SELECTIVE TIMBER MANAGEMENT

IN THE

DOUGLAS FIR REGION

By

BURT P. KIRKLAND and AXEL J. F. BRANDSTROM

Division of Forest Economics
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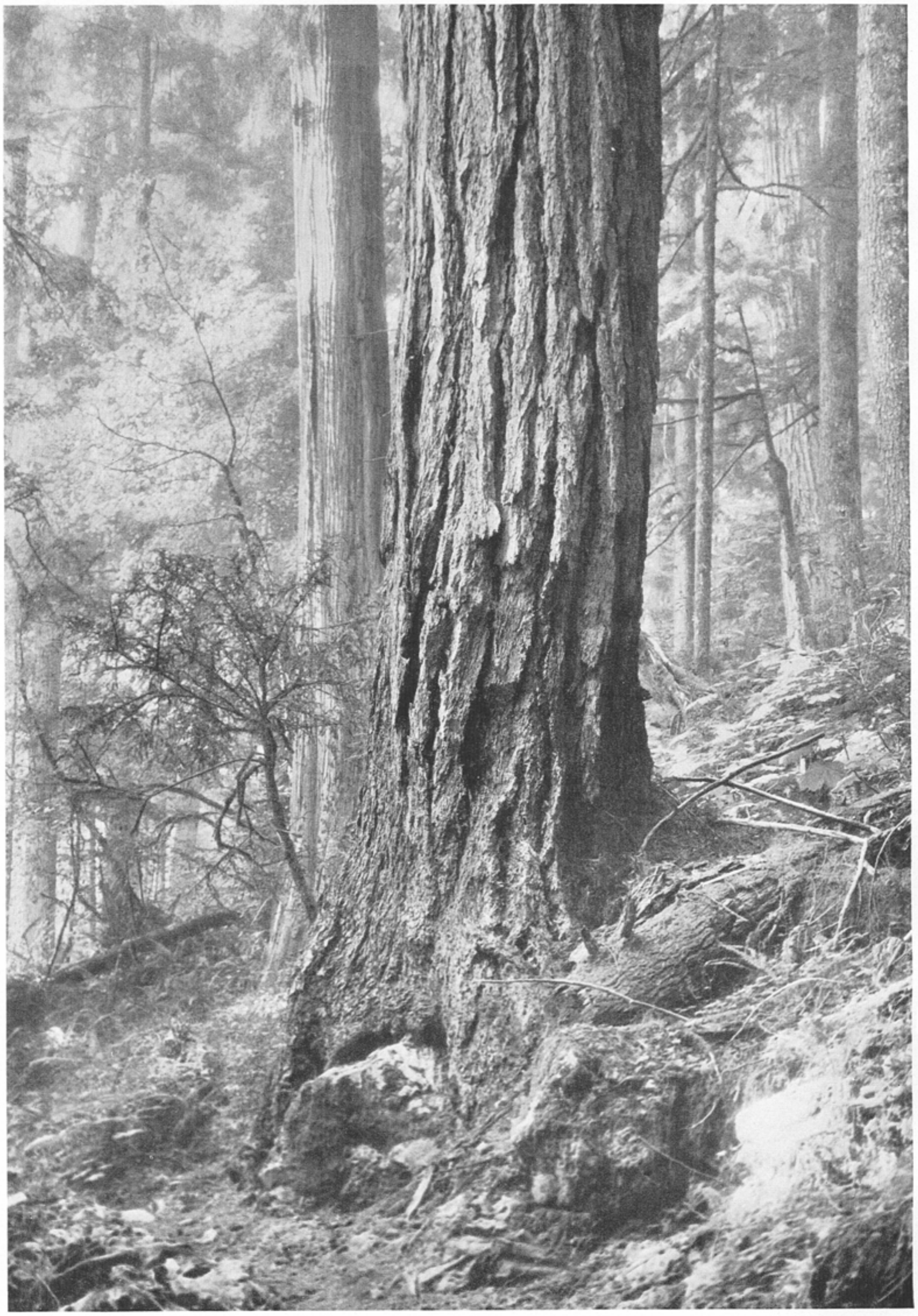

In the perpetuation of the mixed forest and in the continuous production of large high-quality trees lies the future of the diversified forest industries of the Douglas fir region. (Photo by C. F. Todd.)

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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.

Washington, D.C.
February, 1936.

BURT P. KIRKLAND
AXEL J. F. BRANDSTROM

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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 driven 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 up to the present time

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

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 tranquility 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 it 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

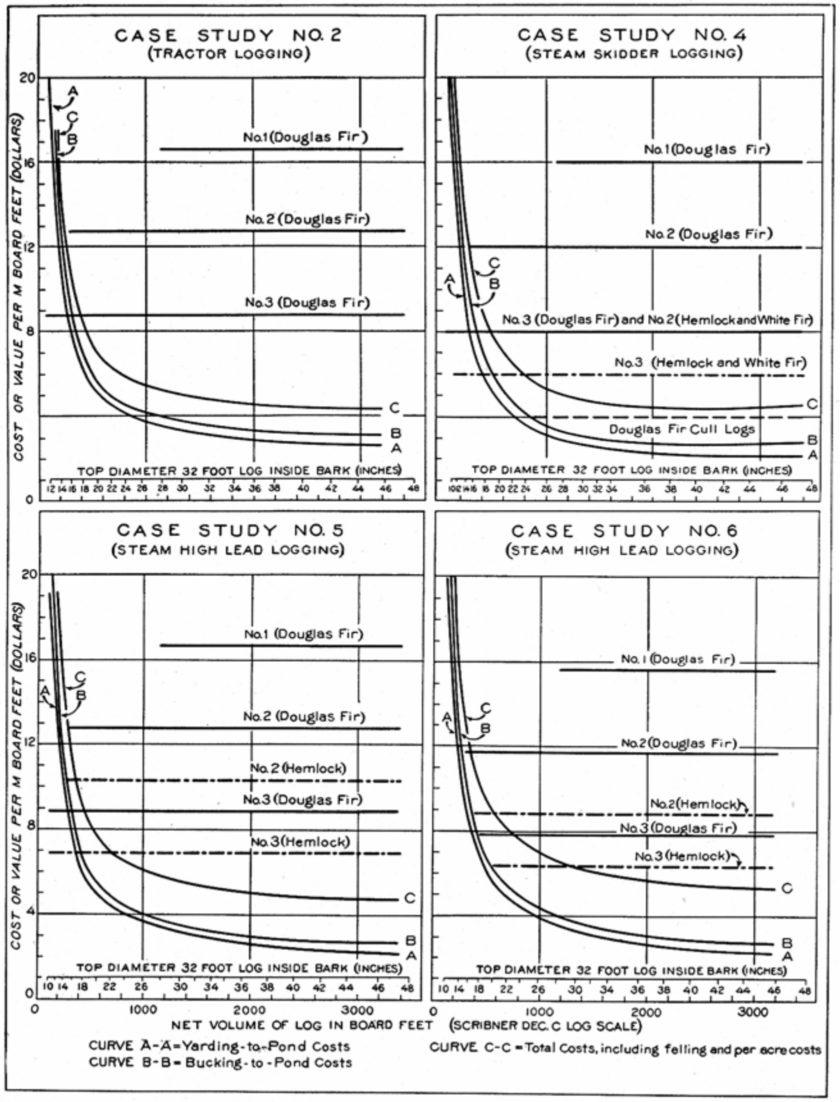


Fig. 1 - Logging Costs, Market Values and Stumpage Conversion Values of Logs

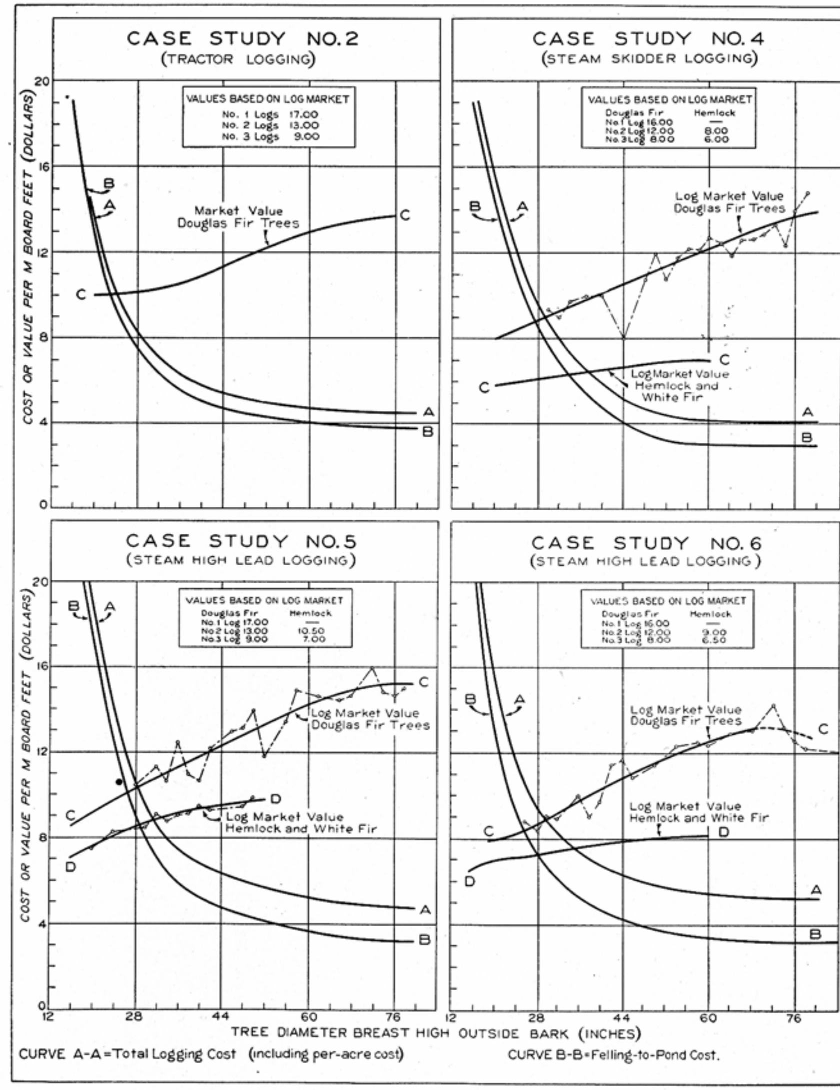
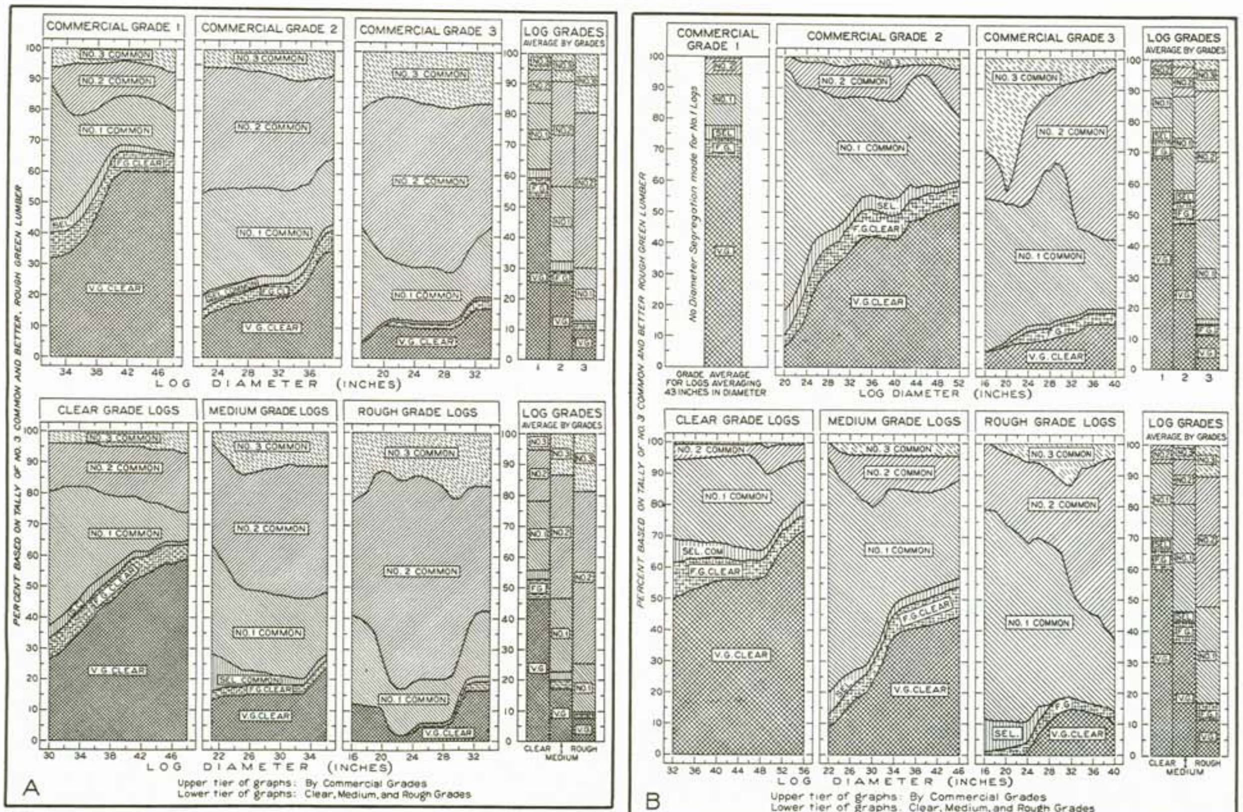


Fig. 2 - Logging Costs, Market Values, and Stumpage Conversion Values of Trees



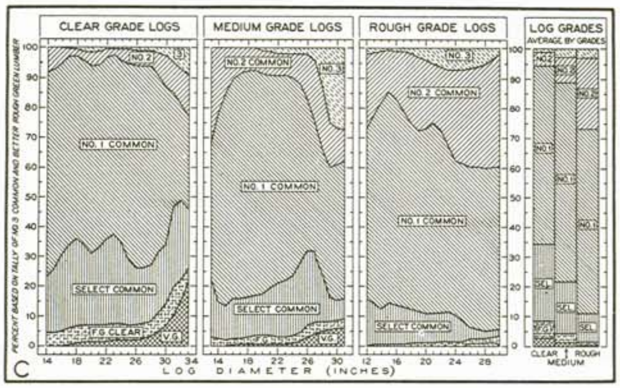


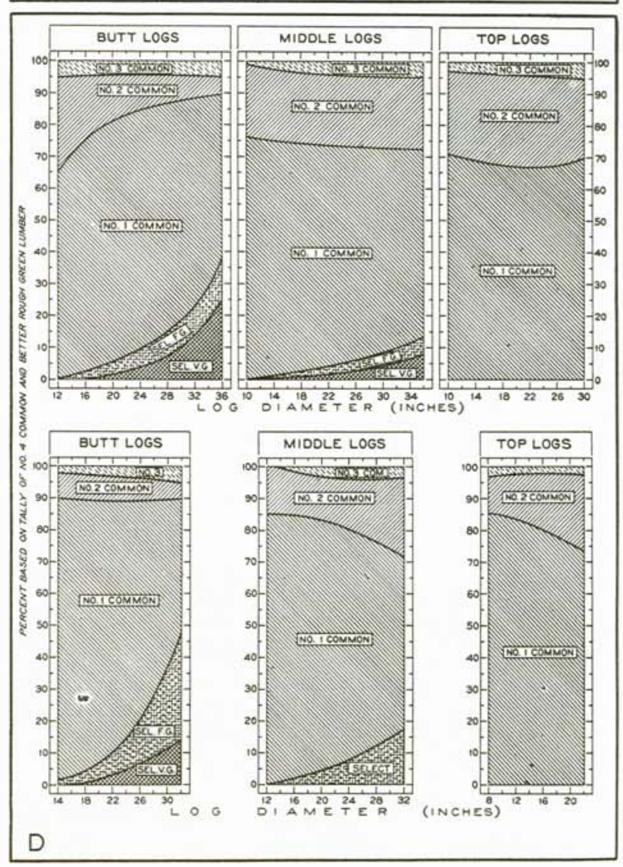
FIG. 3 - GREEN-LUMBER GRADE PRODUCTION IN DOUGLAS FIR LOGS

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 at 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 percent.

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	Over-run 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		Saw-mill	Re-manufacture	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 2.22
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.

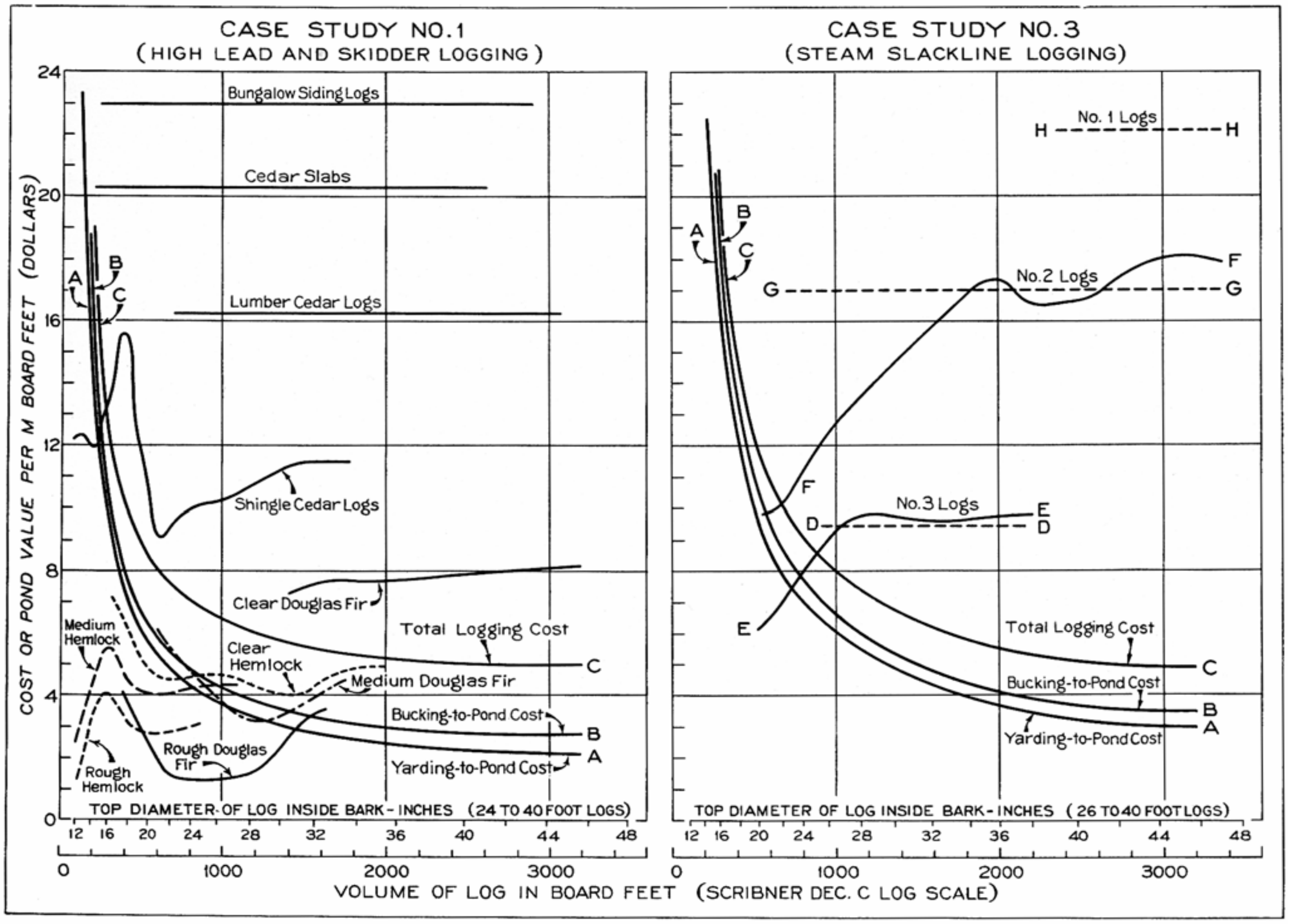


Fig. 4- Logging Costs, Pond Values, and Stumpage Conversion Values of Logs
(Pond Values based on Mill Recovery Studies - Year 1931)

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

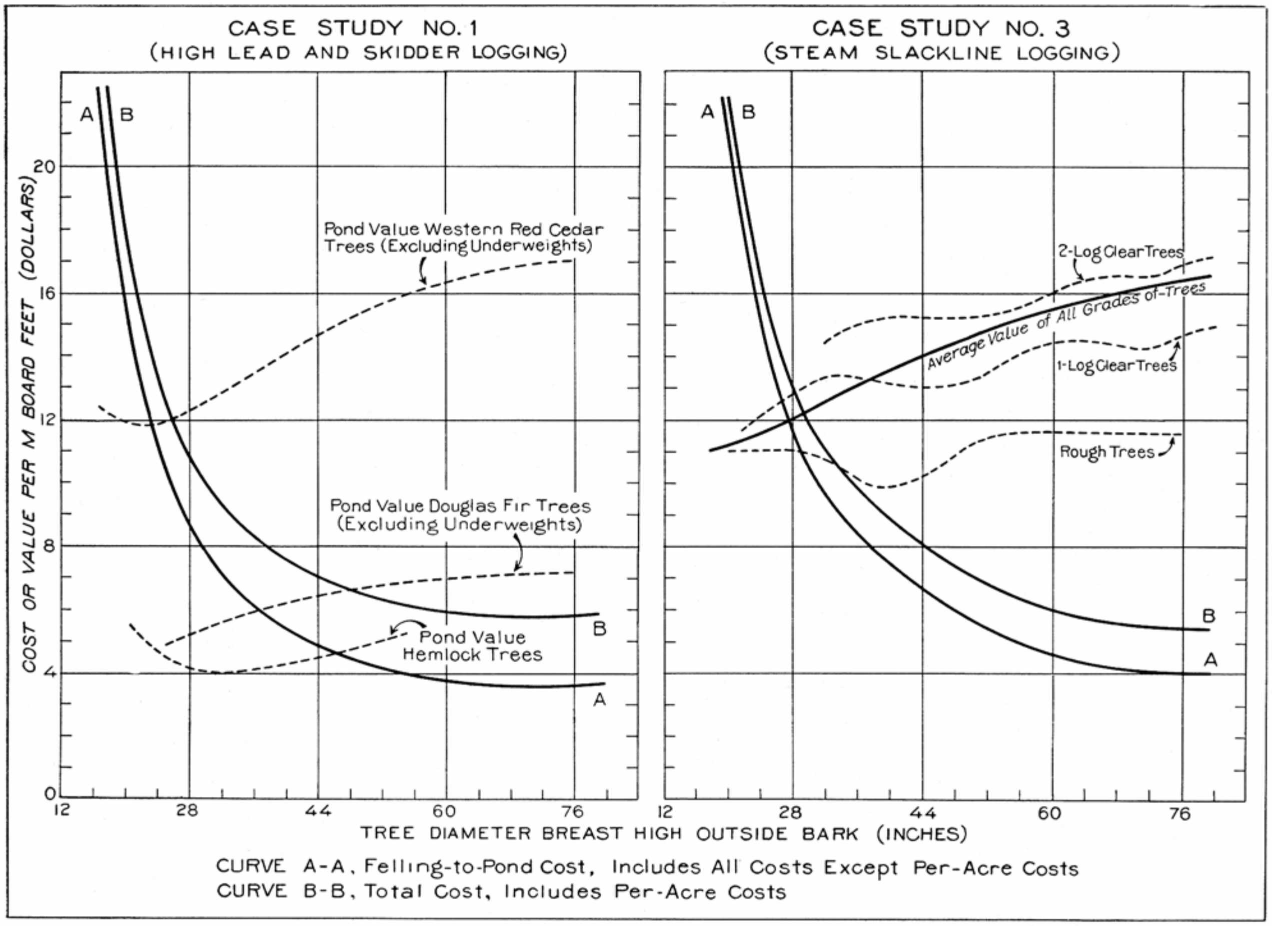


Fig. 5 - Logging Costs, Pond Values, and Stumpage Conversion Values of Trees
(Pond Values Based on Mill Recovery Studies, Year 1931)

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 fol. lowing 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 Band 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

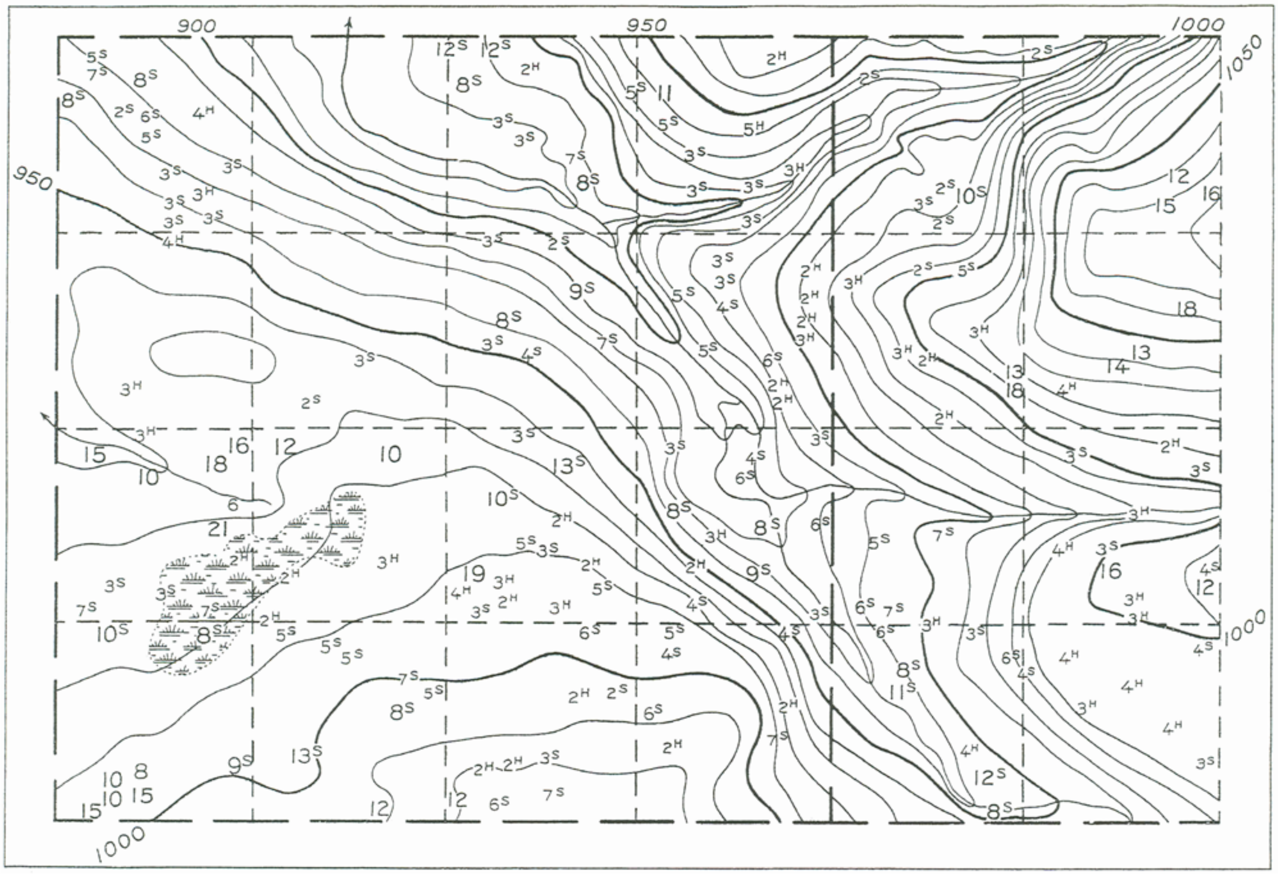


FIG. 6-PLOT A, 60-ACRE AREA, TYPICAL IN TOPOGRAPHY AND IN DISTRIBUTION OF TIMBER

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.

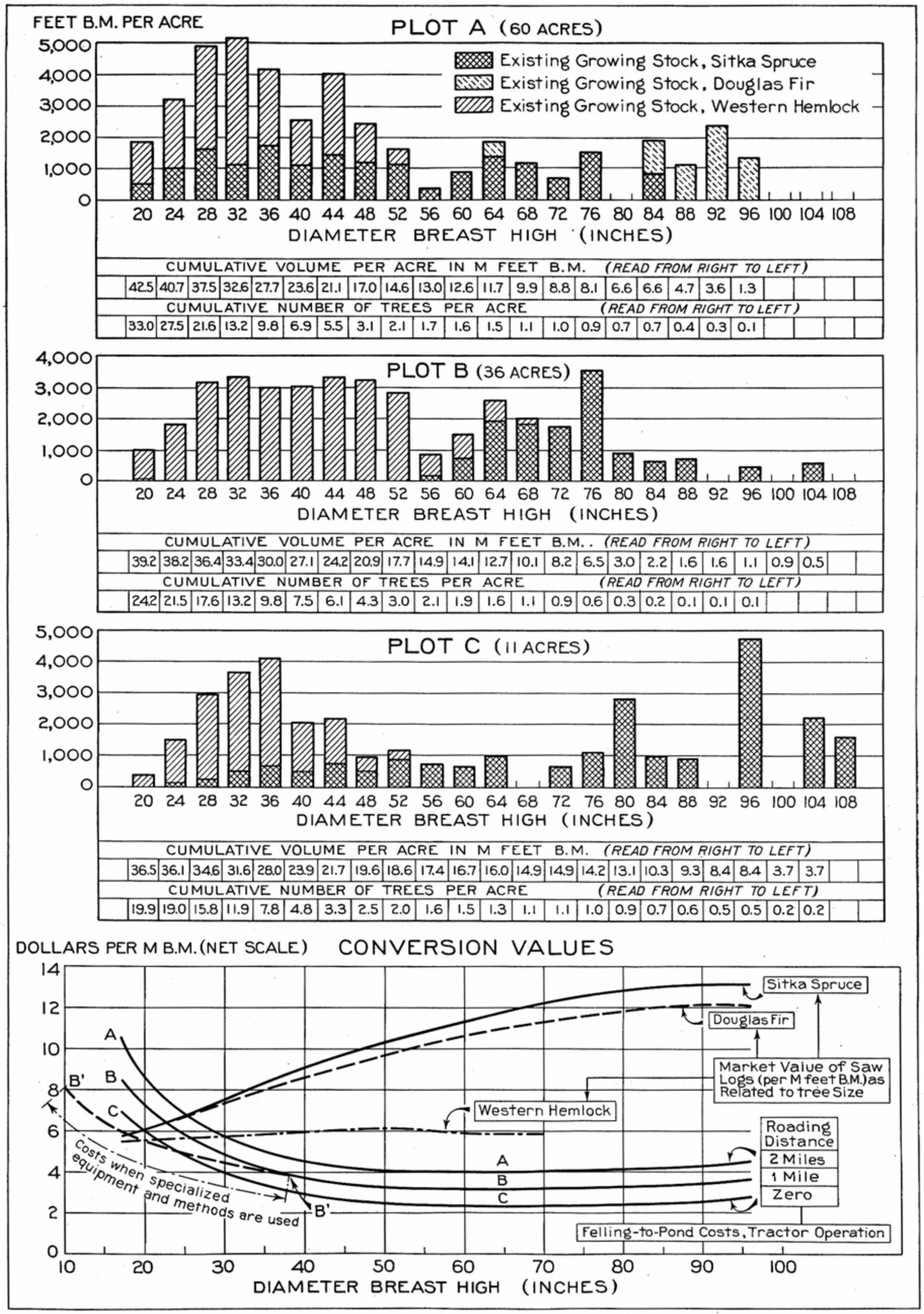


Fig. 7 - Stand Structure on Plots A, B, and C and Conversion Values of Trees of Different Diameter Classes and Species
(Costs and Values as of the Summer of 1932)

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

Loads per load	Average volume per load, gross log scale: 60 h.p. gasoline tractor[1]	75 to 80 h.p. Diesel tractor[2]
Numbers	*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 of 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 fir 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.

[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.

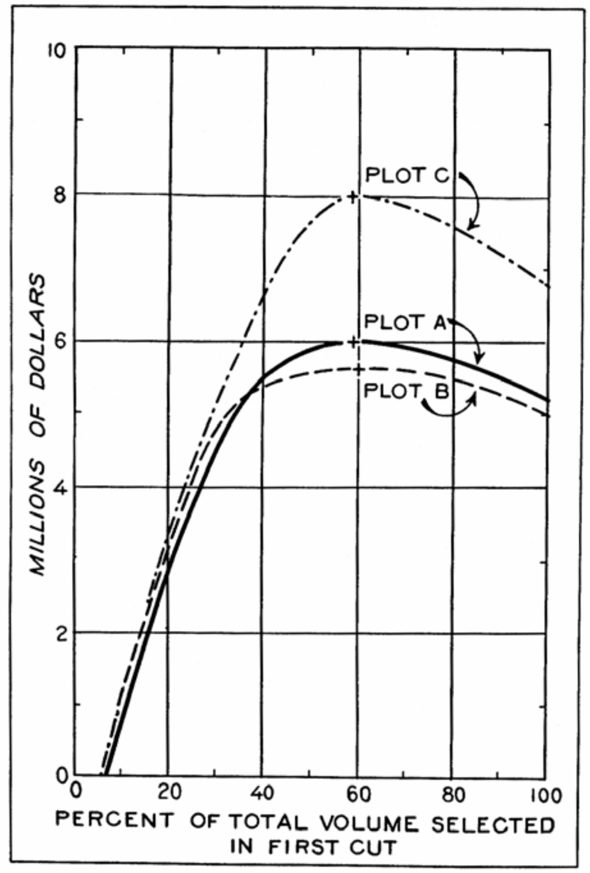


Fig. 8 - Present Net Worth of First Cuts of Various Intensities

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 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			Costs and returns per M feet b. m.			Volume in board feet per acre				Trees per acre
	Sitka spruce	Douglas fir	Western hemlock	Logging costs[1]	Log value	Stumpage conversion value[2]	Sitka spruce	Douglas fir	Western hemlock	Total	
	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			Costs of and returns from initial cut per M feet b. m.					Annual income from 100 million board feet cut	Duration of initial cut	Present net worth of initial cut (discount rate 6 per cent)
			Sitka spruce	Douglas fir	Western hemlock	Logging[2] costs	Log value	Gross stumpage conversion value[3]	Cost of road construction, etc.	Net stumpage conversion value[4]			
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

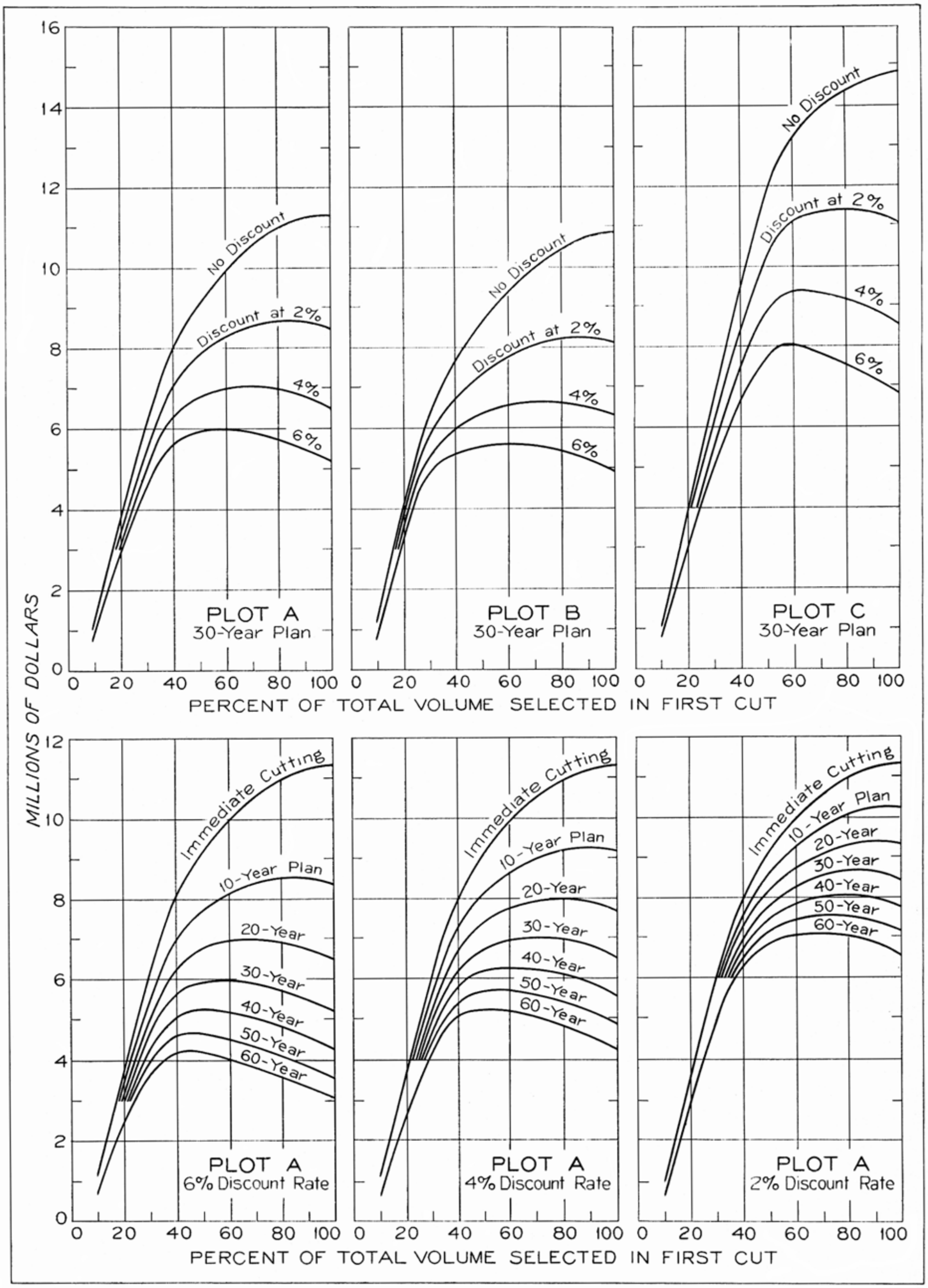


Fig. 9–Present Net Worth of First Cut as Influenced by Various Rates of Discount, Various Lengths of Operating Periods, and Various Degrees of Partial Cutting

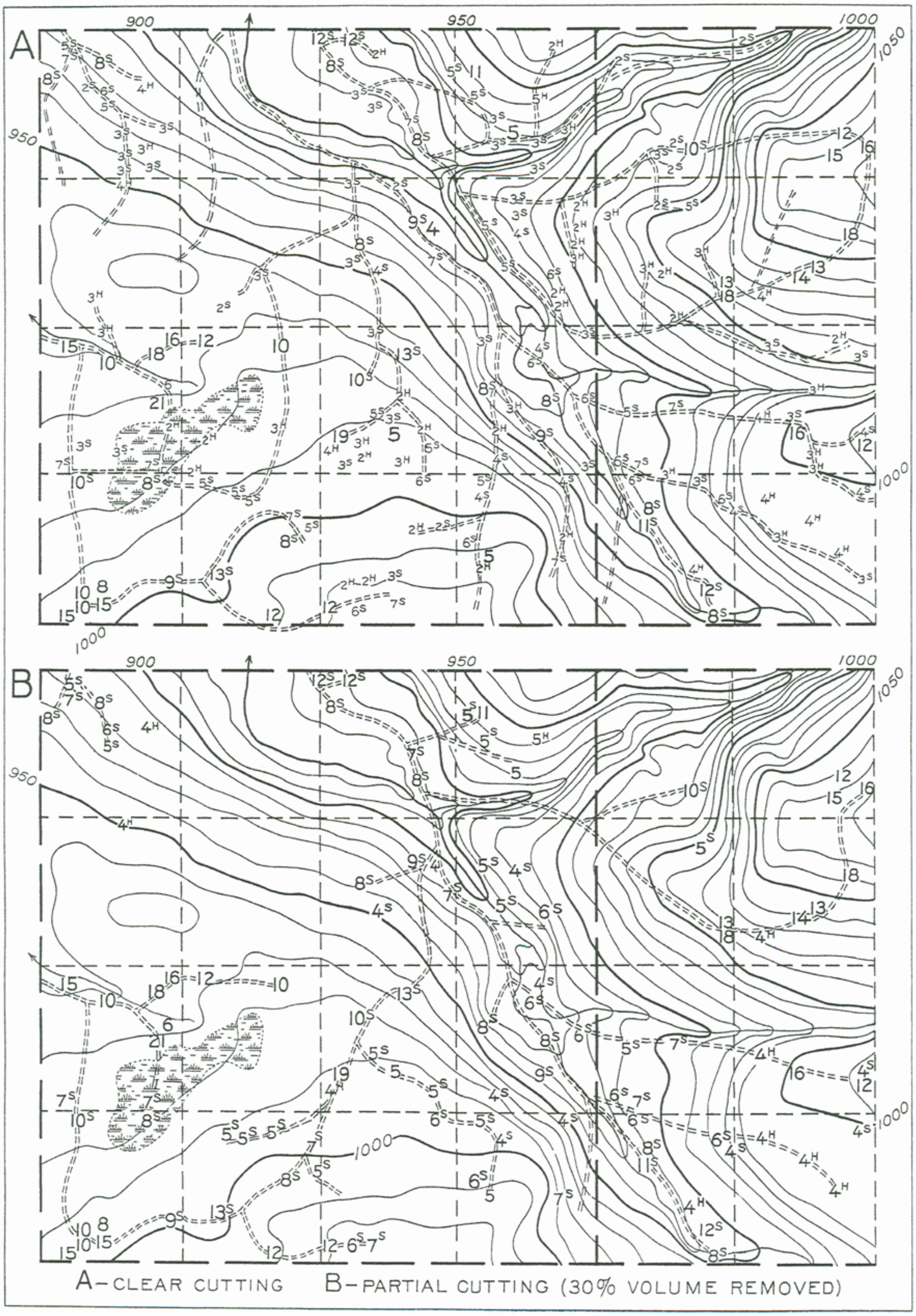


FIG.10 TRACTOR-TRAIL SYSTEMS REQUIRED (A) UNDER CLEAR CUTTING AND (B) UNDER 30 PERCENT SELECTIVE CUTTING

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

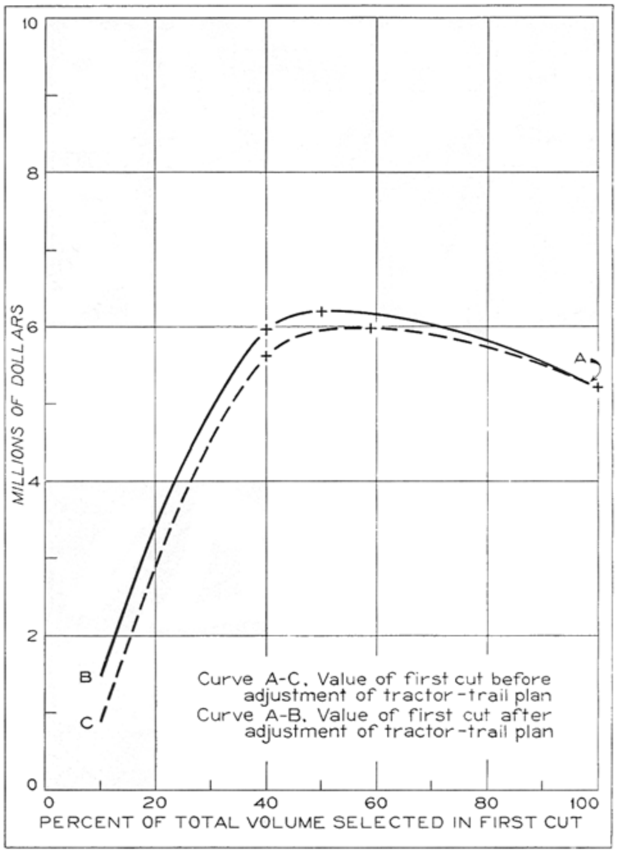


Fig. 11 - Present Net Worth of First Cut as Affected by Plan of Tractor-Trail Construction

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 $034. 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 clearcutting 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, 6 ¼ cents for 12 years, 8 ⅓ cents for 9 years, 12 ½ 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[3] 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)[3] 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.

[3] 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 or 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 at owner's equity*[1] *under plans 1 to 4, on basis at different discount rates*

Plan	Present net worth[2] on basis of discount rates indicated			
	6% Thousands of dollars	4% Thousands of dollars	2% Thousands of dollars	0% Thousand 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	5,614
(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 clearcutting 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.

Wind throw 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 wind throw; 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 wind throw 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 over mature 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.