action. The dynamic nature of forest values, brought out in previous discussion and particularly in chapter VI, precludes rigidity and demands that the central theme of any management plan be flexibility in execution at any given time.

With operations planned for flexibility, it becomes possible to work at all times toward the most harmonious adjustment among biological and other factors of physical change, general economic factors, and factors pertaining to industrial relations and community welfare. This adjustment involves regulating the volume of the annual cut to conform to the yield possibilities of the forest and to market outlets; selecting the tree species and sizes that will bring the best returns on the current market; very gradually adjusting the growing stock in total volume and distribution of tree sizes, in order that on the one hand best use may be made of the site and on the other hand the material removed in cyclic cuttings may have a unit value far higher than the average value of the growing stock and the cuttings thus yield adequate earnings on the investment; and, finally, constantly adjusting the business enterprise to the needs and rights of its owners, managers, workmen, community, and general public. As all these management factors are subject to constant change, only alert, resourceful, and flexible management has any chance of outstanding success in keeping in true adjustment to new situations as they arise.

The chief function of management of a timber property has often erroneously been supposed to be to sweep the timber from a certain area annually; to get out a certain volume of logs annually; or to supply a certain plant with raw material. In fact, all timber utilization is or should be subsidary to the purpose of making the property of the highest economic use to the individual and the community. A sound operating policy aims to introduce order into the operations to the end that high-earning investment values may be continually conserved and that income may be realized at the proper times.

Most forest capital possesses the dual nature of utility as a continuously producing asset coupled with the possibility of immediate conversion to income. Intelligent forest management is, therefore, a continuing process of converting to income capital that has begun to decline in earnings and building up capital of high or increasing earnings. In this respect the aims are similar to those of intelligent management of other kinds of property. The chief difference lies in the fact that in managing live standing timber there is greater freedom in selecting values to be withdrawn from investment. As a capital asset timber possesses the peculiarity of being capable of growth in volume, quality, and price, whereas most natural resources are subject to growth in price only, if at all.

Again, forest capital differs from capital assets arising chiefly from expenditure of labor because whereas it is capable of increasing in quantity and value with time the latter are, generally speaking, subject to heavy depreciation charges. These favorable aspects of stored forest capital require consideration of many factors not affecting other forms of property.

As the aims here being considered go beyond mere utilization of the existing stand but include also preservation and development of the residual stand, plans for a few months or even a year are wholly inadequate. The basic operating policy, looking to the preservation of all the capital assets, should be established for a period of at least 5 to 10 years. The main reasons for this are: First, under conditions existing in accessible parts of the Douglas fir region, most stands should be cut over about every 5 to 10 years for either financially mature timber, thinnings, salvage, or all three items.

Second, adequate consideration of timber values involves looking to future values as well as present values. Neglect to observe the movements of stumpage values is generally more costly than most other shortcomings in the management of forest properties. Third, if the foresight needed in dealing with timber values is reasonably developed, it is sure to result in better planning of transportation methods and systems and of utilization operations.

The principal elements to be considered in forest organization are (a) the volume of various sizes of timber on hand, (b) the volume of high-value timber (major product) to be removed during the period of the plan, (c) the order of cutting for thinnings and other minor products so far as it supplements cutting for the major products, (d) the demand and changes in demand for various products, (e) a forecast of changes in volume and value of the residual stand, and (f) the development of the forest improvements necessary to carry into execution the foregoing elements. Before any of these steps can be taken the necessary facts concerning the forest property and all phases of its operation must be obtained.

49. Obtaining general information.—It is assumed that the managers of each forest enterprise will keep themselves familiar, through statistical and other information from public and private sources, with market conditions and other factors affecting the operation of the enterprise. The information here considered relates chiefly to conditions within the forest property itself.

In most cases the private forest properties within the Doulgas fir region have been cruised one or more times and the owners have more or less reliable information concerning the gross volume of the stands by legal subdivisions. Information is usually available as to drainages, and in many cases as to contour. If preliminary information of this nature is not available it should be procured by accepted methods. Prevailing opinion now supports taking accurate data on circular or square plots at definite intervals along a surveyed line rather than on narrow strips as was formerly common practice. Lines should be so spaced that the plots will constitute an adequate sample of the whole area and of each major subdivision and yield sufficiently accurate topographic information. If the property is 5,000 acres or more in extent 4 rows of plots to each section (1 row to the "forty") with plots located every 330 feet will provide adequate sampling for each square mile or larger area, but not for each "forty". Unless accurate survey-control lines are already available, it will be necessary to establish such primary control by running baselines along main streams or roads or along certain section lines. From these baselines, secondary baselines, preferably along section lines, may be run with double Abney levelling. Strip lines will usually be run by 2-man crews of which one member runs compass and records plot data while the other acts as rear chainman and records topography. Both men may work together in obtaining plot data. When much work is to be done several 2-man crews may work from the same camp, under the direction of a competent party chief.

The plot data should be combined to obtain the average acre for each type and stand condition that has been located on the general map. The data should also be compiled so as to show the timber volume of temporary forest divisions containing usually from 500 to 5,000 acres, according to the size of the property. When intensive information is obtained later, the boundaries of these divisions may be revised and, where necessary, subdivisions may be established.

With these general data from existing records, or from a general survey, covering property already owned and other property within the natural economic unit that must figure in organization, whether to be acquired and operated under a single ownership or operated under a divided ownership, it will be possible to determine which portions of the area should be operated first and which should follow in succession.

50. Collecting and compiling detailed information.—When the location of the first year's or a few years' cut has been tentatively decided upon, an intensive survey of the proposed cutting areas should generally follow. Experience amply proves that it pays to give careful attention to choice of transport routes and methods, of logging equipment, of timber to be taken out at a given cut, etc. To obtain the necessary information and give due consideration to these factors costs ordinarily from 5 to 10 cents per M board feet. This cost of adequate planning is low in view of the fact that the most effective logging methods thus made available for a given area often may cost $2.00 to $5.00 per M board feet less than the methods sometimes chosen. Furthermore, information collected for this purpose, if properly recorded, will be useful for several cutting cycles, and the choice of transport routes and methods is likely to influence costs for many decades to come.

Information to be collected for this intensive planning includes at least the following:

(a) Accurate topographic data sufficient to provide a map with contour interval of 10 or 20 feet.

(b) Location of all existing transport routes.

(c) Volume of timber, by species and size classes, on each legal subdivision or other area unit (data such as will permit accurate summary on each division of the forest or logging unit).

(d) Quantity and quality of timber in each part of the logging unit.

(e) Location of individual trees 40 inches or more in diameter or of groups of such trees. (Sometimes information from detailed type maps is such that this item can be omitted.)

(f) Growth rates within each diameter class or diameter group.

The information concerning the stands on a logging unit, constituting a timber inventory for that unit, should be compiled and permanently recorded. Such recording of data on the growing stock, repeated at suitable intervals and permanently maintained, can properly be termed a continuous inventory *(17)*. The authors, on the basis of rather extended previous experience in forest surveys, have been experimenting with various methods of intensive surveys since 1927. Everything considered, without detail concerning steps that are common to all forest inventory or survey procedure, the following methods have been found most satisfactory under representative conditions:

(1) If the primary control established for the general survey is not sufficiently accurate it should be rerun as required to reach areas undergoing intensive survey. At frequent intervals along main railroads or roads, monuments and bench marks should be established that can be used permanently to reference in any future survey or engineering work. From these primary control lines or monuments secondary lines, along either section lines or projected roads, should be run as needed to provide starting points for strip-survey lines, which usually should not extend more than 1 mile from baselines.

(2) Strip-survey lines at intervals of 330 feet (4 lines to the 40) should be run by 2-man crews (topographer and estimator), so far as possible approximately at right angles to the slope. The four main features of this survey and their purposes are as follows:

(a) Slope distances are taped and converted to horizontal distances by the trailer-tape or slope-chart method. By the same method, elevations are obtained and contours are drawn on the map as the strips are surveyed. If this work is performed carefully by competent technicians, it results in an accurate topographic map that can later form the basis for locating roads and other forest improvements and generally assist in planning timber removal.

(b) As the topographer proceeds along the line he records the approximate location and size, by 10-inch diameter classes, of each tree more than 40 inches in d.b.h. or each group of such trees, with appropriate symbols such as are shown in the legend of Plate V. This provides essential primary information that with the topographic information permits sound decisions as to what timber to cut and how to get it out.

(c) As the estimator proceeds along the strip he watches the distribution of trees 12 to 40 inches in diameter and makes a rough tree count which enables him to set down for each 2½-acre tract (of which the sample plot next described is the center) a rough estimate of the total volume of such timber. This important secondary information is of use in planning cutting operations partly from the standpoint of providing for removal of some trees of such sizes but chiefly to facilitate judgment as to the effect of the removal of larger trees on the residual stand. This information can best be recorded on the special timber map in colors or cross-hatching, indicating density of the stand of 12- to 40-inch trees. On the same map will be shown the large trees recorded under (b).

(d) At intervals of 330 feet along the strip are located one-tenth acre circular plots (37.2 ft. radius). On each such plot accurate record is made of all trees 6 inches or more in diameter, by 2-inch diameter classes. Notes may also be made concerning regeneration, soil and other conditions. A 3- by 5-inch card provides sufficient space for this record. These plots constitute accurate, regularly spaced mathematical samples of the area cruised. They can be combined to set up stand tables for each forest division or subdivision, or for each type within such division or subdivision. The tree of merchantable size (over 11 inches diameter) nearest the center of each plot may be bored to determine number of rings in the last inch, or if preferred, in the last 2 inches, as a basis for growth calculations. Sufficient growth data on premerchantable sizes (5 to 11 inches diameter) should be recorded to show rate at which recruits are being added to the merchantable sizes. These are recorded on the back of the card, with a description of the crown. On this card is recorded also the estimator's ocular estimate of the volume of 12- to 40-inch trees provided for under (c).

Compilation of an accurate topographic map.—As the intensive maps will be on a scale of 1 inch to 200 feet, it will be necessary on a large property to compile maps in sheets usually representing 1 square mile each. For the purpose of building up a general map of the property photographic reductions of these sheets should be made, usually to a scale of 4 to 8 inches to the mile. Since intensive work is done on only a small portion of the whole property each year, systematic methods are imperative to assure fitting each piece of work into the primary control map and thus gradually perfecting an accurate map for the whole property.

If the preliminary general map has been built around a system of accurate primary control, each new piece of map work can be fitted in to replace a less accurate section. Otherwise a separate map, including accurate primary control extended as needed and with all the intensive mapping added as completed, should be gradually built up. This map should contain only permanent data such as contours, streams, permanent survey lines, permanent railroads, and roads. It can be reproduced from the tracing in the form of blue or black line prints. Such a map is shown in Plate I.

Compilation of a timber map.—With the 200-foot scale topographic map as a base, a timber map of each logging unit should be prepared. Such a map is similar to that shown in Plate V. This map can be prepared most conveniently by placing a separate piece of tracing paper or cloth over the topographic map, placing thereon division and subdivision lines and, in proper location, the appropriate symbols representing the diameter classes of the trees over 40 inches and in figures any desired cruise summaries. A negative can then be made with this tracing superposed on the topographic tracing. From this as many prints can be made as desired, showing topography and timber figures. Upon these prints forest types can be indicated in color as in Plate I. Density of the stand under 40 inches diameter on each $2\frac{1}{2}$-acre subdivision can be superposed in cross-hatchings if desired. One copy of each timber map should be placed among the permanent records; other copies may be used in planning primary and secondary roads and in making other detailed plans for utilizing the timber.

Subdivision of forest property.—As the intensive maps are made and transport routes planned thereon, the boundary lines of permanent divisions and subdivisions can be established. The main divisions of the property should usually remain at 500 to 5,000 acres, in order to simplify record keeping. As roads are constructed and cutting proceeds it will often be desirable to break these large divisions into subdivisions, but only as it will actually facilitate operation and future care of the property.

Because of the prevailingly rough topography, in the Douglas fir region the lines of legal subdivisions seldom constitute economic boundaries for permanent management units. Where forest holdings have been consolidated into continuous areas management units should be laid out with a view to economical extraction of timber from each unit by itself. This will make possible control of operations and accurate records of costs and volume of timber extracted. The simplest basis for setting up divisions and subdivisions, where these are necessary, is to use the permanent railroad and truck road system as the basic permanent boundary lines. Then consider all the area tributary to each landing or coming out over a single tractor road and its branches as an operating unit or subdivision. In some cases of tractor logging these units may be rather large. The subdivisions are likely to vary from 25 to 1,000 acres, according to the form of logging machinery used. In time, if it becomes desirable to break the larger units into still smaller subdivisions, streams, ridges, and tractor roads should be used as boundaries. Each of these units should form the basis for record and cost keeping.

Stand tables.—When permanent divisions and subdivisions have been decided upon, the timber-stand data for each should be compiled for use in planning immediate operations, to forecast future development of the stand, and to establish permanent records. Adequate use of cruising data is often made impossible by inadequacy of permanent records. To prevent such loss, records of the character of Forms 1 and 2 are suggested. These are largely self-

Form 1

INVENTORY AVERAGE ACRE____________CUTTING________CUTTING CYCLE
(Before or after) (No.)

Forest__________Division_______Comp. No.____Site Index_______Soil Type__________Inventory Date_______

Based on _______acres inventoried

Diam. Classes (Inches)	Premerchantable Timber[1] 1″ to 11″: Seedlings[2] Merch. Species Under 1″, 2, 4, 6, 8, 10	Species Totals	Small Timber[1] 11″ to 21″: 12, 14, 16, 18, 20	Species Totals	Medium Timber[1] 21″ to 41″: 22, 24, 26, 28, 30, 32, 34, 36, 38, 40	Species Totals	Large Timber[1] 41″ and up: 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, Over 60	Species Totals	Grand Totals all tree groups
Species									
No. of trees each diam. class by principal species	1		1		1		1		1
	2		2		2		2		2
	3		3		3		3		3
	4		4		4		4		4
Other species	5		5		5		5		5
Total No. of trees in each diam. (all species) and in each tree group[3]									
Species									
Basal area (sq. ft.) each diam. class by principal species	6		6		6		6		6
	7		7		7		7		7
	8		8		8		8		8
	9		9		9		9		9
Other species	10		10		10		10		10
Total basal area of trees in each diam. class and tree group									
Species									
Ave. height (ft.) each diam. class by principal species	11		11		11		11		11
	12		12		12		12		12
	13		13		13		13		13
	14		14		14		14		14
Other species	15		15		15		15		15
Species									
Vol. (cu. ft.)[4] each diam. class by principal species	16		16		16		16		16
	17		17		17		17		17
	18		18		18		18		18
	19		19		19		19		19
Other species	20		20		20		20		20
Total volume (cu. ft.) of trees in each diam. class and tree group									
Species									
No. of years required for principal species to grow 2 inches[5]	21		21		21		21		21
	22		22		22		22		22
	23		23		23		23		23
	24		24		24		24		24
Other species (ave.)	25		25		25		25		25
Species									
Vol. growth per year (cu. ft.)[6] each diam. class by prin. species	26		26		26		26		26
	27		27		27		27		27
	28		28		28		28		28
	29		29		29		29		29
Other species	30		30		30		30		30
Total vol. growth (cu. ft.) by diam. class and tree group									
Conversion factors by diam. classes (each species) cu. ft. to bd. ft. (100 cu. ft. × factor = 1,000 bd. ft.)									
Conversion factors by diam. classes cu. ft. to cords (100 cu. ft. × factor = 1 cd.)									

NOTES: 1 Preferably based on cruise at time of marking timber for cutting operations, but may be based on plot surveys.
2 Omit or base on regularly spaced sample plots.
3 Tree group refers to the group of diam. classes included under seedlings, premerchantable timber, small timber, medium timber or large timber. Only the number of trees in seedlings usually given.
4 All inventory is based on cubic stem volume including tip, putting all locations and species on same basis. This standard of measurement will include all utilizable volume for the next 50 years, possibly permanently. When desired to determine actual utilizable volume in terms of saw timber, cordwood or other product it can easily be done by applying a ratio to each diameter class based on utilization standards at the time and place. See conversion factor above.
5 From one diameter class to next higher.
6 Volume growth is usually computed only for the principal species assuming it to be a function of management to eliminate inferior species.

Form 2

INVENTORY AND YIELD RECORD__________CUTTING_____CYCLE
(Before or after) (No.)

Forest_______________Division_________Sub-division No.______Inventory Date_______

Diam. Classes (Inches)	Species	Premerchantable Timber 2 4 6 8 10	Species Totals		Small Timber 12 14 16 18 20	Species Totals		Medium Timber 22 24 26 28 30 32 34 36 38 40	Species Totals		Large Timber 42 44 46 48 50 52 54 56 58 60	Over 60	Grand Totals Over all tree groups
Vol. (cu. ft.)[1]	1			1			1			1			
each diam.	2			2			2			2			
class by prin-	3			3			3			3			
cipal species	4			4			4			4			
Other species	5			5			5			5			
Total volume (cu. ft.) of trees in each diam. class and tree group													
Saw Timber	Species												
Vol. (ft. b.m.)[2]	6			6			6			6			
each diam.	7			7			7			7			
class by prin-	8			8			8			8			
cipal species	9			9			9			9			
Other species	10			10			10			10			
Total volume (ft. b.m.) of trees in each diam. class and tree group													
	Species												
Vol. growth per	11			11			11			11			
year (cu. ft.)[3]	12			12			12			12			
each diam. class	13			13			13			13			
by prin. species	14			14			14			14			
Other species	15			15			15			15			
Total vol. growth (cu. ft.) by diam. class and tree group[3]													
Total vol. growth (bd. ft.) by diam. class and tree group[4]													

Supplementary data____

NOTES: [1] Obtained by multiplying cubic volume figures for average acre by number of acres in compartment or by 100% cruise at time of marking trees before cutting operations or by ordinary cruising methods.

[2] Cubic volume figures by diameter classes multiplied by converting factor shown at bottom of Form 1.

[3] Cubic volume figures by diameter classes multiplied by growth in cu. ft. shown on Form 1.

[4] Figures for cubic volume multiplied by converting factor from Form 1 excluding premerchantable diam. classes.

Form 3

RECORD OF TIMBER REMOVED AND TIMBER LOSSES DURING CUTTING CYCLE

Forest__________ Division__________ Sub-division__________ From__________ (Date) to__________ (Date)

DIAMETER CLASSES (INCHES)

	Premerchantable 1" to 11": 2 4 6 8 10 Species Totals	Small Timber 11" to 21": 12 14 16 18 20 Species Totals	Medium Timber 21" to 41": 22 24 26 28 30 32 34 36 38 40 Species Totals	Large Timber 41" and up: 42 44 46 48 50 52 54 56 58 60 Over 60 Species Totals	Grand Totals all tree groups
No. of trees removed by cutting at beginning of cycle by principal species					
1__________		1	1	1	1
2__________		2	2	2	2
3__________		3	3	3	3
4__________		4	4	4	4
5__________		5	5	5	5
Total trees in cyclic cut					
No. of trees cut during cycle by species					
6__________		6	6	6	6
7__________		7	7	7	7
8__________		8	8	8	8
9__________		9	9	9	9
10__________		10	10	10	10
No. of trees cut during cycle					
Trees killed by fire, insects and disease (estimated) during cycle and not utilized					
11__________		11	11	11	11
12__________		12	12	12	12
13__________		13	13	13	13
14__________		14	14	14	14
15__________		15	15	15	15
Total trees removed during cycle					
(1) Total basal area of trees removed					
(2) Number of cubic feet utilized volume for each square foot basal area by diameter classes. (Obtained by compiling falling and bucking reports)					
(3) Utilized volume (Items under (1) multiplied by factors under (2))					
(4) Cubic volume removed during cycle (number of trees multiplied by figures from cubic volume table)					

Form 4

RECORD OF MATERIAL SOLD FROM DIVISION (OR SUB-DIVISION) SINCE INVENTORY

(Compiled from invoices or scale books)

	Saw Logs						Poles and Piling			Posts		Pulp Wood		Other Cordwood		Miscellaneous		
Species	Veneer logs bd. ft.	No. 1 logs bd. ft.	No. 2 logs bd. ft.	No. 3 logs bd. ft.	Cull logs bd. ft.	Saw logs volume converted to cu. ft.	No.	Lin. ft.	Est. cu. ft.	No.	Est. cu. ft.	Cords	Est. cu. ft.	Cords	Est. cu. ft.	Units	Est. cu. ft.	Total cu. ft.
1																		
2																		
3																		
4																		
5																		
Totals																		

Grand total of cut in cubic volume__________ Per cent of stem volume utilized from trees cut__________%

explanatory. Form 1 gives complete data on an average acre, compiled by combining the data from intensive survey sample plots by groups representing each division, subdivision, or type. It comprises a complete inventory of an average acre from every important aspect. This form may seem to include a great deal of detail; but since it will ordinarily be revised only before and after the main cut at the beginning of each cutting cycle, only a few compilations pertaining to areas where cutting is to be done or is in progress need be made each year. The cost, therefore, should be insignificant.

Attention is invited to the method suggested for recording volume measurements. Cubic volume of the full stem is used because this unit will be stable over a long term of years and will give full measure for any form of utilization. In order to permit ready conversion of these figures to board feet, converting factors applicable to saw-timber sizes are provided. Converting factors applicable to all sizes are also provided for converting to equivalent volume in cords. Other converting factors, such as for piling and poles, can be added if desired.

The average acre figures are multiplied by the acreage to set up the totals for each division or subdivision or type as recorded on Form 2. Forms 3 and 4 provide space for recording by diameters and by character of products all trees removed.

At the beginning of each cycle, before the cyclic cut, the results of operations during the previous cycle should be summarized. If new field studies are necessary before the cyclic cut they should be made and the results set up directly on new forms 1 and 2. If new estimates are not necessary the figures representing balance of the stand as shown by the previous inventory, less trees removed during the cycle, should be compiled for new forms 1 and 2, and the old forms transferred to closed files. These records, as they accumulate, will form the most valuable basis for judging the results of management and for improving management.

In order that judgment of management results from cycle to cycle may be facilitated still further, it is desirable to prepare for each division or subdivision at the beginning of each cycle a diagram of the basal area on the average acre by diameter classes, in the manner of that shown in figure 13 (chapter V). As these diagrams accumulate they will show progress or retrogression in the stand after the manner of the successive diagrams in figure 14. Unlike figure 14 these diagrams contain no element of forecast but are strictly records of stand conditions at each cycle as in figure 15. They can also be used to compare conditions on different divisions and subdivisions.

To simplify files and records as far as possible, it is suggested that forms 1 to 4 be printed on the inside and outside of ordinary plain manila folders. Within the same folders may be filed the basal-area diagrams mentioned above and supplementary notes and data pertaining to the divisions or subdivisions covered by the records. As new inventories are set up from time to time folders containing older records may be transferred to closed files. The current file should contain as many folders as there are divisions and subdivisions. Under present conditions there may be from 10 to 50 of these, but the number may be expected to increase as management practice is intensified.

The foregoing methods do not depend on doing any more field work than is now customary nor do they involve much additional compilation. They do demand preparing certain records in permanent form. These accumulating records, besides showing past yields from each forest division will provide a continuous inventory of the permanent growing stock.

Through this inventory and mapping process the forest will assume the character of an orderly warehouse in which the location of goods of different character is known and from which any goods may be taken as desired. When the time for the cyclic cut arrives for any division these past and current records and the present conditions on the ground should be studied to determine how much of the goods shall be disposed of during the next cycle (5 to 10 years). If unusual demands should arise during the cycle, such as the war-time demand for spruce, the records will show just where the special material is located.

Since, as cutting reaches each division, the records of the residual stand (growing stock) are to be revised before and after the cut, the inventory of each division will be up to date at all times except for minor changes resulting from growth subsequent to the last inventory. Approximate adjustments for growth may very readily be made if needed. To obtain the inventory of the entire forest property at any time it will only be necessary to add together the adjusted inventories of all the subdivisions.

51. Determination of the volume to be cut.— In the early years of organized management, determination of the volume to be cut should be based partly on the information obtained in the general cruise of the property which shows the total volume of the merchantable size classes. After intensive study and inventory have covered all divisions of the forest, the volume of merchantable timber ascertained by summarizing these records should be relied upon insofar as the annual cut depends on the total stand available. Trees of the smaller merchantable diameter classes of certain species and, on certain areas, larger trees that are difficult to log, cannot under present conditions be taken out except at a loss. For this reason, an intensive study of the tracts soon to be logged must be depended on to determine what portion of the stands should be removed within the period (5 to 10 years) under consideration.

A practice often advocated in forest management is to set up a rigid prescription of the amount to be cut annually for a period of 10 years or more. To follow a rigid plan of action may under present conditions force direct operating losses upon the forest owner in some years and result in unnecessary losses of earning assets in others. It is preferable, therefore, to set up a tentative operating schedule, based largely on the quantity of timber that is capable of extraction at a reasonably high stumpage rate or that if left standing will not make satisfactory earnings from growth in volume, quality, and price. Typical examples in various parts of the region, cited in chapters III, IV, and V, indicate that from the standpoint of limiting the cut, in very few cases is an excessive portion of the timber on any given property ready for immediate conversion. The proportion available for cutting within a decade will seldom exceed 20 to 40 per cent of the total stand 12 inches or over in diameter. When it exceeds 30 per cent, some liquidation of the growing stock is usually involved. If the owner aims at sound financial management the cutting limitation policy should be supplemented by a general determination to handle cuttings in such manner that the net value of stumpage removed during a 5- to 10-year period plus the value of the remaining property, shall be maintained at a maximum. This will mean that timber left standing has received equal consideration and that no timber more valuable to hold for future cuttings has been cut.

Review of underlying principles.—The practice of removing all timber when it culminates in value and before its earning power declines below an established point may not meet with the approval of some forest-management authorities who lay great stress on absolute regularity of yield over long periods. In support of the procedure here proposed two sets of facts may be cited.

1. Logging and milling studies in numerous forest types have, in late years, proved conclusively that a relatively small proportion of the average stand has reached its highest value. One-fourth to one-third of the average stand, by volume, has not even reached the point of having any present net value; another third or more is of very moderate value. Removing the portions that have reached high values or culminated in value, therefore, will not usually result in a serious overcut according to older ideas of regulating the cut. The essence of the methods here proposed is continuing adjustment of the forest capital to the level at which it will produce the most satisfactory continuing earnings. Available data indicate that adoption of this standard will mean a permanent growing stock larger, not smaller, than would be maintained under older standards.

2. Unless standing timber that has culminated in value is continually converted to income before its earnings decline too far, the forest investment cannot compete with others forms of investment. To compete with other security investment, for example, *the forest property must in normal times yield every 10 to 25 years net income equal to the capital value of the property, without impairment of the capital value.* By way of comparison with other kinds of business enterprise, the following ratios of earnings to price for several common stocks may be cited. (Price-earnings ratio indicates figure by which annual earnings must be multiplied to obtain price.) These investments produce income equal

Corporation	*Price-earnings ratio*	*Years record on which ratio is based*
Company No. 1	11.31	13
Company No. 2	18.22	11
Company No. 3	20.00	13
Company No. 4	9.98	13

to their capital value in from 9.98 years to 20 years. The stocks selected also show that the more stable and well established the business the lower the average rate of earnings on capitalization (see also section 40 chapter VI).

In the Douglas fir forests many earning assets have been neglected and consequently not capitalized. It is believed that under skilled management many properties can be made to yield in the first 10 to 15 years net income equal to the value actually invested at the beginning, without serious impairment to future capital value.

In a forest property that has reached a balanced condition as to the size classes (see figures 14 and 15) the volume removed in a decade will usually be 25 to 35 per cent of the total volume on hand at the beginning. In other words, under sustained yield management the cut on the better sites for every 30 to 40 years should equal the volume of the permanent growing stock on hand at the beginning of the period. Actual records from certain selectively managed Swiss forests show such accomplishment (*4*, *5*).

It is appropriate to consider the correlation of the foregoing facts with the principle brought out in chapter VI (sec. 38) that a growing stock should be maintained of sizes well distributed in the larger diameter classes, such as will permit the annual cut permanently to include 40 to 50 per cent by volume of trees over 40 inches in diameter. The value per unit of timber cut should then be three or more times the average value of the stand. Under this management policy it is entirely possible for the percentage of gross earnings on the investment to be three times the percentage rate of growth, or more. Putting these related facts together, it becomes clear that under selective timber management the money yield should approximate 100 per cent of the growing stock value each 10 to 20 years. Failure to realize such a return arises from such errors as clear cutting extensive areas; from overcutting in the large tree sizes; from failure to remove mature trees of declining value in time to prevent impairment of the returns; and any other violations of economic or good silvicultural procedure in handling the forest property.

Practical procedures involved in fixing the cut.—In view of these facts it becomes clear that the amount of timber to be cut within a decade should include all stationary and declining values; all values earning a rate, after allowing for risks, well below what the capital which might be withdrawn would earn in other elements of the forest property investment or in other investments of like risk; and those elements of dense stands which are earning relatively low rates as compared with other elements which would be favored by removal of the lower-earning portions. In some cases these removals are subject to certain limitations, as for instance when large tree sizes have been unduly depleted by past mismanagement, cutting must be very conservative in those classes in order that there may be due proportion of higher grades in the later cuts.

As a general rule, 3 per cent net earnings after all risks have been allowed for may be decided on as the low point. In favorable properties minimum earnings may be fixed at a higher rate; while in depleted properties, where the growing stock is being rebuilt, it may be necessary to fix the minimum earning as low as 2 or even 1 per cent. In addition to the high value major product designated for removal, the plan should, if practicable, provide for systematic procedure of cutting over the forest, unit by unit, for salvage (of timber damaged by insects, fungus, fire, etc.), thinnings, and other improvement cuttings, generally at the same time with or immediately after the removal of saw timber. As a general rule all such material will be removed whenever the returns will equal or exceed operating costs. The marketability of products from such operations may depend in part on a demand for pulpwood, fuel wood, posts, poles, etc.

The general cruise by the sample-plot method provides the means of determining approximately what percentage of the entire stand and what total volume should be cut within the period (5 to 10 years) for which plans are being made. The annual cutting volume will be a fraction of this total, depending on the number of years over which the cutting is to be spread. It is inadvisable to attempt to cut precisely the same amount each year. For one reason, each operator must expect to absorb some part of the periodic fluctuation in market requirements. For another, average returns can be increased by stepping up output during the prosperity portion of the business cycle. Owing to the necessity of providing continuous employment and preserving an efficient administrative organization it may be impractical to reduce the cut in bad years by more than 50 per cent. The exception is when the operating concern possesses operating reserves that in bad years can contribute conservatively to the extension of forest improvements, so as to afford employment opportunities in place of those lost by reduction in the current timber cutting schedule. For these reasons the final determination of the cut for a given year should not be made far in advance. The information from the general timber survey is sufficient only for laying down a general policy. Intensive study of each logging unit is prerequisite to final determination of the cut therefrom but the condition of other units within the forest property has an important bearing on the decisions reached, as was brought out in chapters III, IV, and V.

52. Selection of timber for annual cutting operations.—Chapters III, IV, and V show, as applying to three actual forest properties, the principles and practices that should rule in selecting timber for immediate cutting if the major objectives of high current income and sustained property values are to be reached. Chapter VI summarizes certain information on growth and other factors which create a dynamic status or condition of continuous change in value of nearly all growing-stock elements. These chapters also bring out the discount losses involved in holding certain classes of values. These discussions serve to emphasize the importance of correct procedure while at the same time they show that the proper selection of timber for the current cut is the most intricate problem confronting the technician.

This problem involves the separation of growing-stock elements that are earning at a satisfactory rate from those that no longer earn sufficiently to be retained as part of the stand. The elements to be removed must also be so selected that their removal will not result in damage to the remaining stand. This includes the possibility of damage by fire, wind, insects, and fungus disease. There is also to be considered development and maintenance of forest improvements, market values of the cut at a given time, and numerous other factors.

When all the factors are carefully weighed it is plain that, in order to hold all mischances and risks to a minimum, all the more productive properties should be worked under a policy of light cuttings and short cutting cycles. Light cuttings are extremely desirable because they cause the least disturbances to the balance established in Nature. Frequent cutting on the same area provides the means of correcting mistakes in previous cutting by salvaging any windfalls or other damaged trees before much volume is lost. In brief, light cuttings and short cycles best provide for sustained growth and high continuous yields.

The intensive cruise described in section 50, with the resulting compilations and maps, particularly the timber stand map, provides the means of selecting the annual cut in the manner illustrated by Plate V. In typical old-growth timber approximately half the cut may come from small groups which frequently have volumes of from 100,000 to 300,000 board feet per acre. The remaining cut comes from tree selection on adjacent areas. These selections provide for the main cut of high-value material. Immediately following this cut, if market conditions permit, a salvage cutting should be made to utilize smaller trees knocked down and to remove any undesirable elements of the stand.

After the groups to be clear cut and the tree-selection areas are chosen on the map the roads can also be located tentatively on the map. It was shown in chapter IV that the road mileage required is proportionately less where cutting is to be light and can be charged off as current expense.

Work now transfers to the woods, where the selected groups and trees are marked for cutting and the roads are laid out on the ground. Under the continuous-inventory system a record is made of the trees marked, so that they may be recorded separately from the inventory of the residual stand as shown on Form 3.

It is often desirable that roads be constructed some months in advance of logging operations. The construction can thus be carried on more efficiently, and road operating conditions may be improved through allowing time for new grades to become settled.

Thinning and salvage operations.—On areas where saw timber is to be removed, thinnings and salvage can be most economically carried on either just in advance of the initial cut, at the same time with it, or immediately after it. This permits use of the temporary as well as of the permanent roads. If such cutting follows the saw-timber cut it may often include clean-up of the tops and other unused portions of saw-timber trees. It has been pointed out elsewhere that spreading the cut through the cycle results in maintenance of roads through use.

All areas with trees 12 inches or more in diameter where no mature saw timber will be cut during the period of the plan should be cut over for salvage and thinnings, if possible, at least once each decade. The plan may call for proceeding over the area systematically, or may leave it to the resident forester to allocate these cuttings, as time goes on, to the divisions where the most material is in need of salvage or where thinnings are most desirable.

53. Volume and future value of residual stand.—No plan for removal of timber that has culminated in value is wholly sound unless it considers the effect on the residual stand. If cuttings are sufficiently moderate to fit present economic conditions, there will be left an average of from 20,000 to 50,000 board feet of timber per acre. This growing stock should lay on annual increment at the rate of from 300 to 1,000 board feet per acre. In a decade or less, portions of this timber will generally move into the economic position of financial maturity now occupied by the timber that is ready for cutting. Adequate records, as already described, should be made of the tree sizes and volumes in order that records of the progress of growth and changes in value may be available as a basis for the next revision of the inventory and the planning of cutting operations. In this way the data for improved management can be gradually perfected.

Emphasis on the proper point of view in the current cutting operations is so important that the fundamental objectives will be repeated. They consist, first, of recovery from the stand, so far as possible, of financially mature and overmature trees, salvage of dead trees, and thinnings in immature stands which are most in need of removal. However, the value of forest land is so low that it is cheaper to store inferior elements of the stand until they become of some value than it is to remove them at a loss. Removal at a loss is advocated only in exceptional cases. Second, the high-earning elements of the growing stock to be left standing deserve as much consideration as the timber to be cut. Under present conditions these may include from 75 to 90 per cent of the trees. If they are neglected the waste in capital value will often be as serious as waste from mismanagement of cutting operations.

These two aims of management are not conflicting but are wholly harmonious. The means of carrying them out have been illustrated in three typical cases in chapters III, IV, and V. The evolution of the growing stock on a single forest division where the cyclic cut and the residual growing stock receive equal consideration is particularly discussed in chapter V, and illustrated in figure 14.

54. **The investment in forest improvements (chiefly transportation facilities) in relation to timber management.**—During the first third of this century, while liquidation of forest productivity was occurring through destruction of the physically and the financially immature growing stock at the same time that the mature timber was being cut, expenditures on transportation facilities reached a level as high as from $75 to $100 per acre of timber cut. These costs could never have been met except for the heavy stands, but such stands do not constitute a reason for continuing this type of waste. The engineering calculations on which these high expenditures were based generally included the assumption that the entire stand could share in carrying the burden. It has subsequently been demonstrated *(7)* that from one-fourth to more than one-half of the stand was of too low market value to carry any portion of these costs.

It should be noted that under the liquidation policy this huge per-acre charge (for what under a continuous-production policy would mostly constitute permanent forest improvements) had to be charged entirely to current operating expenses or charged off in a very short period. It had no residual value for future use since no timber remained or would be produced to be hauled over the facilities provided.

The forest-improvement situation under sound selective timber management is in sharp contrast to the foregoing. In the first place, a conservative policy should rule in making forest improvements, building only what are needed and keeping transportation facilities out of timber that is not ready for immediate operation. Under this policy, with truck and tractor operations to main railroad line or deep water connections, the investment per acre for truck roads with gravel or crushed-rock surface and for tractor-roads should very seldom exceed $15.00. This would constitute a charge seldom exceeding 75 cents per 1,000 board feet removed, as against $1.00 to $2.00 under the clear-cutting, cable-logging system. As the timber removable only at a loss will not be cut the average value of the timber utilized will be raised, which is an additional reason why it will be better able to carry the improvement charges than under the practice prevailing in recent years.

The practice of charging off the entire expense for truck and tractor-road construction to current operations should, therefore, continue. This will reduce the capital burden on industry and will pave the way for introduction of improved facilities as they are developed. Although the expenditure will be thus amortized the utility of the improvements will remain so long as they are utilized during each cutting cycle. Over a period of several cycles they will transport not only the present volume of timber cut but also the additional volume resulting from growth.

As noted later, desirable accounting procedure will charge both construction and maintenance of improvements in forest divisions which are undergoing current cutting operations directly to utilization costs. Expenditures for construction and maintenance in other parts of the property may be carried in a special account from which they may in future be transferred to utilization costs, fire protection costs, or such other activity as may logically permit them to be charged off within a short span of years.

Under these circumstances these forest improvements, though amortized, may be moderately valued as a part of the permanent forest investment. Under the conversion-value method of rating the investment they may be assigned an arbitrary value of a few dollars per acre. Under the method of capitalization based on net earnings they will naturally become a part of the capitalized value since their existence adds to the conversion value of the timber.

In planning the development of a forest property, determination of the extent and location of the forest improvements (chiefly transport facilities and camps) affords the best opportunity for economy in capital outlay. Under present conditions it appears that a minimum mileage of permanent railroad (needed only for the largest properties), combined with a well-planned system of truck roads which in turn are connected with more or less temporary tractor roads, would result in the lowest cost transportation for timber after the skidding operations. Planning for these developments calls for the best ability of the technician, who can here lose or make several times the cost of his salary. In order to avoid errors, planning at the beginning of a period should generally include only location of the main skeleton of the road system. Addition of branch roads should be studied and decided upon from the intensive topographic and cruise data, especially those on the timber map, as cutting operations progress into the property.

In the selection of timber values to be converted to income detailed consideration should be given to the utilization of capital in existing transportation facilities and camps. If these are not used deterioration and loss will occur. Therefore, it will very frequently be desirable to allocate early cuttings to areas already served by transportation and later cuttings to areas where transportation has to be extended. Light cuttings and frequent returns to the same cutting areas should result in such continuity of use for the transportation system that permanent maintenance of the basic system (railroads or truck roads) will result in the lowest charge against utilization.

55. **Protection of property against fire, etc.**—The necessary organization and planning of protection against fire and other destructive agencies may properly form a supplement to the regular forest management plan. Or these phases may be handled independently. In this report a separate chapter (chapter VII) is devoted to the subject.

56. **Conclusion.**—Many of the problems of organization under selective timber management are continuing problems intimately associated with administration. This is true because essentially the method is continuously experimental, in that it relies on the experience of the past, especially the immediate past, to guide the future, especially the immediate future. This experience relates particularly to timber-utilization costs; gross and net values; growth rates in volume, quality, and price; and market outlets.. In order to gain the advantages of favorable factors and avoid the pitfalls constantly arising from unfavorable factors, systematic control of all operations is necessary. This is discussed in the next chapter.

CHAPTER IX

ADMINISTRATION AND CONTROL OF LOGGING AND TIMBER MANAGEMENT OPERATIONS

57. **General.**—With a firm operating policy, based on sound principles and permitting the full degree of flexibility necessary for continuing adjustment of operations to changes in economic and physical conditions, it is obvious that an intimate relation must exist between administration and the development of further operating plans. This relationship will be controlled in part by the continuous inventory system, briefly described in chapter VIII, and in part by operating records which will be discussed in the present chapter. With these two types of records, kept in the form designated by Harrington Emerson as "immediate, reliable and accurate" *(10)*, the best experience of the past in forest production and operating results will be continuously available as a foundation for further improvement. The first requisite of good management is that as far as possible all timber actually removed shall yield a reasonable margin, preferably a wide margin, of returns over costs. This cannot be ascertaind or controlled unless records are adequate and are so kept as to yield immediate information concerning current operations.

58. **Simplification of operating methods.**—In the logging cost report *(7)* it was shown, and general experience confirms the fact, that under the extreme development of cable and railroad logging, methods of operation are so complicated that administrative burdens are extremely heavy. They generally include operation of a railroad system of considerable magnitude; the operation of heavy yarding machinery, involving intricate problems of mechanical engineering; civil engineering problems such as making of topographic surveys, laying out railroads, location of settings to allow proper skyline deflections, etc. Under these conditions it is not surprising that important problems of timber management were almost completely neglected. Difficulties were increased by the fact that, once entered upon, an operating plan could not readily be modified.

The same report shows that in contrast to the above methods modern motorized equipment renders heavy fixed investments per acre unnecessary, and in consequence can relieve management of the necessity of long commitments to fixed operating plans which before they are completed may lead to heavy losses. Simplified methods of operation carried out systematically and based on adequate current records are thus indicated.

Under these conditions private railroad operations may be confined to the larger properties and the railroad mileage may be reduced to comprise seldom over one-fourth of that common under steam and cable logging. Frequently it may be reduced to just a mainline system such as that illustrated as possible for the first cutting cycle described in chapter IV. Investments and investment charges for railroad construction can be correspondingly reduced. Transportation from stump to car should usually be by mobile motorized equipment. It has been shown in the three examples discussed in chapters III, IV, and V that truck roads and tractor roads required for this form of transport are of such low cost that they may be charged to current operating costs as operations are extended. Likewise the motorized equipment itself is highly productive while in operation but is subject to rapid depreciation, or in other words, it permits rapid recovery of the investment. The capital investments in such equipment, therefore, do not involve any long commitment to a given operating policy. The net effect of the change to flexible equipment will be greatly to reduce capital investment and to facilitate rapid amortization of such capital investment as remains.

It is clear that these changes in operating equipment and methods will release the energies of managers and technicians to such an extent that the process of continuous adaption of operations to changing conditions of markets, labor costs, and other factors may be markedly facilitated, provided the opportunities thus made available are utilized.

59. Determining the essential elements of the operation.—Before effective administrative control can be established the operation as a whole must be analyzed and broken down into its essential administrative elements. Over each of these, effective administrative and accounting control must be established. The elements usually encountered are as follows:

Forest technician in charge—

- (a) Mapping and inventory.
- (b) Protection and general development of the entire property.
- (c) Selection and designation of timber for cutting.

Logging superintendent in general charge with foreman or strawbosses as assistants in charge of each element. An adequate technical staff under direction of forest technician should plan roads and other permanent improvements with due regard to general plans for the property—

- (d) Truck road construction.
- (e) Tractor road construction.
- (f) Felling and bucking.
- (g) Skidding.
- (h) Drum unit yarding.
- (i) Loading (truck).
- (j) Truck transportation.
- (k) Loading (railroad).
- (l) Rail transportation.
- (m) Water transportation.
- (n) Any other major items.

60. The initiation of administrative and accounting control over the forest property and utilization operations.—The selection and designation of timber for cutting for the initial operations under continuous inventory methods has already been discussed in chapters III to V. This, however, will be a continuing process, always going on. Under it the technician in charge will annually study new areas or additions to old areas within divisions being operated or soon to be operated. Until the entire productive area has been covered by detailed topographic maps this work will include both topographic mapping and timber cruising and stand studies. In the course of the first few cutting cycles the mapping phase of the studies will be completed but periodic reconsideration of each area should continue as long as the property is under management. While studies are proceeding over the area the first time it should be divided into fairly permanent blocks (3,000 to 15,000 acres each), divisions (500 to 5,000 acres each), and where necessary, subdivisions (25 acres and up). The permanent road system (railroad, truck roads, and tractor roads) should also be virtually completed. These two developments should render all the timber accessible at all times, while the continuous inventory should record the volumes by species and tree sizes for each operating unit.

After this stage of development has been reached the forest technician can intensify his investigations of increment (volume, quality, and price) and determine more and more closely the tree sizes at which physical and financial maturity is reached. These maturity limits may be expected to fluctuate continually with changes in market conditions and utilization technic. Continuing investigation of general conditions affecting them and of specific conditions pertaining to each unit, however, should enable the technician to prescribe for each cycle the amount of timber that should be cut. This should be the amount which will accomplish the maximum conversion of timber capital to current income that is consistent with the policy of maintaining a balanced growing stock in sufficient volume to insure a high continual yield in volume and quality and consequently a high level of earnings.

The forest technician should be the custodian of the continuous inventory records and in addition should have free access to the cost records covering all steps in utilization. The inventory records of the growing stock may be based largely on sampling in the early stages and as time goes on should develop more and more toward actual complete enumeration in connection with timber marking. Records of the timber removed in cuttings may be drawn from records made in connection with contract or day work, felling and bucking (Forms 5 and 6) or tractor operating record (Form 8). From this record information (Form 3, chapter VIII) can be accumulated which will permit adjustment of the inventory before and after the cyclic cut on each division or subdivision. As Form 6 gives the volume of logs obtained from each tree it will provide the information from which to determine current utilization standards, either by complete statistical summary or by occasional sampling of the data, as for example by taking every 10th report. By all odds the most accurate way to state volume is in terms of cubic measure which can be used almost equally well for any form of utilization.

Equivalents of 100 cubic feet in terms of other measurement units are to be recorded at the bottom of Form 1.

Felling and bucking.—This work is under the supervision of the bull-bucker. The points of importance are economy in costs so far as consistent with good quality work. This includes guarding against breakage and other waste and felling the timber so that subsequent operations will be facilitated. To attain both objectives experience indicates that contract work under certain safeguards is the most effective. The preferred (though not very common) method is to pay for felling at an equitable rate per square foot of stump surface. Bucking may best be paid for in the same manner although very commonly it is paid for on log scale. Where tractor skidding and roading are let by contract felling and bucking may be included in the contract with suitable penalties for wastage. As the time required per thousand board feet both for felling and for bucking is much greater for small than for large trees (about twice as great for 20-inch trees as for trees over 40 inches) *(24)* rates must be higher on smaller trees in order to be equitable.

Forms 5, 6, and 7 are suggested as sufficiently complete records to provide the information required to pay for the contract work, to show the standards of utilization, and to provide the information needed for controlling the timber inventory within each block, division, or subdivision. These forms may be bound in books for convenient field use. The sheets may be of a vertical width to make the books of pocket size. Alternate sheets should be perforated for use as carbon copies or otherwise used as duplicates to be detached and used to support the entries on the original of Form 7. During stormy weather records may be taken on waterproof forms and transferred to permanent forms each day. The originals of Forms 5 and 6 go to the custody of the forest technician's office and are used to keep the timber inventory up-to-date. The originals of Form 7 go to the accounting office and constitute authority for payment of these accounts and for entry of felling and bucking costs in the books of account. Five ledger accounts cover this section of operation costs. These are listed under felling and bucking in section 60.

Skidding.—This term is used in the sense common throughout the United States, viz., the dragging of logs resting in whole or in part on the ground from the stump to some point where they may be loaded on a conveyance for further transportation. The term "yarding" is reserved for those cases where cable equipment has to be used for initial transportation from the stump. No attempt will be made here to discuss methods of railroad spur and cable logging which are now being rapidly superseded, since these are impracticable in intensive selective timber management.

The mobility of the operating units and the absence of heavy accompanying investments in fixed improvements permit complete flexibility in operating methods and require administrative records and controls which will preserve these operating advantages. Specifically, cost records should provide immediate information, daily if necessary, which will permit quick withdrawal from untenable operating situations and thus avoid unnecessary losses. The records should also be adapted to the type of administrative control necessary to serve operating efficiency without undue increase in overhead costs. Records of daily output and records of current operating costs such as shown by Forms 8 and 9 and ledger accounts later listed are suggested.

Form 8 is to be filled out by the hooker, who has ample time to scale and record the next load of logs and place chokers during the absence of the tractor while hauling in a turn. Operating experience shows that if scaling is not done the volume of loads will not be maintained and costs will rise. Making this record will involve no extra cost except for daily entry of summaries on the record of performance for each tractor. This may be a suitable card record or a bound book to which are transcribed the daily operating totals. Whether skidding is done by contract or by day work will not much influence this record. If by contract the logs will be check scaled at the landing in addition and this may be advisable in any event. Where a tractor is operating to a storage landing (logging cost report *(7)*, chapter XXI) the check scale will be when the logs are periodically loaded out and will be recorded in a regular scale book.

Form 9 is to be filled out by the workman making repairs. As each tractor will constitute a rather heavy investment a ledger account or series of accounts should be established for each machine to show at the end of each accounting period (at least annually) its status, including balance of capital investment, repair charges, etc. For the skidding operation as a

Form 5

FELLING RECORD

Block .... Division .... Subdivision ....
(Name) (No.) (Letter)

Name .... Date ....19....

Tree[1] No.	Species	D. B. H. *Inches*	Stump D. I. B. *Inches*	Surface area stump inside bark[2] *Sq. Ft.*	Rate per Sq. Ft. *Cents*	Add bonus for avoidance breakage 10 per cent *Cents*	Net earned each tree *Cents*
Totals							

[1] Start new series of numbers each week.

[2] Compute to nearest tenth of a square foot.

whole the ledger accounts shown in later summary under skidding will be necessary.

Through the device of a columnar ledger account all of the accounts except the first can, if desired, be charged directly or prorated to each machine. On the basis of these accounts there will be continually built up cost figures which will give the daily machine rate (operating cost) for each machine. This, divided by the output per machine shown by the output record accumulated from Form 8, will show the skidding cost per M feet. Taken in connection with other cost elements of logging this will show at any given time whether costs are being maintained on an efficiency level and whether operation along current lines is justified in view of the returns from sale of the product.

Cable Yarding.—When cable yarding with drum units has to be performed on steep areas these costs may be handled in the same manner and should be added to skidding costs unless the yarding is direct to truck road or railroad landings. Costs covering operation of drum units should be kept in manner described for skidding.

Tractor roading.—In numerous instances the next form of transportation after skidding or yarding with tractors will be roading. The record system for this operation is the same as for skidding and the same forms may be used. Tractors used in construction work may be handled under similar accounts except that output records should be in terms of footage of tractor road graded or yardage handled.

The sum of the costs of felling and bucking, skidding, yarding, roading, and preparing roads will be the current cost of delivering logs at landing ready for the next form of transport.

Loading.—When truck loading is performed independently, which is very desirable, a device which can travel or be transported by tractors from landing to landing is the most efficient. The same device or a locomotive crane may serve this purpose on railroads. Output records should be kept showing the number and volume of logs loaded each day. An ordinary scale book will serve the purpose if the output figures are taken off daily in form to be easily summarized. Costs should be accumulated in a manner to show the daily operating cost of the crew and the machinery used, i.e., the machine rate. Ledger accounts similar to those used in skidding but properly designated to apply to loading will be necessary.

Truck haul.—This is usually done on contract and the logging operator needs a system of scaling the loads, for which an ordinary scale book will serve. Usually the check scale on the basis of which skidding is paid for should be the basis for payment for truck haul. Payment may fairly be made on gross scale. If on contract, one ledger account will serve. Necessary ledger account or accounts are later indicated in the summary of ledger accounts.

Tractor road construction.—This work is conducted on the same basis as skidding. Daily, weekly, or monthly reports are made of footage graded or yardage moved. The same simple

Form 6

BUCKING RECORD

Block__________________ (Name) D vision________ (Number) Sub-division________ (Letter)

Bucker's Name____________________________ Date__________ 19___.

				1st log					2nd log	3rd log[1] and higher							
Tree[2] No.	Species	D.B.H.	Stump D.I.B.	Length	Top D.I.B.	Gross log scale	Net log scale	Surface area top inside bark			Total gross scale of tree	Total net scale of tree	Total surface area log cuts	Rate paid per sq. ft.	Return for each tree	Bonus for avoiding wastage if any	Net earned each tree
		Inches	*Inches*	*Feet*	*Inches*	*Bd. ft.*[3]	*Bd. ft.*[3]	*Sq. ft.*[4]			*Bd. ft.*	*Bd. ft.*	*Sq. ft.*	*Cents*	*Cents*	*Cents*	*Cents*
Totals																	

[1] Record any additional logs on following line.
[2] The same numbers as on Form 5.
[3] Cubic measurement is more accurate for this record, but board feet measurement is more customary.
[4] Compute to the nearest tenth of a square foot.

Form 7

FELLING AND BUCKING PAY SHEET
(2 weeks or monthly)

Name of payee............ ....half........19....
(1st or 2nd) (Month)

Dates	Daily earnings			Dates	Daily earnings		
	Gross	Deductions	Net		Gross	Deductions	Net
	Dolls.	Dolls.	Dolls.		Dolls.	Dolls.	Dolls.
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			
				31			
Total							

Total earned $....................
Deduct advances $................
Balance due $.....................

to direct labor accounts as a flat percentage of each; general supervision and general expense prorated according to direct expenditures on each operating element; depreciation charged directly or prorated according to the investment in each piece of equipment or in the ensemble of equipment used in one element of the operations; and fire insurance prorated according to residual investment. Although interest unless paid out does not usually properly enter into financial accounts it is chargeable as a part of costs incurred by the investment of capital. This may be accomplished by charging to each overhead or equipment capital account interest at the rate of six per cent per annum on the depreciated investment as shown after closing books for the previous years. The offsetting credit entries may be credited to a control account set up for the purpose and disposed of at the end of the year by charging to surplus

DAILY OPERATING RECORD — Form 8

Tractor No...............

Block ....Division ....Subdivision ....
(Name) (No.) (Letter)

Operator's Name ....19....
(Date)

Logs in turn: Turn No.	Logs in turn: Log No.	Species	Top D. I. B. *Inches*	Length *Feet*	Gross scale *Ft. b.m.*	Gross scale in turn *Ft. b.m.*	Net scale[1] *Ft. b.m.*
Totals							

[1] May be omitted.

system of ledger accounts to establish daily machine rates, constantly kept up to date, will be necessary.

Truck road construction.—This may be handled the same as tractor roads but in a separate account. In addition to tractor grading operations the services of a rock crusher and gravel trucks will at times be required but this work may be done by contract. If not by contract, capital accounts will be necessary for each machine as in the case of tractors.

Indirect or overhead charges.—Certain social security, ownership, and capital charges should be charged directly or prorated to the overhead account of each of the foregoing operations at each accounting period or at least annually. These include industrial insurance, old age insurance, unemployment insurance, and insurance against strikes, riots, etc., prorated

Form 9

MAINTENANCE REPORT[1]

Tractor No...........

Date.....................19....

Workman's Name ....

List type of repairs

Order No.
Work performed
Date Stop
Start
Date Stop
Start
Date Stop
Start
Total hours ....
Total cost labor ....
Materials cost ....
....
....
....
....
....
....
TOTAL COST ....

[1] Total costs will be charged to ledger account for the tractor concerned and credited to control accounts for labor, materials, etc.

account if earned or writing off as loss and gain account.

Forest operating and property accounts.—Certain elements involved in caring for the forest property as a whole independent of logging operations require recognition in financial accounts (which also serve as cost accounts). These elements are listed among the forest operating ledger accounts.

Summary of ledger accounts.—

Felling and Bucking

Felling, direct labor (at end of each accounting period industrial insurance, etc., is prorated to labor accounts).
Bucking, direct labor.
Felling and bucking, equipment and supplies.
Felling and bucking, maintenance of equipment.
Felling and bucking, direct supervision.
Felling and bucking, overhead (including general supervision, depreciation, taxes, insurance, and financial charges prorated each accounting period).

Tractor Skidding

Operating direct labor (see note above).
Operating supplies.
Maintenance labor.
Maintenance supplies.
Supervision (direct).
Overhead (including general supervision, depreciation, insurance, taxes, and financial charges prorated each accounting period).

Tractor Yarding (drum units)

If any operations use similar ledger accounts to those for skidding.

Tractor Roading

If any operations use similar ledger accounts to those for skidding.

Swinging

If any operations use similar ledger accounts to those for skidding. .

Loading (Trucks)

Use similar set of ledger accounts to those used for the skidding operation.

Truck Haul

If trucking is done on contract one ledger account designated "truck haul" is necessary. If trucks are owned and operated by the logging operator a series of ledger accounts similar to those described for tractor skidding should be used with designations indicating that they apply to truck haul.

Tractor Road Construction

Use similar set of ledger accounts to those used for the skidding operation.

Truck Road Construction

Use similar set of ledger accounts to those used for the skidding operation. If rock crushing and hauling is done by the regular organization instead of by contract capital accounts should be set up for the rock crusher and each truck.

General Accounts

In order to accumulate the items later to be prorated to direct labor and overhead accounts under each of the foregoing the following ledger accounts are necessary so far as applicable:

Industrial insurance	General logging supervision
Old age pensions	Depreciation reserve
Unemployment insurance	Taxes
Strike and riot insurance	Interest earned
Fire insurance	

Railroad Haul

If operated as a subsidiary only "freight" need appear in the general ledger covering logging.

Forest Operations

These vary but may require the following ledger accounts:
Forest administration—salaries.
Forest administration—expense.
Fire prevention—salaries.
Fire prevention—expense.
Fire suppression—labor.
Fire suppression—expense.
Forest engineering—salaries.
Forest engineering—expense.
Road construction—labor.
Road construction—expense.
Road maintenance—labor.
Road maintenance—expense.
Taxes.
Insurance.
General forest expense.
Any other items of expense that may pertain to the certain property.

Most of the above rate as general accounts to be charged off through proration either directly to operating accounts or indirectly through forest property accounts.

The forest property account should be kept by area units, that is, a ledger account should be set up for each block or forest division. To this will be apportioned annually the forest operating charges, usually on an acreage basis. In like manner there will be credited to each division the sales made therefrom, either directly or by prorating according to volume of timber cut. At the end of each year accounts for all blocks or divisions from which sales have been made will be closed by charging off accumulated expense, adjusting to the inventory, and disposing of the profit or loss through loss and gain account.

The ordinary accounts usually necessary to complete a system of corporate accounts, including provisions for annual closing of the books are as follows:

Capital Stock	Loss and gain
Notes—payable	Sales accounts with customers
Notes—receivable	Rent
Accounts—payable	General expense
Accounts—receivable	Administrative salaries, etc.

Economy in the conduct of accounting practice can be promoted by a judicious use of columnar journals and payroll books which permit distribution of costs to various ledger accounts without individual posting of every item. Columnar ledger pages though not very popular with accountants may also be used. This may be illustrated as follows for tractor No. 1 skidding operation.

With this ledger device the original entries will be in a suitably arranged columnar journal or other books of original entry. From these they will be posted direct to operating accounts or to control accounts. They will be posted as usual in the operating accounts to the right-hand page under Debit and Credit. On the left-hand ledger page the debits will be distributed to the cost categories indicated. In

Left-hand Page

ILLUSTRATING LEDGER FOLIO

Distribution of Debits

Operating		Maintenance		Super-vision	Skidding Overhead	Capital Account
Labor Dr.	Supplies Dr.	Labor Dr.	Supplies Dr.	Dr.	Dr.	Dr.

Right-hand Page

Account.—Tractor No. 1

Skidding Operation

Items		Distribution of Credits			
Debits	Credits	Cr.	Cr.	Cr.	Cr.

effect the right-hand page constitutes the essential financial account and the left-hand a cost account directly tied to the financial accounts. Only a few credit entries will occur in the account cited, mostly connected with handling depreciation and with periodic closing of the books. If any distribution of these items is used two or three distributing columns can be provided on the right of the main credit column.

61. Determination of current operating costs.—With the foregoing administrative and accounting system perfected as to further necessary details applicable in a given case it is obvious that each element of cost can be readily determined. Thus with tractor No. 1 skidding, suppose the cost for the month just closed, including distribution to overhead account and a charge to depreciation reserve, is $750. Suppose further that output records accumulated from Form 8 show that 1,300,000 feet b.m. were skidded during the month. The cost per M feet was therefore 58 cents. Other current elements of cost can readily be summarized in the same manner. Total operating cost per thousand board feet can then be summarized as in the following example:

	Cost per M ft. b.m.
1. Selection of timber for cutting and planning extraction methods	$0.06
2. Felling and bucking	1.00
3. Road construction	.30
4. Skidding	.58
5. Loading	.20
6. Truck haul	1.25
7. Common-carrier transport	1.50
8. Scaling, booming, and rafting	.25
Total cost delivered to log market (excluding stumpage)	$5.14

If other forms of transportation are necessary they should be included with the above.

The conversion value of the stumpage per M feet is the sale value of the logs less the above cost. This will, of course, depend on the quality of the timber selected for cutting. The level of conversion values is the most important operating factor and, since it fixes the returns from the forest property, it must be constantly watched. It directly influences timber selection policies.

62. Railroad haul.—Where this form of transport is retained, whether private or common carrier, it should be set up as a subsidiary operation. Capital charges usually outweigh direct operating costs. Accounting should be so handled that costs will be accumulated against each major element of the operation. Direct labor costs can readily be distributed by use of a suitable payroll form. The following subdivisions of costs, each covered by a ledger account, will usually be sufficient.

Train Operation—
- Direct labor
- Supplies
- Supervision

Other operating costs—
- Direct labor
- Supplies
- Supervision

Locomotive maintenance—
- Direct labor
- Supplies
- Supervision

Rolling stock maintenance—
- Direct labor
- Supplies
- Supervision

Track Maintenance—
- Direct labor
- Supplies
- Supervision

Other structure maintenance—
- Direct labor
- Supplies
- Supervision

Depreciation—
Rolling stock
Trackage
Structures
Industrial and social insurance and insurance against strikes, riots, etc., prorated to all direct labor accounts.
Taxes—Prorated to each portion of investment.
General supervision to general expense.
Fire insurance and
Other insurance—Prorated.

Interest at a moderate rate may be considered as a cost and may be handled as suggested for the logging operation proper. As the cost of railroad operations consists overwhelmingly of capital charges an alternative method is to omit interest from cost accounts and watch earnings of the investment as a whole to determine whether conduct of the business is satisfactory. Depreciation should be levied at as heavy a rate as possible owing to uncertainty as to permanence of this form of transportation for any distance less than 30 miles. The simplicity of truck operation and its adaptability to contract hauling may be expected progressively to curtail railroad hauling. Where railroading operations are organized independently such additional ledger accounts should be added as are necessary to handle business operations and close the books annually.

63. Forest production costs under selective management accumulated by methods described shown in terms of direct money outlay.—If the annual costs of administration, protection, and taxes are accumulated without interest by means of the foregoing forest operating accounts for any forest division during the period of a cutting cycle, say five years, the sum total for the period will constitute the actual money outlay incurred in producing the timber volume that is added to the stand during the period. For example, if the production costs on a forest division of 1,000 acres should be as shown in table 23, and if the growth rate should be 600 board feet per acre per annum or 3,000,000 board feet for the division for 5 years, the money outlay would be $1.33 per thousand board feet. If a growing stock of well-distributed sizes should be maintained so that a cyclic cut of 3,000,000 board feet (equal to the growth) can be taken, the stumpage value might be $5.00 per M board feet, thus yielding a gross profit of $3.67 per M board feet or about $11,000 for the 5-year increment on 1,000 acres. This profit would be available to pay returns on the investment in that forest division. Capitalizing this income at 5 per cent annual interest yields a capital value of $44 per acre for the division.

TABLE 24.—*Typical production costs for a five-year cutting cycle, Douglas fir region*

Cost Items	Cost per acre per annum	Cost per acre for 5 years	Cost for 1,000 acres 5 years
	Cents	*Cents*	*Dollars*
Administration	10	50	500
Forest Protection	10	50	500
Taxes	60	300	3,000
Totals	80	400	4,000

64. Conclusion.—The foregoing suggestions for setting up administration and a system of administrative records are only in rough outline. The competent business manager will adapt his organization and records to the needs of the particular situation. The services of an expert accountant may be necessary but his work must be closely supervised to avoid setting up a complicated and apparently systematic and very detailed accounting system which, however, will completely fail to collect the essential information. It is not here suggested that any one rigid type of organization and administration can be adapted to all situations. The principal aim is to show the simplicity, from the administrative standpoint, of the methods that are available.

With complete flexibility and complete control established it will be wholly unnecessary to take out timber at losses such as have often occurred. It may at times be necessary to sacrifice some portion of normal stumpage values in order to meet taxes and other fixed charges, but continuing operating losses for the mere sake of completing some operating commitment unwisely entered into should be a thing of the past. In cost studies distributed throughout a large part of the Douglas fir region and conducted in various depression years no well situated tract has been found where properly selected stumpage logged by the lowest cost methods available did not have a substantial conversion value. Selective timber management will confine operations to such stumpage. In periods of restricted demand the additional responsibility rests on each operator of limiting operations to his fair share of the market.

CHAPTER X

REVIEW AND CONCLUSIONS

65. Résumé of intensive selective timber management as applied to long-time timber supply.—An understanding of the conditions prevailing in the Douglas fir region with respect to the forests, timber values, and markets points the way to selective timber management. In this region there are wide differences in rate of tree growth as influenced by timber type, site quality, and density of stocking; mortality, decay, and risk factors also vary widely. A wide range in stumpage conversion values is characteristic of typical forests of the region. These differences in value arise from differences in timber types, topography, and location, as well as in species, quality, and size of timber (chapters II to V, inclusive). Then, too, market fluctuations which occur from time to time may temporarily upset normal value relations among different species, qualities, and types of timber.

The rapid evolution of flexible logging equipment and methods *(7)* that has taken place during the last few years has a significant effect on the possibilities of selective timber management. Crawler tractors, fairlead arches, bulldozers, tractor-mounted drum units, etc., combined where necessary with skyline swinging, constitute practical operating tools for intensive selection by individual trees and by small groups. They offer the flexibility and selectivity that are needed for both long-term selective management and current market selection. They also bring important savings through reduction of timber breakage and, wherever conditions are suitable for their effective use, a substantial reduction of logging costs. Curiously enough, this reduction in costs may often be relatively the greatest in rough-country areas (chapter IV) even though the new methods in their present state of development may not be directly applicable to all portions.

A large part of the reduction of logging costs is brought about through the striking economy of long-distance tractor roading and in many cases also through substitution of motor roads for railroad spurs. Such a road system differs radically from the old system; including tractor roads, the mileage will be much greater, but both the initial and maintenance costs will be much less—usually less than one-third as much.

Light initial cut will permit quick liquidation of overmature timber.—The advantages of selective timber management are most clearly demonstrable in connection with large, well-stocked properties with a long-time supply of timber. In such a forest the first step, as shown in the examples cited in chapters III, IV, and V, is to start with the best and handiest logging shows for an initial removal of only a small portion of the stand (generally 15 to 25 per cent by volume), partly by individual tree selection and partly by small-group selection (generally 1- to 10-acre areas), according to the character of the stand. The immediate aim is to liquidate quickly the financially most overmature portion of the realizable timber capital. In typical cases the timber taken out in this cut would consist to a large extent of decadent old-growth timber of very high stumpage conversion value, together with outright salvage of merchantable windfalls or other dead and rapidly deteriorating timber. If liquidation of these nonproductive or declining, though generally high-value elements of the stand were long delayed, a serious loss, relatively speaking, would be suffered; mortality, decay, other risks, and above all, discount of long-deferred income work together to make a heavy financial pressure for early liquidation. Prevention of these excessive losses requires rapid extension of the local road system so as to facilitate a light initial cut. The savings effected through this hastened liquidation of only a small portion of the stand will pay for such a road system. Snag felling and other necessary fire protective measures will pay for themselves in the same way.

Permanent road system is key to successful selective management.—The roads thus constructed can and should be charged off against the initial cut, or in any event amortized within a few years after construction. This is an important point to remember. A permanent road system of this kind will give convenient and quick access to all parts of the operating area. It will place the growing stock under complete selective control, and where continuously maintained through constant or relatively frequent use, will constitute as essential a part of an intensively managed forest as do the land and the trees themselves. It is the key to management methods featuring short cutting cycles and light cuts. It is the key to market selection and to effective fire protection. Further than this, in conjunction with a relatively large aggregate of landing space for log storage, it is the key to high operating efficiency, because it will make possible (a) complete separation of yarding from loading, (b) decentralization of yarding into small, independent operating units, and (c) a high degree of specialization in handling timber of widely differing sizes. All of these are prerequisites in the attainment of maximum operating efficiency in logging *(7)*.

Closely following the initial cut as it gradually progresses through the tract, the road system will permit light return cuts to be made one after another. A regular cutting cycle of 5 years is indicated in the cases discussed in chapters IV and V, and the cyclic cut on any given area may be further split into two or more cuts as may be desired for various reasons, such as market selection and salvage. The logging operations should sweep back and forth (touching only lightly in some places, not at all in others, and clear cutting small patches here and there) constantly aiming at removing that portion of the growing stock which at any given time is most urgently in need of removal. This means that logging can always be kept closely attuned to the market. It means that fire-killed, bug-killed, windthrown, or otherwise damaged merchantable timber can be salvaged before serious deterioration sets in, usually in the course of the regular logging operations. It also means that the bulk of the current cut would ordinarily continue to come from the most mature and generally more valuable elements of the stand, from which the market would be supplied with its requirements for high-grade timber. For increased production of the lower grades—to whatever extent profitable market demand might permit—the cut would be centered on the naturally complementary sources of low-grade material. Such material should preferably be obtained through closer top utilization of the trees actually cut, and through sanitation cuttings in old-growth stands and improvement cuttings in second-growth stands, in effect it would constitute free surplus stumpage, the removal of which would enhance rather than detract from future returns.

Selective management will lead to increased growth.—As this program is carried out, the net productivity of the forest, originally in equilibrium, with growth offset by mortality, should gradually increase. Most rapid progress in this direction should be made during the initial cut. Here mortality losses in merchantable timber will be practically stopped as soon as windfalls and dead or defective old-growth trees are removed and the remaining timber placed under intensive management. Growth on the remaining merchantable timber should thereafter offset a large part of the cut and so extend the life of the timber supply. Further and continued progress should be made as young timber responds to release cuttings, and as new growth comes in to take the place of the slow-growing old timber that has been removed.

Skillful management of new growth is, of course, necessary to the ultimate development of such methods. Highly favorable conditions will be created for the successful regeneration, survival, and management of new growth, because the selective method, unlike extensive clear-cutting will provide an overabundant seed supply, will retain for the most part the forest climate with its naturally moist growing conditions and relative safety from fire, and will provide permanent roads, a permanent logging organization, and intensive fire protection—all as a part of efficient management of the existing merchantable growing stock. High density of stocking, which is the key to full use of the soil for both quality and quantity production, will here be within relatively easy reach of skillful management that recognizes the silvicultural requirements of the various species and timber types. In densely stocked patches of second growth, intensive stand management would generally begin with thinnings at the ages of from 40 to 60 years, and this treatment would be repeated at short intervals over a long period before liquidation-and-regeneration cuttings again took place. The result of this procedure, as described in chapters III through VI, should be sustained yield of high-value timber. The growth capacity of the soil would be permanently devoted to trees mainly of merchantable size, for the pre-merchantable period would be short in relation to the average life span of the trees that make up the bulk of the cut. Most of the cut, even after the original old-growth trees are gone, would continue to come from large, high-quality trees generally from 100 to 200 years of age; the remainder would be supplied from thinnings in stands from 40 to 100 years old.

Silvicultural and fire protection practices developed and tested on the basis of accumulating experience.—No attempt has been made in this report to set forth the precise measures required for attainment of the best silvicultural and fire protection results. As a matter of fact, since widespread operating experience is still lacking, final judgment cannot be rendered as to how these problems generally should be handled. This is furthermore a problem many of the details of which will have to be worked out on the ground for each individual forest property. From the silvicultural point of view the essential thing to know before hand is that the selective program provides a permanent road system and selective control of the growing stock. Furthermore it provides for group selection (clear cutting) as well as for tree selection. These two forms of cutting can be made complementary to each other to whatever extent regeneration or other requirements may dictate. It is also well to know and to recognize that in initiating selective timber management on any large area of natural forests, the immediate probelm is not how to get regeneration but how to get the growing stock into the most productive condition possible. A good many years will elapse before the initial task of cleaning up stagnant and declining values and placing the growing stock under selective control is completed. In the meantime, the regeneration results obtained from various degrees of tree selection cuttings and various forms of group selection cuttings can be observed and studied for the purpose of determining the future course in this particular respect.

From a fire protection point of view the situation is much the same. The main points in a sound fire protection program is to preserve the forest climate, to maintain a fire resistant stand, and by means of a permanent road system to promptly utilize matured timber and salvage timber killed by fire, insects, and other destructive agencies. Through these measures and through giving time for widely distributed slash to decompose and return to the soil, selective management aims at gradual attrition of the inflammable debris in the forest to the point where fire hazards will be less and fire control more feasible than under existing conditions. The experience of countries where such methods have been used over long terms of years warrant the belief that these expectations are realizable.

Selective sustained yield management gives highest returns.—To summarize, then, intensive selective timber management, applied to well-stocked properties with long-time timber supply to begin with, should bring a relatively high immediate income and at the same time lay a foundation for a relatively high sustained yield income. The guiding principle in balancing plans for immediate income against provision for high future returns is to manage a property for its highest capital value, as determined by discounting a series of deferred annual incomes to their present net worth—a principle that is recognized in all branches of investment management, as for example in life insurance, banking, farming, and real estate. This means that attention should be given not only to current income but also to the capitalized value that remains. It means essentially that liquidation of timber should take place in an orderly manner, while remaining amply flexible for immediate response to changing market demands and prices. In other words, non-earning and low-earning timber should be liquidated in the order of its relative financial maturity, and higher-earning timber should be held until financially mature or until its turn to be liquidated arrives. The constant aim should be to keep the land productive; the logger's ax should work with Nature rather than against her, and guide and speed her productive processes rather than destroy them. The productive capacity of the soil will thus be directed toward sustained production of high-quality timber, the source of a permanent capital value that is now being left undeveloped.

Selective management builds for the future without undue gambling, on the uncertainties of the future. It first of all looks after the present. Many decades will be required to remold the forest to the pattern desired; it will not at first present an orderly or finished picture. But from the very start of selective operations Nature's productive forces, starting with very moderate gains, can be progressively released to work toward the desired ends.

66. Contrast between forestry starting with bare land and selective sustained yield management of existing timber.—Timber growing in this region has been and is still being thought of very largely in terms of conventional "bare-land" forestry. In its purest form, this contemplates that the timber-growing enterprise would start with an investment in logged-off lands and a further investment in planting, and thereafter continue for perhaps 60, 80, or 100 years with annual expenses for administration, protection, and taxes. Compound interest, at rates sufficiently high to cover the extraordinary risks that are here involved, will commonly run the total accumulated investment to large amounts. The prospective timber grower, under such circumstances, is confronted with the problem of building up a forest from "scratch." He finds that there are many uncertainties involved as to costs and returns. He logically reasons that he is spending money in the present for uncertain returns in the long-deferred future; that he is tackling a job that will not be finished during his lifetime; that he is attempting to work against the devastating effect which compound interest has on an enterprise in which for many long decades money will constantly be going out with nothing coming in.

Intensive selective management as applied to a forest with a long-time timber supply will create an entirely different basis for the timber-growing end of the business. Timber growing will begin with orderly selective liquidation and intensive management control of the existing timber, and the forest will be gradually brought to a high state of productivity by eliminating the declining or least productive growing stock and by putting the land to work at its maximum productive capacity. This, as has been shown, may be accomplished very largely by taking money out of the forest, not by putting money into it. Such timber growing "costs" as the owner may find it advisable to assume in order to obtain increased productivity can be charged off currently like any other item of current production costs. This will avoid the stumpage depletion costs that would have to be charged against the annual cut in case the productivity (i.e., the capital value) of the forest were not to be maintained on a permanent basis. The current costs of forest management should seldom amount to more than a very small fraction of such depletion charges.

67. The status of short-term operations.—It is true that there are many existing properties in the Douglas fir region which, considered by themselves, do not qualify for the type of management herein discussed. As a result of the method of disposal of timber from the public domain and of later transfers of ownership, a considerable number of properties have been segregated which cannot stand on their own feet. This does not mean that all or even a majority of such small properties need be excluded from sustained yield management. If a property is large enough to allow a periodic or cyclic cut every 5 to 10 years without undue sacrifice of operating efficiency, it is perfectly feasible to manage it for a sustained yield, though the returns in such cases will not be annual. With modern methods of truck transportation, however, it will frequently be possible for a single operator to combine the yields from several small tracts into a continuous operation, even if they are scattered over a considerable area.

The existence of a large number of enterprises engaged in liquidation of certain areas must not be overlooked, because of their effect on forest management in the Douglas fir region as a whole. If extensive clear cutting were economically the most desirable practice, destruction of these small properties might be inevitable, but it is not. The fact that selective cutting is more economic, with respect both to immediate returns and to preservation of future values, makes complete liquidation undesirable. As matters stand these liquidating operations have preempted to themselves an undue share of market outlets in proportion to the timber held, and they occupy a privileged position in this respect which is preventing the marketing of the legitimate output of sustained yield operations throughout the entire region. It will no doubt take some time to correct these practices, but their damaging effect on industrial welfare, on the communities, and on regional interests generally should receive the earnest attention of all parties concerned.

On first thought it may seem that the most profitable course for short-term operators to follow is to take full advantage of the opportunity to liquidate without regard for the need of other owners to market their timber or for regional interests in general. In reasoning along this line, however, it should not be overlooked that pressure for liquidation is forcing many owners of non-operating timber to attempt disposal of their holdings at whatever price will attract a buyer. This depresses the prices of all timber and logs and severely reduces the capital recoveries from liquidating short-term properties.

An enlightened selective policy by existing operators is needed, designed to supply the market with its full requirements of high-value logs, such as the plywood industry requires, together with all the pulp and other low-value logs that forest industries can profitably use, but avoiding dumping excessive quantities of inferior material on an overburdened market. This would soon permit selective cutting of higher value timber and receipt of some income by the less remote non-operated properties. Thus a policy of light selection, first within present operating properties and later within non-operating properties (now available at discounted prices), would become operative in much the same manner as shown in the case of the long-term property discussed in chapter III. Experienced short-term operators by quickly realizing on high-value timber and acquiring interests in non-operated timber would thus become long-term operators holding less valuable portions and elements of their present properties for future operations. In this way the operating experience, equipment, and market outlets of these operators could in natural sequence be applied for the common good of the forest industries and the Douglas fir region. Obviously these measures require the individual operator to realize the identity of his own welfare with that of the regional forest industries as a whole, but accumulating evidence indicates that this point of view is rapidly growing for many reasons in addition to community of interest in the standing timber supply. Without it, not even successful operations rest on a firm foundation, and disbandment of many competent operating organizations will soon occur. If this regional or industry point of view prevails, successful consolidation of operating short-term and non-operating timber properties into sustained yield units can readily take place in a voluntary and wholly natural manner.

Such consolidation of existing short-term units and stoppage of further disintegration of existing sustained yield units are the principal measures required to eliminate destructive liquidation, to bring about sustained yield, and to introduce an orderly economic system of marketing the region's timber resources. If the market outlets are fairly divided among all the management units, public and private, there is no question but that on the one hand there will be sufficient outlets for practically all the sustained yield products, and on the other hand that such markets as have existed in the past will be fully supplied. There are, of course, certain rough, remote units with low-quality timber which are not yet ready for operation. The temporary holding back of such areas will permit those of the present short-term operations that cannot be fitted into the sustained yield picture to complete their present program and then permanently to retire from the scene. As these short-term operations drop out, the slack in production would be taken up by the more remote units, and in time also by restoration of production on the large areas from which the growing stock has been removed in the past.

68. **Restoration of production on areas clear cut in the past.**—The growing stock has now been completely removed from approximately 7 million acres of the most accessible and, for the most part, the highest quality timber lands in the Douglas fir region. The result is that the operable timber zone has been pushed back into generally rough areas, remote from the manufacturing centers and principal shipping outlets. This imposes a severe transportation-cost handicap on the bulk of the forest materials that will be available to industries for many years to come, in comparison with the raw material costs that would have been posisible had selective timber management been continued, as originally started on the accessible areas, and improved upon as time went on. However, in spite of this handicap, the timber of the Douglas fir region remains as accessible to deep-water shipment as that of any coniferous forest region in the world.

Restoration of the major part of these depleted forest areas that are not fit for other and higher uses must for a long time remain one of the extremely important problems before the forest industries and the communities of the region. At the present time it imposes heavy expenses for fire protection and maintenance of public services in scattered communities and settlements while contributing very little in return. Rehabilitation of the best located of these areas is particularly important in view of the opportunities they offer for integration of forestry and agriculture. Whether brought under intensive management as farm woodlands or as commercial forest units, they are obviously capable of contributing in an important way to the economic well-being of the communities concerned. The forest enterprises themselves will, in turn derive important benefits, such as availability of labor, public roads, local markets, and low costs for public services.

The problem of restoring these areas cannot be stated in terms of going operations, with current outgo and income, but must be considered first in terms of restoration of a destroyed capital value. Only after this restoration has been accomplished will continuous operation of forest enterprises actually be possible.

The period over which this restoration will necessarily extend cannot generally be less than a century if high quality material is to be produced. The region possesses industries, however, that can absorb considerable material from young stands as they develop, beginning with ages from 40 to 60 years, for pulpwood, poles, piling, posts, etc. If the young stands are again ruthlessly cut over, as they inevitably would be under the present wholesale clear-cutting system, they will continue to produce only the lowest grades of forest products, and will occupy the markets that should be reserved for thinnings and improvement cuttings from better managed forests. If, on the other hand, virtually all owners should adopt a sound system of selective timber management, the yield of high-quality material from these areas can be reestablished. Each owner would then have a reasonable share of the market for the smaller materials removed periodically in thinning his timber stands, and the rebuilding process generally could be counted on to pay its way and yield some profit after the stands are from 40 to 60 years of age. Large areas of young stands are already old enough for selective management to begin.

69. Continuous supplies of large, high-quality timber and concurrent production of lower grades are essential to the forest industries of this region.—The form of forest management heretofore assumed feasible in the Douglas fir region contemplated the production of relatively small-sized, and generally, from the viewpoint of the lumber industry, low-value material. Such a program does not take into account the fact that unless adequate provision is made for continuous production of large-sized, high-quality timber the most profitable industries of the region will not long be able to maintain their existence. The plywood industry, which depends exclusively on high-grade material, is still making remarkable progress and is the support of numerous secondary wood-using industries, such as door and furniture manufacture. The lumber industry itself, which still uses the greater mass of material taken from the forest, also depends to a great degree on its command of a supply of high-grade logs. If the supply were cut off, most of the profitable lumber items, including high-grade interior finish, flooring, and large timbers, for which there is a world market, would drop out of the picture. It is well known that the returns from these higher grades are the source of virtually all the profit in the industry, many of the other grades being no more than by-products that often sell below the actual cost of production. The high grades pay the primary cost of logging and manufacture, and without them most forest areas could not be operated at all.

If the supply of high-quality timber is allowed to diminish there is no escaping the conclusion that a large proportion of the foreign markets and most of the remote domestic markets will be lost. The lower grades of lumber cannot stand on their own feet for distant shipments. In particular, the large eastern domestic markets for these grades of west coast woods are sure to dwindle, because it has been amply demonstrated that the southern pine region with its 200 million acres of forest lands can produce them at lower cost and with a large freight differential in its favor.

Although the maintenance of supplies of large timber is of the first importance, smaller trees, necessarily removed from the forest in the selective management process, will fit in a much more limited way into a balanced industrial program in the region. Sound and straight trees, varying from post to long piling sizes, are useful in producing very high-value products in certain industries, of which the wood-preservation industry is the best known. The smaller trees, although logged and sawn at higher cost than the larger trees, also provide excellent lumber of the common grades. The continued supply of these grades at reasonable costs undoubtedly will have an important beneficial influence on the continued demand for finishing lumber, plywood, etc., produced from larger trees. Obviously the local Pacific Coast markets will continue to absorb large quantities of these grades, even though more distant markets may be increasingly supplied from sources nearer to them. Thus, taking all grades of lumber and plywood into consideration, balanced production will be essential if large market outlets are to be continually assured.

Finally, it should be noted that although lumber continues to constitute about half of the wood utilized from American forests, some persons believe that existing trends in utilization indicate that wood fiber products, chiefly pulp and paper, may eventually become the major products of the forest. However, even if "cellulose forestry" should increase in importance far beyond what is now anticipated, the findings of this study are in no wise invalidated. In this region, large trees can be grown and logged more cheaply per thousand board feet than small trees. Under any conditions yet visualized saw-timber forestry should pay its own way and provide as a by-product all the pulpwood that can be used, whereas pulpwood produced separately will have to bear all forestry costs. Selective management offers the most practicable means of maintaining the ready-grown stand of pulpwood species of proven value; and such management favors these species in regeneration, in contrast to extensive clear cutting, which favors Douglas fir, a species as yet of very limited use in the pulp industry.

70. Perpetuation of existing resources and investment values is at stake.—The principal problem before the Pacific Northwest is perpetuation of existing forest resources at a high level of continuous productivity. If this is accomplished there is little doubt that the investment values of forests and forest industries also will be maintained. Ample evidence exists that extensive clear cutting as at present practiced will not accomplish this, but that on the contrary it will result in depletion of the resource and loss of most of the capital values dependent thereon.

The methods described herein do not contemplate the making of extensive new investments in the forests, but on the contrary provide for early withdrawal of large but nonproductive investments already made in the existing timber supply. Building up of a new growing stock with adequate representation of diameter classes above 40 inches would be the work of centuries, but carrying on an existing stock in which these diameter classes are already well represented involves only the continual reservation of sufficient medium-sized trees to grow into the place of the large trees as they are cut. In like manner, the small trees already existing in large numbers will replace the medium trees, premerchantable trees will be recruited into the small-tree class, and abundant regeneration will replenish the premerchantable ranks. All these progressions taking place simultaneously in a forest already well stocked involve no long-time financial commitments and no accumulation of costs or earnings at compound interest. It is only necessary to find for each forest property the most favorable margin or balance of net returns resulting from the relationship between annual costs and annual income. Investment values would thus be based upon capitalization of stable net earnings rather than upon the entirely fictitious idea that all merchantable trees are capable of liquidation in a year or in a few years. If good management can be attained for each individual property in a given locality or within the region, the result should be a continued flow of income to labor and a continued safeguard of all other community interests.

Other values of the forest will be maintained by selective management methods.—Throughout this discussion little consideration has been given to forest values other than for commercial timber production. It is perfectly clear, however, that a management procedure that preserves a heavy growing stock and generally excludes extensive clear-cutting will promote also the aesthetic, protective and other functions of the forest which make it of multiple utility.

A comprehensive view of the forest management problem must include these aspects and work toward a program that will preserve all possible regional values and opportunities. Under this broad policy the economic foundation should be ample to support, without undue burden to any interest, those services of the forest which have come to be indispensable in the modern world.

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PLATES

PLATE I

TOPOGRAPHY AND FOREST TYPES OF SUSTAINED YIELD AREA (CHAPTER IV)

Approximately 65,000 acres of the 74,000-acre sustained yield unit are shown on the map. Most of the area is covered with a highly defective stand of 300- to 400-year-old Douglas fir, aggregating more than 2 billion board feet. Younger Douglas fir stands, varying from 60 to 120 years in age, extend over 12,000 acres, and premerchantable stands, 1 to 20 years old, cover 10,000 acres. The youngest stands in block 1 have come in following clear cutting; the older young stands have come in as a result of past forest fires, small and large.

The topography in many portions of the area is extremely steep and rough, elevations ranging from 1,000 to 5,000 feet.

A motor road extends from the proposed mill site through block 9, and a logging railroad has been built into block 2.

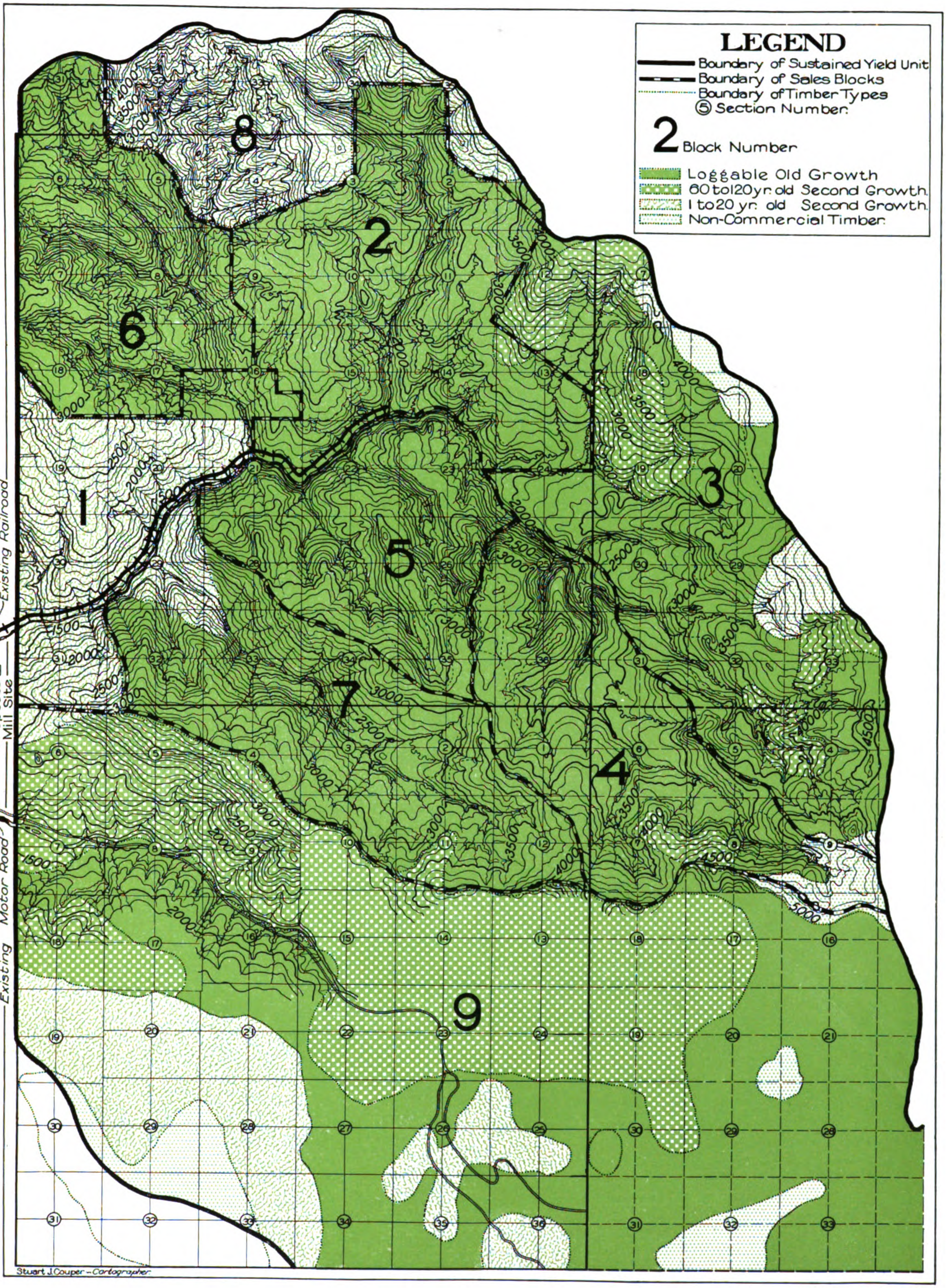

LEGEND
Boundary of Sustained Yield Unit
Boundary of Sales Blocks
Boundary of Timber Types
⑤ Section Number
2 Block Number
Loggable Old Growth
60 to 120 yr. old Second Growth
1 to 20 yr. old Second Growth
Non-Commercial Timber
Existing Railroad
Proposed Mill Site
Existing Motor Road
Stuart J. Couper—Cartographer

PLATE II

OPERATING MAP OF BLOCK 2 (CHAPTER IV)

This map depicts in more detail one of the nine blocks shown on Plate I and shows in broad outline plans of operation under cable and motorized logging.

The block comprises more than 6,000 acres with a total volume of about 400 million feet of old-growth Douglas fir. The topography of the block as a whole is steep and rough, but tractor logging is nevertheless possible on about two-thirds of the total area. Cross-hatched areas indicate portions suitable only for cable logging or for various combinations of skyline swinging and drum-unit yarding, etc.

Under motorized logging, truck and tractor roads, represented by red lines, take the place of about 39 miles of railroad spurs which had been planned under the cable logging system. Resultant reduction in railroad construction and operating costs are largely responsible for a saving in logging costs estimated at about $2 per M feet b.m.

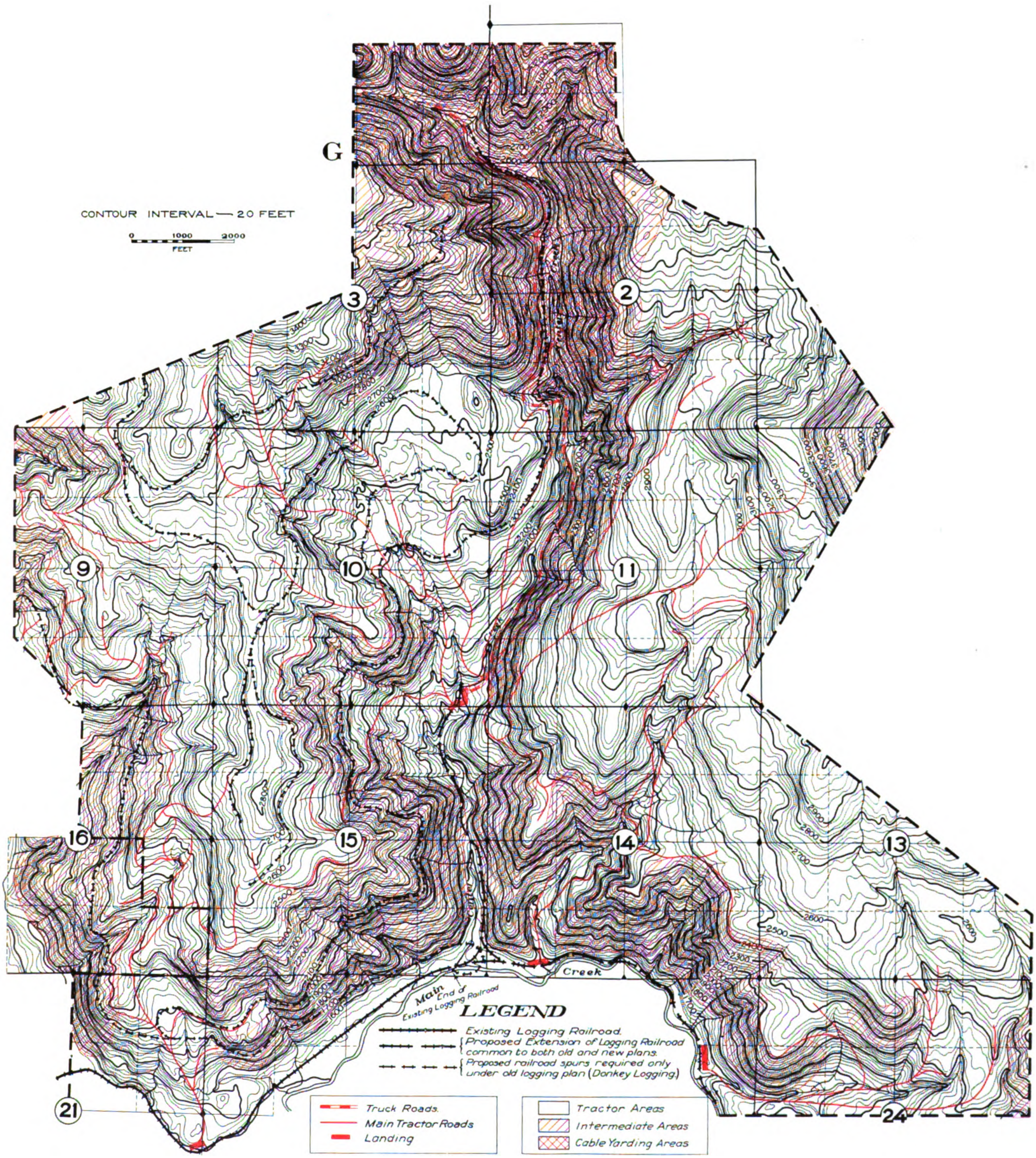

G
CONTOUR INTERVAL — 20 FEET
0 1000 2000
FEET
3
2
9
10
11
16
15
14
13
21
24
Creek
Main
End of Existing Logging Railroad
LEGEND
Existing Logging Railroad.
Proposed Extension of Logging Railroad common to both old and new plans.
Proposed railroad spurs required only under old logging plan (Donkey Logging)
Truck Roads.
Main Tractor Roads
Landing
Tractor Areas
Intermediate Areas
Cable Yarding Areas

PLATE III

ORDER OF ROAD DEVELOPMENT AND CUTTING ON SUSTAINED YIELD AREA (CHAPTER IV)

In order to obtain the highest returns during each cycle, accessible and gently sloping areas should be developed first, followed in order by rougher areas. The map shows how cutting should spread rapidly throughout the entire tract. The roads should be charged off against the current cut. Only road maintenance will then be a charge against future cutting operations.

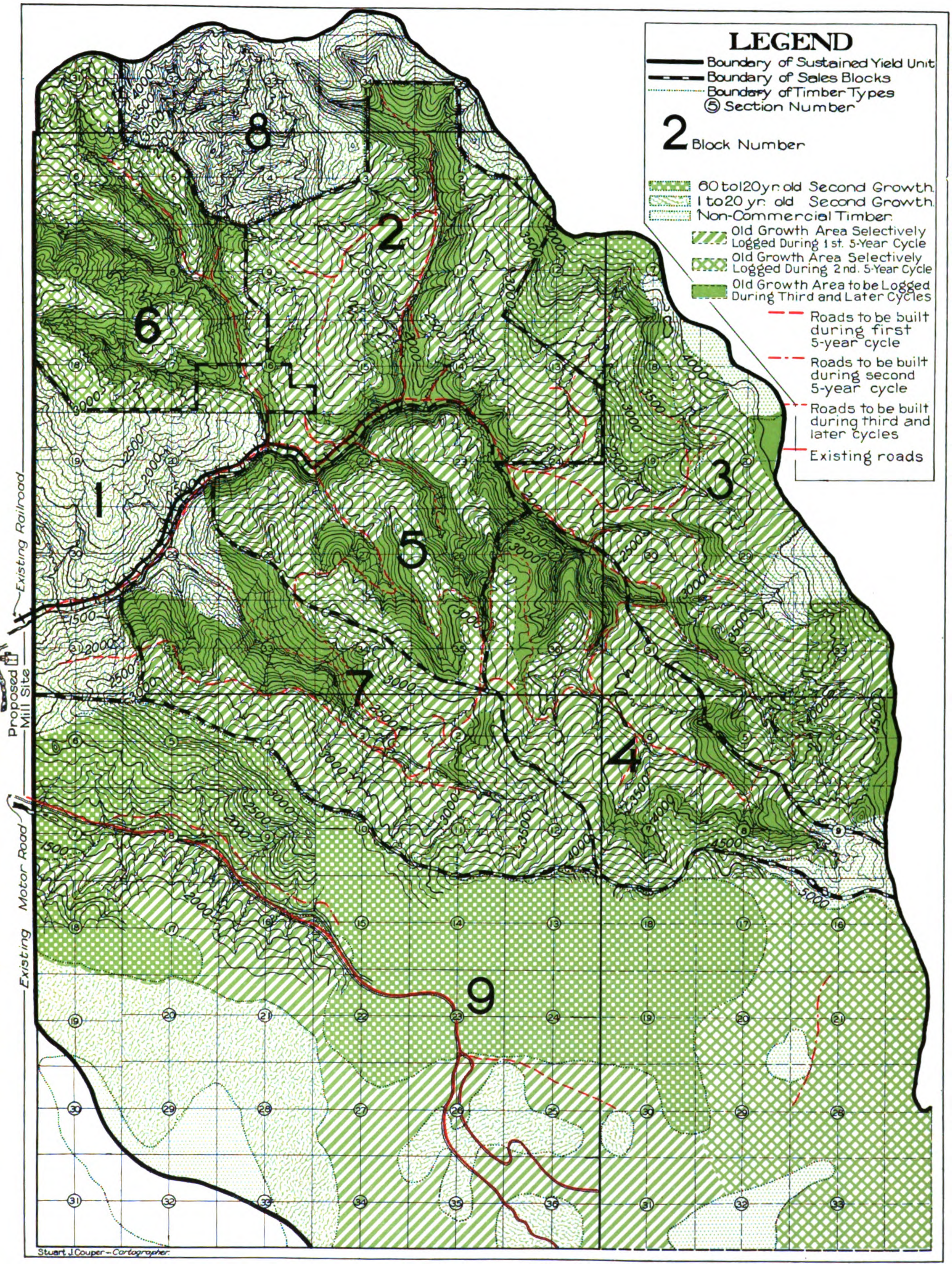

LEGEND
Boundary of Sustained Yield Unit
Boundary of Sales Blocks
Boundary of Timber Types
⑤ Section Number
2 Block Number
60 to 120 yr. old Second Growth
1 to 20 yr. old Second Growth
Non-Commercial Timber
Old Growth Area Selectively Logged During 1st. 5-Year Cycle
Old Growth Area Selectively Logged During 2nd. 5-Year Cycle
Old Growth Area to be Logged During Third and Later Cycles
Roads to be built during first 5-year cycle
Roads to be built during second 5-year cycle
Roads to be built during third and later cycles
Existing roads
Existing Railroad
Proposed Mill Site
Existing Motor Road
Stuart J. Couper—Cartographer

PLATE IV

TOPOGRAPHY, TIMBER TYPES, BLOCK BOUNDARIES, AND ROADS OF SUSTAINED YIELD AREA (CHAPTER V)

Blocks 1 to 5 contain heavy stands of accessible old-growth timber and should yield most of the cut during the first 3 or 4 cycles. Blocks A to E contain mostly young stands with some inferior old-growth. The development of roads and enlargement of cutting operations should be gradual in these areas. Fundamentally, the same criteria should control cuttings in old and in young stands; these are conversion to current income of investment values in timber incapable of making further profitable earnings and reserving of timber capable of yielding satisfactory earnings.

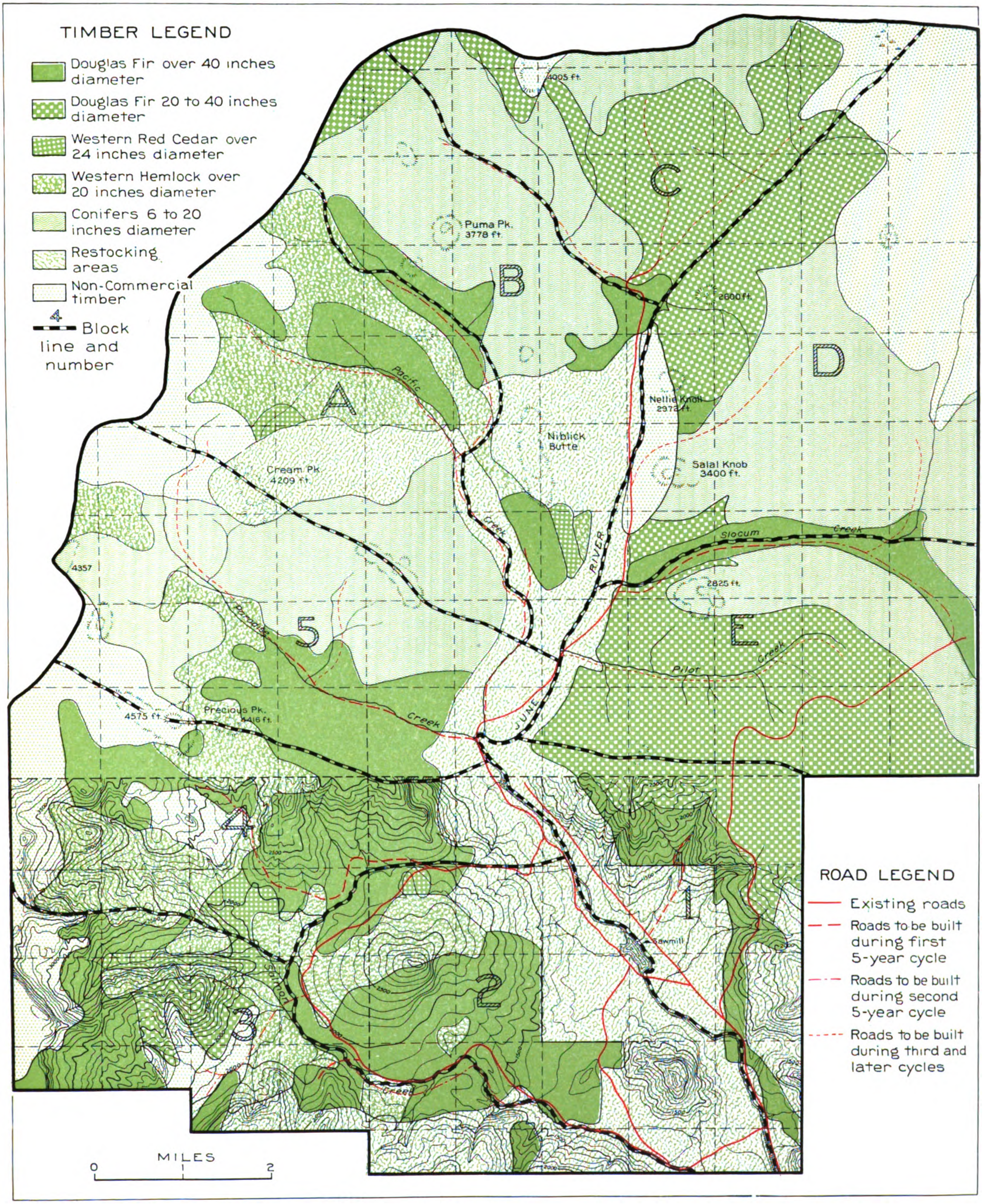
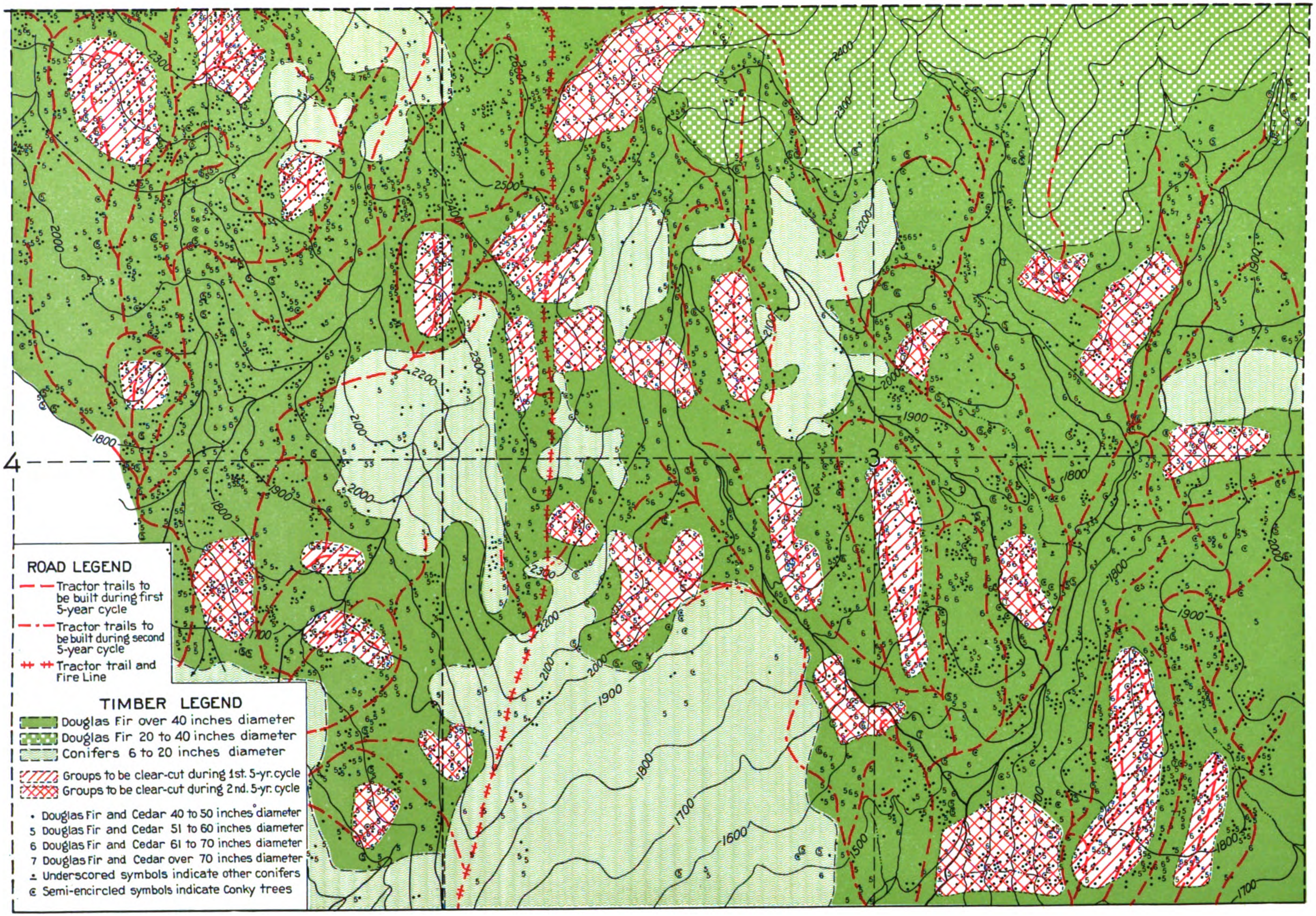

TIMBER LEGEND
Douglas Fir over 40 inches diameter
Douglas Fir 20 to 40 inches diameter
Western Red Cedar over 24 inches diameter
Western Hemlock over 20 inches diameter
Conifers 6 to 20 inches diameter
Restocking areas
Non-Commercial timber
4 Block line and number
ROAD LEGEND
Existing roads
Roads to be built during first 5-year cycle
Roads to be built during second 5-year cycle
Roads to be built during third and later cycles
MILES
0
1
2
A
B
C
D
E
1
2
3
4
5
Puma Pk. 3778 ft.
4005 ft.
2800 ft.
Nellie Knoll 2372 ft.
Niblick Butte
Salal Knob 3400 ft.
Cream Pk. 4209 ft.
4357
2825 ft.
Precious Pk. 4416 ft.
4575 ft.
Pacific
Creek
June
River
Slocum
Creek
Pilot
Creek
Sawmill

PLATE V

PLAN OF FIRST TWO CYCLES INITIATING SUSTAINED YIELD OPERATIONS IN BLOCK I (CHAPTER V)

When this area was cruised, trees more than 40 inches in diameter were located as shown on the map (see legend). It is possible, therefore, to locate on the map the boundaries of heavy groups which will yield 75,000 to 200,000 board teet per acre. These should constitute about half of the cut. The remainder should come from tree selection in intervening areas.

Groups selected for the first cycle cut require the least road construction and are cheapest to log. Roads constructed during each cycle are charged off to current expense but serve gradually to establish a complete road system. Slash on the clear-cut spots can be readily burned. Most of the scattered tree-selection slash may be left to decay to improve soil conditions and help keep down vegetation competing with tree growth.



ROAD LEGEND
Tractor trails to be built during first 5-year cycle
Tractor trails to be built during second 5-year cycle
Tractor trail and Fire Line
TIMBER LEGEND
Douglas Fir over 40 inches diameter
Douglas Fir 20 to 40 inches diameter
Conifers 6 to 20 inches diameter
Groups to be clear-cut during 1st. 5-yr. cycle
Groups to be clear-cut during 2nd. 5-yr. cycle
• Douglas Fir and Cedar 40 to 50 inches diameter
5 Douglas Fir and Cedar 51 to 60 inches diameter
6 Douglas Fir and Cedar 61 to 70 inches diameter
7 Douglas Fir and Cedar over 70 inches diameter
Underscored symbols indicate other conifers
Semi-encircled symbols indicate Conky trees

PLATE VI

LOW QUALITY TIMBER DEVELOPS FROM UNDERSTOCKED YOUNG STANDS

A. Wide-spaced regeneration on clear-cut areas will develop into worthless "wolf trees." Sufficient density may later be attained when these trees provide an abundant seed fall on the open area, but productivity of the soil will have been lost for several decades. (F. S. Neg. 273703.)

B. Partially stocked area. Trees at margin of opening will have persistent low branches and will produce low quality timber. (Photo by G. R. Ramsey, 1931.)

C. Worthless timber produced in sparsely stocked stand 64 years old. (F. S. Neg. 195022.)

D. These older trees grown in very open stands are valuable only as seed trees. (F. S. Neg. 228118.)

E. Older timber. Although now appearing dense the quality is still low because of insufficient early density of the stand which is about 250 years old.


B


A


C


D


E

PLATE VII

THE EARLY STAGES OF STAND DEVELOPMENT. CLEAR TIMBER DEVELOPS ONLY FROM DENSE REGENERATION

(SEE ALSO PLATES VIII TO X)

A. Mixed conifer regeneration, including Douglas fir, in small opening. Note the trees growing well under the crowns of old trees and the short side branches. Early natural pruning may be expected in this stand. (Photo by W. W. Ashe, 1899. F. S. Neg. 11800.)

B. Reasonably dense regeneration in the open, about 20 years old. Branch deadening and clearing of the trunks will be somewhat slow on the largest trees. (Photo by G. R. Ramsey, 1931.)

C. Young conifer stand about 35 years old, mostly hemlock. Natural pruning well advanced. (Photo by E. T. Allen, 1900. F. S. Neg. 10145.)

D. Middle-aged Douglas fir stand about 100 years old. Natural pruning is completed to about one 32-foot log length. The timber is still of low value for immediate utilization, but under selective management trees removed will yield poles, piling, and common lumber. An amount equal to the growth (15 to 25 per cent of the volume of the stand) may be removed each decade, the best trees being reserved for future growth. The reserved trees having been cleared of branches from this stage will lay on clear, high-value wood on the butt logs. Fifty to one hundred years of additional growth on selected specimens will be necessary to produce veneer logs, and in the meantime cuttings will yield profits each cutting cycle. (Photo by F. G. Plummer, 1910. F. S. Neg. 27580.)

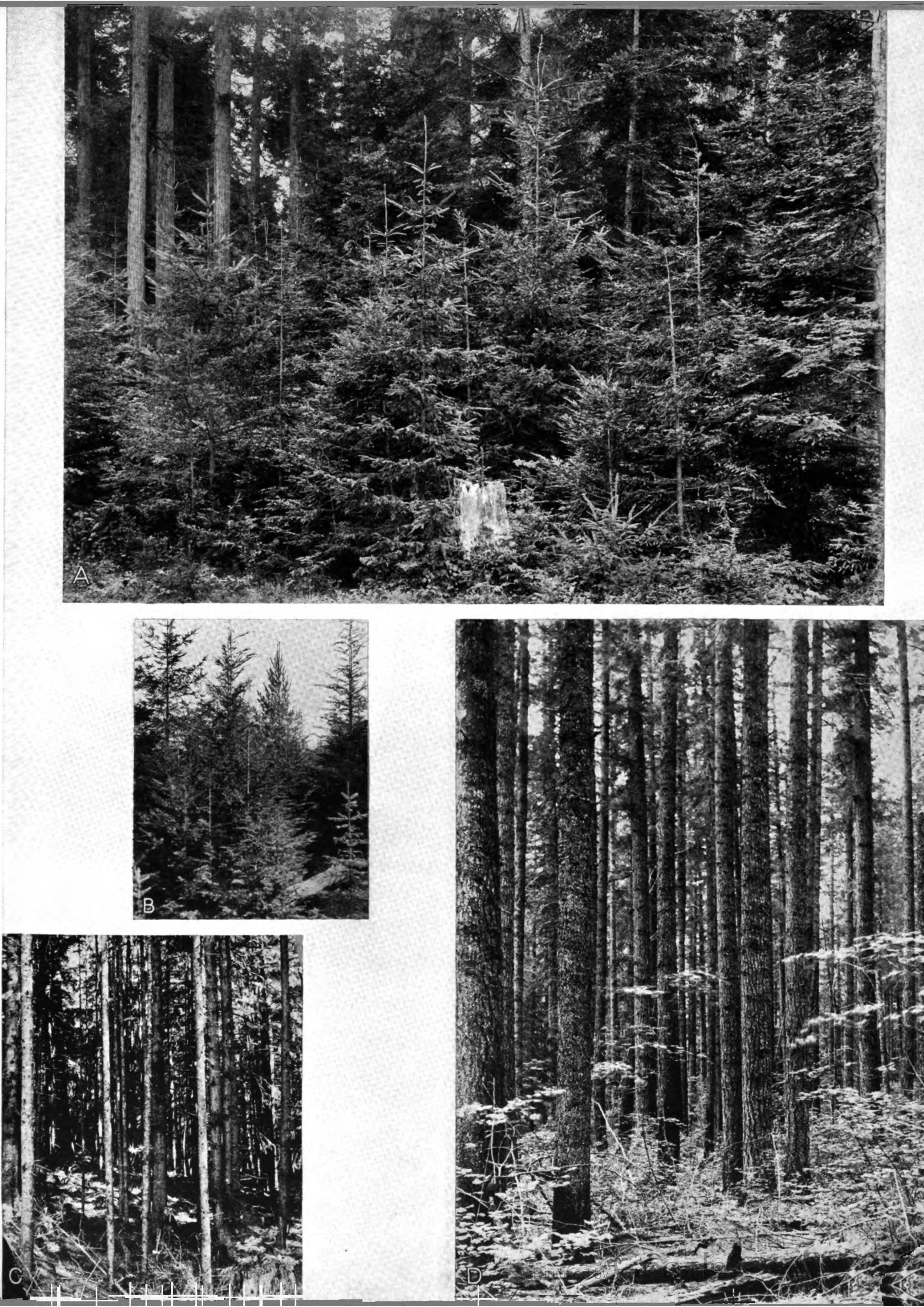

A
B
C
D

PLATE VIII

OTHER EXAMPLES OF CONIFER STANDS APPROACHING MIDDLE AGE IN THE DOUGLAS FIR REGION. NO CUTTINGS HAVE BEEN MADE IN THESE STANDS

A. Pure western hemlock stand about 63 years old. Owing to the more rapid decay of its dead branches the trunks are practically clear at an earlier age than were those in the Douglas fir stand shown in Plate VII, C. The stand will soon begin to lay on clear wood. Note debris on the ground from natural thinnings. (F. S. Neg. 293000.)

B. Mixed stand of Sitka spruce, western hemlock, and Douglas fir about 80 years old. Note the extreme density of the stand. Formation of clear wood, outside of the knotty heart, has begun on some trees well in advance of the time usual in pure Douglas fir stands. (F. S. Neg. 295207.)

C. Open-grown Douglas fir stand about 66 years old. It appears improbable the trunks will be cleared and ready for producing clear wood even at 100 years of age. (F. S. Neg. 222981.)

D. Young Douglas fir stand about 50 years old showing debris from natural thinnings. This contrasts with European stands in which regular thinnings prevent such losses of timber and keep the forest clean of debris (see Plate XI). Density of the stand has brought about early death of side branches. (F. S. Neg. 217648.)


B


D

PLATE IX

DEVELOPMENT OF MANY-AGED FROM EVEN-AGED STANDS

In the later development of such stands as shown in Plate VII, C and D and Plate VIII, the even-aged forest of whatever species is usually invaded on good sites by an understory of shade-enduring trees. This gradually introduces many age and size classes, and stands not already composed of several species in mixture usually become so. In the mixed many-aged stands regeneration continues to come in wherever an opening occurs or the crown cover is broken. Species such as Douglas fir and the pines which cannot regenerate under the dense crown cover gradually drop out of the stand. Neither does regeneration of spruce and cedar readily become established under these conditions, and the forest tends after several hundred years to be made up largely of hemlock and balsam firs. Selective management, including a reasonable application of group cuttings, provides opportunity for all species to persist in the mixed stand.

A. Understory trees beginning to develop in a hemlock-balsam fir stand about 80 years of age. (Photo by A. G. Varela, 1911. F. S. Neg. 95450.)

B. Understory about 25 years old under mixed stand already many aged. (Photo by Gifford Pinchot, 1897. F. S. Neg. 808.)

C. Hemlock developed from understory to occupy a prominent place in the forest with Douglas fir. The finest quality Douglas fir is found in such stands. Selective management here begins with removal of merchantable windfalls such as the large prostrate trunk covered with shrubbery and young hemlocks but still sound. Selection also extends to large trees such as the Douglas fir at the right and to groups of such trees, leaving most of the hemlock and the less mature Douglas fir to increase in value from volume and price increment. The large mass of debris on the ground would be a serious fire menace except for usually moist conditions of the forest climate. Utilization of the merchantable windfalls and the larger trees before they are added to the debris will gradually clean up the forest floor while preserving the forest climatic conditions. (Photo by A. G. Varela, 1911. F. S. Neg. 95445.)

D. Understory of hemlock and balsam firs from 2 to 12 inches in diameter and about 100 years of age under old silver fir. After removal of the large tree and after a period of about 3 years to become adjusted to changed conditions of crown space and root competition, the understory trees will grow rapidly. (Photo by C. F. Todd, 1928.)


A
B
D

PLATE X

TYPICAL PROBLEMS MET IN SELECTIVE TIMBER MANAGEMENT

A. Group of large Douglas firs averaging 150 M bd. ft. or more per acre. The growth on the group (as shown in table 20) may be expected to be slow; the growth of the forest as a whole would be little impaired by removal of this group, and very little small timber would be destroyed. The stand would be cheap to log and the conversion values—and consequently the capital recovery—would be large. For these reasons the group would be suitable for inclusion in early cuttings. (F. S. Neg. 32571.)

B. Even-aged, mature Douglas fir, southwest Oregon. The wide range of sizes permits light tree selection besides taking out here and there a heavy group. (Photo by Tom Gill, 1924. F. S. Neg. 191389.)

C. Valuable large western red cedar surrounded by a stand of silver fir. Since the latter is at present of low or negative value, individual tree selection of the cedar is indicated. The silver fir stand will be in good condition for further growth pending the time when demand for the species in the pulp and paper industry or for other uses becomes more acute. (Photo by C. H. Park, 1917. F. S. Neg. 30576A.)

D. Douglas fir tree 31.6 inches in diameter showing limbiness of dominant trees that originate in scattered stands filled in later with other trees. Millions of such trees are being produced on the understocked extensive clear-cut areas now present in the Douglas fir region. Whenever cuttings are necessary in stands containing such trees and log or lumber markets will absorb the low-grade material in them and repay operating costs, they should be removed because they do not provide a foundation for growth of much value. Surrounding trees will then have a better chance to develop. (F. S. Neg. 214960.)

E. Large rough old-growth spruce. Since such trees are not growing materially in volume or value, early removal from the stand is indicated. (F. S. Neg. 284264.)

F. Mixed stand of many ages and sizes with very few decadent trees. Selective operations may include taking out heavy groups supplemented by sparing tree selection of inferior trees, if possible, leaving the main stand to develop. (Photo by E. T. Clark, 1909. F. S. Neg. 84201.)

G. Pure hemlock stand of many ages and sizes. On account of low value of hemlock now it may be advisable to defer cutting entirely at least until more valuable stands have been cut over. When cutting begins, tree selection will often be the approved method because smaller sized hemlocks will respond promptly to release. In other cases it will be desirable to cut groups and introduce other species by wide-spaced planting. (F. S. Neg. 265202.)

H. Early selective cuttings near Olympia left a stand of hemlock and spruce. Although the initial cuttings were too heavy, the stand was left in quite productive condition. (Photo by M. Rothkugel, 1910. F. S. Neg. 87851.)


A
B
D
E

PLATE XI

COMPARABLE SCENES IN MANAGED FORESTS OF EUROPE

Young European stands do not surpass those of the Douglas fir region in quality except that inferior trees have generally been removed in thinning. A good thinning practice forestalls death of trees in natural thinnings and prevents accumulation of debris and development of fire hazards. Early thinnings are not generally feasible in the Douglas fir region, but in some instances, such as pulpwood cuttings in farm woodlands, could be economically performed. Where intensive care is possible a large increase in utilized volume is probable.

A. Regeneration after group cuttings in spruce. (Photo by E. N. Munns, 1924. F. S. Neg. 240085.)

B. Selectively cut silver fir hauled to the roads, Black Forest, Germany. Note density of remaining stand. (Photo by E. A. Sterling, 1903. F. S. Neg. 43025.)

C. Spruce forest in Germany. Note low stumps of trees removed in thinnings and absence of debris. (Photo by Alfred Gaskill, 1900. F. S. Neg. 195928.)

D. Spruce forest managed by group selection, Black Forest, Germany. Cordwood has been removed from the older groups. Photo by E. A. Sterling, 1903. F. S. Neg. 43024.)

E. Silver fir, Black Forest, Germany. Excellent road system allows frequent cuttings. (Photo by E. A. Sterling, 1903. F. S. Neg. 43026.)

F. Windfall area, Black Forest, Germany. These are not uncommon, but the permanent road system permits immediate salvage of down timber. (Photo by E. A. Sterling, 1903. F. S. Neg. 43019.)


A
B
D
E
F

PLATE XII

THE EFFECT OF FIRE ON THE FOREST

A. View within the mapped area of figure 20. The area in the foreground was clear cut prior to 1910 and has grown up to worthless hardwood brush. The lower slopes were clear-cut, slash-burned, and have since been swept by fires. The slash and subsequent fires penetrated the timber on the upper slopes and have killed most of it. Prior to 1905 this entire area was heavy old-growth timber such as shown by Plate IX, C. Extensive clear cutting and fire have destroyed productivity for the time being. Some 50 years of intensive fire protection with possibly some planting operations will be necessary before selective cutting operations (thinnings in this case) can bring in any income from the area. (Photo by G. R. Ramsey, 1931.)

B. Crown fire originating from land clearing swept this area in 1902. The snags still standing are from 4 to 6 feet in diameter and still contain some sound timber. On a developed forest property immediate salvage would have averted most of the immediate loss but not the loss of productivity. Successful fire protection has resulted in development of an excellent young stand now 40 to 50 feet tall. The standing snags still constitute a serious fire hazard to the young stand. (Photo by G. R. Ramsey, 1931.)


A


B

PLATE XIII

LOG GRADES PRODUCED BY TIMBER OF VARIOUS SIZES AND CONDITIONS

A. Clear grade logs from large timber (excepting the two logs in center and right foreground). These can be obtained only from large, fully matured timber such as shown in Plate IX, C. These logs will yield a large percentage of clear grades of lumber as shown in figure 3-B. The log in center foreground is of the rough grade and will yield only the lower grades of lumber. (F. S. Neg. 244951.)

B. Medium grade logs from younger timber. These logs will yield a large percentage of No. 1 common lumber. (See fig. 3-D.) (F. S. Neg 244956.)

C. Cross-section (at stump cut) of a 150-year-old Sitka spruce, diameter 60 inches. This tree grew at an average rate of 2 inches each 5 years throughout its life and still maintains a rate of 2 inches each 12 years. This illustrates the practicability of holding selected trees for further growth after they have attained an age and size when only clear wood of high value is being laid on the butt log and sometimes the second log as well.


A


B


C

PLATE XIV

RECENT MECHANICAL PROGRESS IN FLEXIBLE, MOTORIZED LOGGING EQUIPMENT MAKES IT FEASIBLE TO PRACTICE INTENSIVE SELECTIVE MANAGEMENT IN THE DOUGLAS FIR REGION

A. Spruce-hemlock type; the removal of one large and one small tree has left a sufficient stand to make full use of the soil. (F. S. Neg. 293003.)

B. Sitka spruce tree, 750 years old, 11 ft. 9 in. d.b.h., scaling 60 M bd. ft. Scribner scale. First log 110 inches, top diameter, was skidded with 75 h.p. tractor and hauled to log dump. This shows the flexibility of modern motorized logging methods. (F. S. Neg. 293002.)

C. Pure Sitka spruce stand, about 180 years old, with volume of about 80 M bd. ft. per-acre.

D. Selective cutting within the same stand has left a residual stand of about 55 M bd. ft. per-acre.

E. Tractor, equipped with bulldozer, building road through a small opening in the forest. (Photo provided by "The Timberman," Portland, Oreg., 1930.)

F. Tractor (75 h.p.) with fair-lead arch taking out cedar logs. This machine has been skidding to logging trucks a gross volume of 83 M bd. ft. log scale per day. Loss from defect reduces the net output to about 50 M bd. ft. per day. Many-aged mixed forest of cedar and hemlock in the background. (Photo provided by "The Timberman," Portland, Oreg., 1933.)

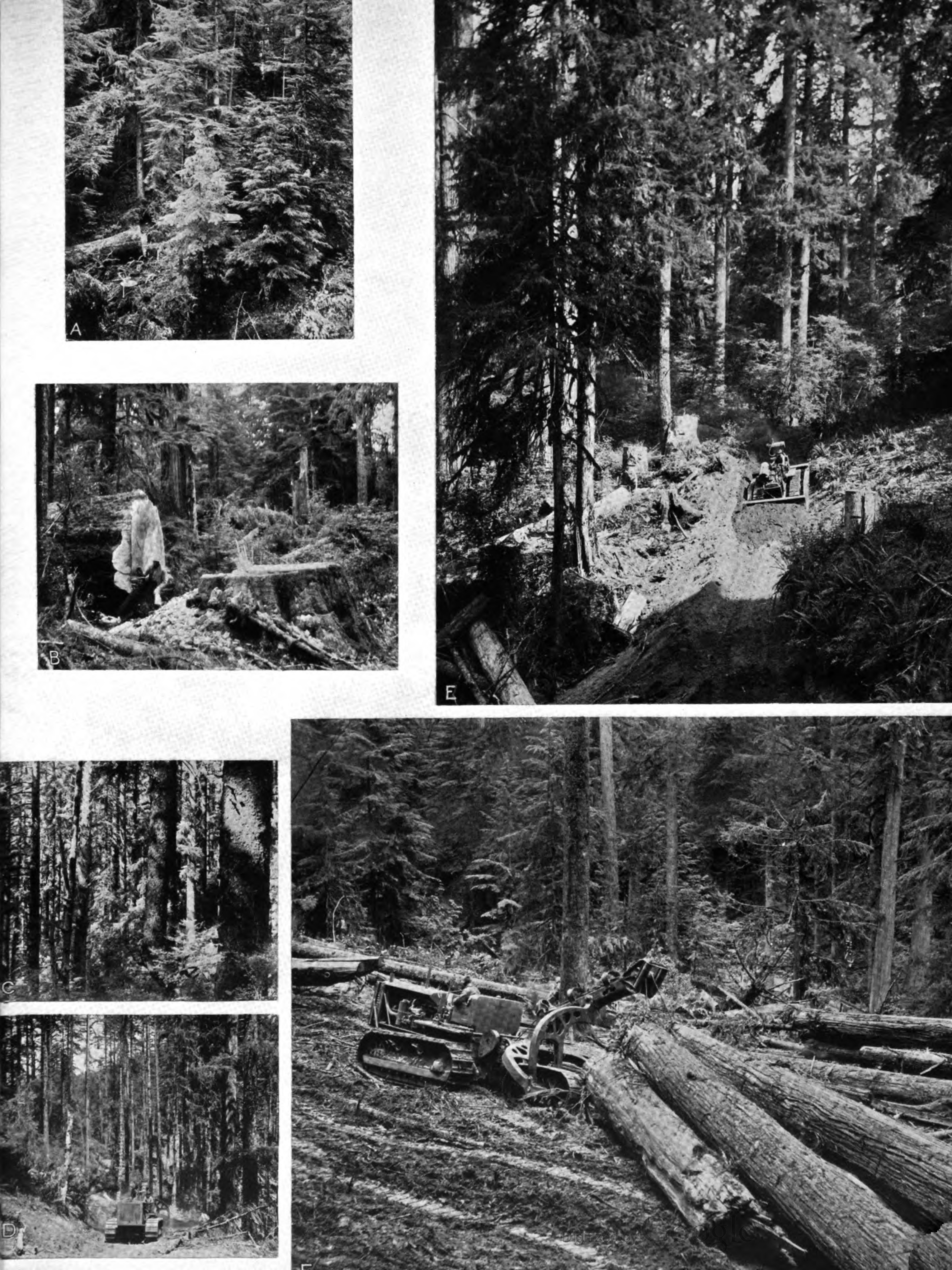

A
B
E
C
D
F

PLATE XV

A MOUNTAIN WATERSHED

Although this report deals only with commercial timber production the values in recreation and other forest uses should not be overlooked. As selective management retains a heavy forest cover, broken here and there only by small openings, beauty of the forest and its values for wildlife are fully preserved. (Photo by C. F. Todd, 1928.)