A SYSTEMATIC APPROACH TO DISTRIBUTING PUBLIC INVESTMENT
TO INCREASE TIMBER SUPPLIES IN BRITISH COLUMBIA

by

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ABSTRACT

Within the recently introduced timber supply policy in British Columbia there is an emphasis on at least maintaining short-term harvest rates. This imposes constraints on the type of investments that need to be undertaken. A system has been devised that will identify and characterize the contribution of proposed investments to public timber supply goals.

A stand can be harvested without financial loss only when the mill-gate value of the stand volume exceeds, or just balances, the costs of extraction and delivery to the mill. The stumpage appraisal system of the Forest Service can be used to estimate minimum average stem volumes for operability over a wide range of stand and accessibility conditions.

Strategic timber supply analysis can provide a time-frame within which the benefits of investment in silviculture must be realized to ensure continuity of supply. This time-frame, in combination with the operability-accessibility relationships, is used to erect zones for investment within the forest estate. Within any zone, at a given radius from the mill, all stands will have similar characteristics for operability. Stands unlikely to reach these characteristics within the time-frame are candidates for investment.

Among candidate stands there will be a great variability in the prospective efficiency of investment. An investment efficiency ratio, based on physical units of production, is provided to characterize potential investments. Rules for its use as a criterion within the field of public forest management have been developed. With this criterion annual activity budgets can be assembled and operational plans instituted.
The proposed system is offered as a replacement for the existing process by which stand treatment guidelines are drawn up and investments undertaken by the provincial Forest Service. It provides an explicit link between timber supply policy and silvicultural planning currently lacking. Its consistent use will lead to a more rational distribution of resources within the framework of supply planning. It is expected that the system will eventually be superseded by improvements in the data base used in strategic supply planning.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii.</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv.</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi.</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii.</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>viii.</td>
</tr>
<tr>
<td><strong>1.0 INTRODUCTION</strong></td>
<td>1.</td>
</tr>
<tr>
<td>1.1 The Proposal</td>
<td>6.</td>
</tr>
<tr>
<td>1.2 The Scope of the Proposed System</td>
<td>6.</td>
</tr>
<tr>
<td>1.3 Objectives of the System</td>
<td>7.</td>
</tr>
<tr>
<td><strong>2.0 THE POTENTIAL FOR GOAL CONFLICTS</strong></td>
<td>9.</td>
</tr>
<tr>
<td><strong>3.0 THE INVESTMENT DISTRIBUTION SYSTEM</strong></td>
<td>11.</td>
</tr>
<tr>
<td>3.1 Stand Attributes and System Benefits</td>
<td>12.</td>
</tr>
<tr>
<td>3.2 Flow of the Proposed System</td>
<td>13.</td>
</tr>
<tr>
<td>3.3 An Important Caveat</td>
<td>14.</td>
</tr>
<tr>
<td><strong>4.0 HARVEST COST ZONE ANALYSIS</strong></td>
<td>17.</td>
</tr>
<tr>
<td>4.1 Adjusting the Margin for the Effects of Utilization Policy</td>
<td>18.</td>
</tr>
<tr>
<td>4.2 Establishing Zone Boundaries</td>
<td>21.</td>
</tr>
<tr>
<td>4.2.1 The Logging Productivity Classification System</td>
<td>21.</td>
</tr>
<tr>
<td>4.2.2 Adapting the System to Provide Zone Boundaries</td>
<td>22.</td>
</tr>
<tr>
<td>4.2.3 Transforming the Cost-Size Relationship</td>
<td>24.</td>
</tr>
<tr>
<td>4.3 Using the Harvest Cost Zones</td>
<td>36.</td>
</tr>
<tr>
<td><strong>5.0 DETERMINING INVESTMENT ELIGIBILITY STANDARDS</strong></td>
<td>40.</td>
</tr>
<tr>
<td>5.1 Using Zonal Goals to Predetermine Eligibility</td>
<td>42.</td>
</tr>
</tbody>
</table>
6.0 ASSESSING INVENTORIED OPPORTUNITIES

6.1 Measuring Stand "Worth"
   6.1.1 Stand Component View of Stand Value
   6.1.2 Total Present Worth of a Stand

6.2 Marginal Effects of Investment
   6.2.1 System Benefits
   6.2.2 Stand-Level Benefits
   6.2.3 Determining the Time-Frame
   6.2.4 Net Physical Benefit

6.3 Cost Per Unit of Net Physical Benefit

6.4 Assessing Inventoried Opportunities

6.5 An Extension to Components: Species Preference

6.6 An Extension to the CNPB: Other Resources
   6.6.1 Extended Benefits
   6.6.2 Extended Costs
   6.6.3 Selecting Preferred Alternatives
   6.6.4 An Example Showing the Influence of Other Resources on a Decision

7.0 ASSEMBLING THE ANNUAL ACTIVITY BUDGET

7.1 Ranking Opportunities by Merchantable Volume CNPB
   7.1.1 Identifying the Most Suitable Product for a Stand
   7.1.2 Ranking Dedicated Stands

8.0 SUMMARY AND DISCUSSION

8.1 Using the System

REFERENCES CITED

APPENDIX
<table>
<thead>
<tr>
<th>TABLE</th>
<th>DESCRIPTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE I</td>
<td>LOGGING PRODUCTIVITY CLASSIFICATION BY TOTAL INDEX</td>
<td>31.</td>
</tr>
<tr>
<td>TABLE II</td>
<td>INDIVIDUAL FACTOR INDEXES FOR PERMANENT SITE FEATURES</td>
<td>34.</td>
</tr>
<tr>
<td>TABLE III</td>
<td>PRESENT WORTH OF MAI (SYSTEM BENEFIT) FOR A STAND HARVESTABLE IN THE 3rd THROUGH 8th DECADES FROM PRESENT</td>
<td>51.</td>
</tr>
<tr>
<td>TABLE IV</td>
<td>SAWTIMBER COSTS PER UNIT OF NET PHYSICAL BENEFIT FOR FOUR HYPOTHETICAL TREATMENTS</td>
<td>62.</td>
</tr>
<tr>
<td>TABLE V</td>
<td>REGRETS FOR SAWTIMBER ALTERNATIVES AT THE ADJUSTED HARVEST WINDOW LIMITS</td>
<td>64.</td>
</tr>
<tr>
<td>TABLE VI</td>
<td>BASIC DATA FOR DETERMINING RELATIVE SPECIES WORTH FOR THE LODGEPOLE PINE - DOUGLAS-FIR EXAMPLE</td>
<td>66.</td>
</tr>
<tr>
<td>TABLE VII</td>
<td>MAN-HOURS OF EMPLOYMENT AND MACHINE-HOURS NEEDED FOR FOUR SAWTIMBER ALTERNATIVES</td>
<td>69.</td>
</tr>
<tr>
<td>TABLE VIII</td>
<td>EXTENDED CNPBs FOR SAWTIMBER ALTERNATIVES</td>
<td>69.</td>
</tr>
<tr>
<td>TABLE IX</td>
<td>REGRETS FOR THE ALTERNATIVES WITH EXTENDED CNPBs</td>
<td>70.</td>
</tr>
<tr>
<td>TABLE X</td>
<td>COMPARISON OF TREATMENTS 2 AND 3 IN A FIXED BUDGET</td>
<td>71.</td>
</tr>
<tr>
<td>TABLE XI</td>
<td>PRESENT WORHTHS OF HARVEST VOLUMES AND COSTS OF TREATMENT FOR THE MOST EFFICIENT SAWTIMBER AND MERCHANTABLE VOLUME TREATMENTS</td>
<td>76.</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>DESCRIPTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCHEMATIC FLOW DIAGRAM FOR THE PROPOSED SYSTEM</td>
<td>15.</td>
</tr>
<tr>
<td>2</td>
<td>RELATIONSHIP BETWEEN MINIMUM DBH's FOR A STAND AT A SINGLE POINT IN TIME</td>
<td>19.</td>
</tr>
<tr>
<td>3</td>
<td>SUCCESSIVE OBSERVATIONS OF THE RELATIONSHIP BETWEEN MINIMUM DBH's FOR A STAND</td>
<td>20.</td>
</tr>
<tr>
<td>4</td>
<td>RELATIONSHIP BETWEEN LOGGING COSTS AND MERCHANTABLE AVERAGE PIECE-SIZE FOR RECOMMENDED LOGGING SYSTEMS</td>
<td>23.</td>
</tr>
<tr>
<td>5</td>
<td>HYPOTHETICAL VALUE GRADIENT OF LODGEPOLE PINE STEMS</td>
<td>27.</td>
</tr>
<tr>
<td>6</td>
<td>RELATIONSHIP BETWEEN MILLGATE VALUE AND MERCHANTABLE STAND AVERAGE STEM VOLUME</td>
<td>29.</td>
</tr>
<tr>
<td>7</td>
<td>SCHEMATIC REPRESENTATION OF THE RELATIONSHIP BETWEEN OPERABILITY, ACCESSIBILITY AND AVERAGE PIECE-SIZE FOR LODGEPOLE PINE IN THE INTERIOR OF BRITISH COLUMBIA</td>
<td>30.</td>
</tr>
<tr>
<td>8</td>
<td>INDICATED COSTS OF HARVESTING FOR RECOMMENDED SYSTEMS FOR STANDS AT MINIMUM OPERABILITY</td>
<td>32.</td>
</tr>
<tr>
<td>9</td>
<td>GRAPHICAL DETERMINATION OF HARVEST COST ZONAL BOUNDARIES</td>
<td>35.</td>
</tr>
<tr>
<td>10</td>
<td>COST ZONE AVERAGE ACCESSIBILITY - STEM VOLUME RELATIONSHIPS</td>
<td>38.</td>
</tr>
<tr>
<td>11</td>
<td>HYPOTHETICAL BEHAVIOUR OF THE MINIMUM AGE OF HARVESTED STANDS</td>
<td>41.</td>
</tr>
<tr>
<td>12</td>
<td>RELATIONSHIP BETWEEN AVERAGE STEM VOLUME AND AVERAGE STAND DBH FOR LODGEPOLE PINE</td>
<td>44.</td>
</tr>
<tr>
<td>14</td>
<td>PLOT OF THE CNPBs FOR SAWTIMBER ALTERNATIVES</td>
<td>63.</td>
</tr>
<tr>
<td>15</td>
<td>PLOT OF EXTENDED CNPBs FOR SAWTIMBER ALTERNATIVES</td>
<td>70.</td>
</tr>
<tr>
<td>16</td>
<td>ILLUSTRATIVE RESPONSE TO MOST EFFICIENT SAWTIMBER, MERCHANTABLE VOLUME TREATMENTS FOR A HYPOTHETICAL STAND</td>
<td>75.</td>
</tr>
</tbody>
</table>
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1.0 INTRODUCTION

The forest industry is acknowledged to be an important component of the economy of many provinces in Canada. Fairly recently, fears that the industry may lose its international competitiveness because of poor or inadequate forest management practices have been articulated. These have arisen from a growing perception of the potential for interruptions in the long-term supply of public timber. Reed (1978), in his survey of forest management in Canada, found the potential for, at least, local supply problems in six of the ten provinces. Of the six, British Columbia, Ontario and Quebec are making efforts to resolve these problems as part of a fresh approach to the management of their forest estates.

The resolution of supply problems may lay within the context of the contribution of the provincial forest estate to provincial or regional economic development goals. Thus the question switches from "can the present level of supply be maintained?", to "what level of supply should the province, or region, maintain in pursuit of its larger goals?" The degree of commitment of society's resources implied by a given level of supply must also be considered. Both British Columbia and Quebec (Lussier, 1976) have begun to develop methods to determine desirable provincial harvest levels.

By contemplating programs of investment in intensive forestry, the provinces are stepping outside their traditional interpretation of stewardship of natural resources. In the process they must face up to questions about the desirable distribution of resources. The scientific discipline of forest economics has developed to deal with these questions. Within the context of the social requirements of forest policy, economic planning of
investment programs will lead to a better distribution of resources than is possible without reference to economic principles or with any other planning system.

This thesis presents an approach to the distribution of investment resources different from that of traditional economic analysis of forest management practices. Partly this is because of the desire to give greater prominence to the wider social context of intensive management, but also to reflect bureaucratic constraints on forest management planning within British Columbia.

In British Columbia the Ministry of Forests is charged with the management of the public forest estate. It has recently adopted as its goal (the realization of) "the maximum contribution of available forest and range resources, now and in the future, toward the social and economic well being of British Columbians" (Ministry of Forests, 1980). Within this goal the specific objectives of natural resource management in British Columbia have been articulated by the Premier (Province of B.C., 1978a) and interpreted by the Ministry as the need to:

(a) increase employment opportunities,
(b) increase real incomes,
(c) ensure stability of employment and incomes in both the long and short term, and
(d) achieve a greater degree of regional balance in provincial economic development (Ministry of Forests, 1980).

The Forest Service, as the sole agency of the Ministry, is responsible for developing programs to further progress toward the objectives of resource policy. To this end it has recently introduced a system to identify the need for, and to plan the implementation of, programs of investment in
intensive management. The system consists of two planning levels which are not yet fully integrated. The first level is used to prepare a series of forest policy options (levels of commitment to intensive management) from which the legislature is to select the option appropriate for the province (Province of B.C., 1978). The second consists of a regional analysis of the demands on, and potentials of, individual management units (Ministry of Forests, 1978). The integrative factor at both levels is the rate of harvest that the provincial forest estate can sustain.

There is nothing in this system that precludes economic analysis. Indeed both planning levels begin with consideration of the demand for forest products and the potential contribution of British Columbia to that demand. However, the Forest Service has not used the traditional economic definitions of supply and demand in its projections. Instead, it has based its analyses on physical supply and industrial capacity. In this it is reflecting its traditional orientation, developed over a long period in the province, during which no explicit forest policy directions have been provided for the forest estate.

To an extent, the provincial resource management objectives themselves provide one reason why the Forest Service has adopted physical yield as a basis for planning. British Columbia contains a large and heterogeneous forest estate in which the distribution of potential opportunities for investment is essentially haphazard with respect to political divisions in the province. The requirement that investment programs recognize the need for a greater degree of regional balance can influence the interpretation of the other resource management objectives. For example, if investment programs were selected in a way which would maximize the present worth of the return to the intensive management budget, the Vancouver Resource Region,
with its high sites and valuable species, could probably absorb the total provincial commitment. Obviously this would lead to a concentration of the benefits of the investment program in one region at the expense of the others.

The end result of the planning process will be a series of management unit timber supply goals. Each goal will consist of a schedule of permitted harvest rates. The planning horizon contains two phases; a short-term, within which harvest rates are to be held constant, and a long-term, within which harvest rates are to be allowed to fluctuate. The short-term consists of a period of 20 years from the start of the supply plan with plans to be reviewed at 5 year intervals (Ministry of Forests, 1978b). Short-term supply goals are not allowed to be set at levels which will prevent the forest estate from providing a long-run sustainable yield at a level associated with mandatory management practices.

It is an underlying assumption of this thesis that there is a strong interest in maintaining historic harvest rates in the short-term where there is an existing forest industry. This is an extension of the concern for greater balance in regional development. However, historic harvest rates were developed under a definition of the forest estate which did not give adequate recognition to environmental concerns or to changes in the forest inventory brought about by the activities of man and nature. It is possible, therefore, that these rates would lead to the development of a forest structure that would be unable to support the required long-run sustainable yield. These rates would either have to be reduced or investment programs in support of short-term harvest rates would have to be undertaken.

One potential component of any such investment program is that group of management activities that can be referred to as stand-tending. That is,
any silvicultural technique applied to a timber stand following establishment and prior to regeneration cutting. Many of these techniques involve adjusting stand density. Characterization of these activities for analytical purposes requires recognition of the effects of stand density on the development of timber stands. The Forest Service is only just beginning to collect information which will enable it to estimate the effects of stand density on yield. In addition, there are no standards for density within the manual of operations for the Silvicultural Branch of the Forest Service. The potential contribution of programs of stand-tending to timber supply goals can therefore only be guessed at.

In the absence of a silvicultural inventory the best that can be done through the timber supply planning process is to identify classes of stand-tending activities that can best contribute to supply goals on the basis of their production of merchantable volume. The assumptions made in the planning phases about the extent of stands available for these practices may require that financially poor risk investments be undertaken. In addition, if it is the short-term harvest rates which have to be supported by investment, there may be a need for programs to be begun immediately. Under these circumstances it is necessary to provide a means to control investment programs that is congruent with current Forest Service practices. It is to be hoped that, given time, the Forest Service will develop a more economic approach to forest management. In the meantime the introduction of basic economic principles of cost-efficiency, as proposed in this thesis, should improve the quality of investment decision-making within the Forest Service.
1.1 The Proposal

A systematic approach to planning investments in silviculture in the provincial forest estate is required if regional development goals are to be reached, or even approached, through intensive management. The timber supply planning system of the Forest Service provides a statement of regional resource policy in the case where short-term harvest rates are limited to below those required to maintain existing industry. A system is described that can translate timber supply goals into annual management unit investment programs under these conditions. It has been designed to focus attention on the generation of alternatives for investment. As far as possible existing sources of information and established administrative techniques have been incorporated into the system.

The system proposes, as a guiding principle, that investment must be cost-efficient with respect to the objectives of management, however these have been derived. An index of cost-efficiency has been derived for investments which have their effects measured in terms of purely physical production. This index can be used to choose among investment alternatives with common production goals. Genuine economic analysis would require that goals be formulated by reference to economic principles. The system takes management goals as given and attempts to introduce economic principles into programs undertaken to achieve them.

1.2 The Scope of the Proposed System

There are both short- and long-term objectives implicit in the timber supply goal-setting system. The supply planning system used by the Forest Service identifies the maximum constant 20 year rate of harvest that a
management unit can support (Ministry of Forests, 1978). The alternative programs presented to the legislature invoke a rising, a falling, and a constant long-term supply scenario (Ministry of Forests, 1980). Investments may be undertaken to contribute to either short- or long-term goals, or to both. Short-term supply goals are accessible to silvicultural investment by the transfer of benefits through the forest acting as a supply system. The definition and magnitude of systemic benefits are a function not only of the structure of the forest itself, but also of the management environment.

The proposed system utilizes a measure of the potential contribution of an investment to short-term supply goals. It also contains sub-systems originally designed to operate in the existing public management environment. For these reasons its scope is limited to investments undertaken, at least in part, to contribute to short-term supply goals. It is particularly suited for use in those areas for which the Forest Service has responsibility for the operational planning of intensive management. This responsibility is largely concentrated in the more than 32 million hectares of forest land in public management units in the interior of the province (Ministry of Forests, 1978a). This area contributed more than 45% of the provincial harvest yield in 1977 and 1978.

1.3 Objectives of the System

The grand objective is to integrate strategic and operational planning. There are two sub-objectives:

(1) To identify the forest estate in which investment should be made, and

(2) To allow for initiative in planning and innovation in prescription.
Strategic plans are subject to review as more information becomes available, as trends in utilization or consumption change, and as the perceived goals of society change. Investment decisions based on strategic analysis reflect the current expectations and goals of society. Once made, an investment is "sunk" and may be made obsolete by changing circumstances. However, when a new decision has to be made the change in circumstances can influence the choices. A system provides a route by which changes can be incorporated into the decision-making process. Thus, if a supply goal changes partway through an investment program the rest of the program can be selected on the basis of the changed goal. The inefficiency of investment associated with this approach can be reduced if changes can be anticipated.

At present timber supply analysis uses forest inventory information which is not based on map grid coordinates. The basis for analysis is the forest timber type which groups all areas within a management unit with similar species composition, age class, and site class. The basis for investment is the timber stand with location, as well as growth attributes. Location can influence both the costs and the benefits of investment.

The Forest Service has a tradition of highly centralized decision-making which may have discouraged innovation. A diversity of approaches to the solution of a problem may reduce the risk of failure. People who are allowed to use initiative may tend to take more interest in the job. Centralized control can be exercised through regulating a decision system rather than by regulating the decisions themselves. The distribution system recommended here may promote initiative and encourage diversity while maintaining control.
2.0 THE POTENTIAL FOR GOAL CONFLICTS

Under British Columbia's forest management policy the rate at which the existing merchantable volume inventory is utilized is linked to the future ability of the forest to provide industrial wood. This linkage is possible because the imposition of an administration on a forest provides a timber supply system. The capacity of the system is related both to the biological nature of the forest and to administrative provisions. In this thesis it is assumed that the emphasis is on providing current harvests; that is, investment in the future growth of the forest is undertaken to permit desirable short-term harvest rates. Under these conditions the worth of investments includes both short- and long-term components.

The short-term component of an investment is its ability to contribute to the current harvest rate. This contribution is related to the annual cut effect experienced when combining land units with complementary age class structures. However, since the benefit may arise from attributes other than age class structure they will be referred to as system benefits. System benefits are associated with the production of merchantable volume as prescribed by Forest Service regulations.

The long-term component of investment worth is obtained when the stand is harvested. It is related to the value of the harvest. Stand value is determined by the interaction of a great many factors amongst which average stem volume is of importance.

The stand conditions necessary to maximize system benefits are not necessarily those that maximize the long-term, or stand, benefit. The timber supply planning framework is likely to impose a time-frame for the realization of stand benefits which will not permit stands to be grown at
densities within the normal range. It is proposed that the potential benefits of an investment be viewed as having two dimensions, value and volume, which describe them completely.
3.0 THE INVESTMENT DISTRIBUTION SYSTEM

Management of the public forest estate is shared between the Forest Service, a public agency with goals set by policy, and entrepreneurs, whose goals include profit-maximization. In order to meet policy goals expressed in terms of short-term harvest rates, the Forest Service must mobilize the resources of private industry. It seeks to do this by offering incentives for intensive management activities.

From industry's viewpoint investment in intensive management is essentially the same as other kinds of investment. It is the magnitude of the stand benefits that characterize them in investment analysis.

It is proposed that both system and stand benefits are valid expressions of the worth of investments and that it is in society's interest to consider both when public funds are to be invested. The need for an analytical system to control public investment arises because of a difference in orientation between public forest management and normal industrial practice. Industry may acknowledge an obligation to society assumed through the use of commonly-owned resources. Because of its profit-maximization orientation it may incorporate that obligation into its decisions by modifying qualifying rates of return on investment. However, this procedure does not explicitly consider the system benefits of investment.

Where the Forest Service has the sole responsibility for planning it must develop means to select among alternative programs of management. Institutional factors limit the choice of approach to this problem. The Forest Service has not, traditionally, used profit-maximizing criteria in its management decisions. Under these conditions it is possible to manage
stands for their contribution to the supply system under conditions not attractive to private industry. The proposed investment distribution system serves this function. It directs investment to those stands and treatments which can contribute to forest-system benefits most efficiently. It operates by considering the attributes of a stand that influence the magnitude of the transferable yield benefits within the existing system.

3.1 Stand Attributes and System Benefits

Predicting the way in which investment in individual stands will influence short-term harvest rates requires knowledge of the "engineering" of the timber supply system. Total supply is realized by harvesting individual stands and is the aggregation of all the stands harvested within a single period. The characteristics of individual stands are "submerged" in the aggregation process and the harvest stream is characterized by average attributes.

In timber supply planning, system parameters can be set through strategic analysis. Silvicultural investment planning is concerned with the implications of these specifications for the type of stand which is to result from management. The system benefits of stand management are the extent to which the stand moves toward a goal which reflects the needs of the timber supply plan.

Supply plan needs are expressed by the timing and extent of the deficits which are to be avoided by investment. The deficits may be of total yield or of specific products, or of both. Investment in an individual stand is intended to ensure that the stand is available during the period of deficit and provides the specific products required. An investment program is needed to coordinate the treatment of individual stands.

What determines the suitability of a stand for investment? Consider
the question only from the forest system viewpoint. The stand must be able to be harvested during a specified time period. The earliest that a stand should be cut is when the value generated from it just covers the costs of harvesting, transportation and processing the wood from it. Stand value is related to stand merchantable volume, average stem size, and the distribution of stem size. Harvesting costs are related to the location of the stand, the nature of the site occupied by the stand, average stem size and distribution, and the other factors. The site quality, stand density, development history and genetic potential of the stand in part determine its rate of growth and the distribution of that growth among the stems in the stand. A stand is a candidate for investment if it has the potential, which would not otherwise be expressed, of growing to harvestable condition within the time required.

3.2 Flow of the Proposed System

How can candidate stands be identified? The forest estate can be zoned to reflect expected harvesting costs. Within any zone the stand conditions needed to permit harvesting are relatively constant. These conditions provide the target for the stands within a zone. Stand types not likely to meet these targets have potential for investment. Not all of the potential opportunities may need to be taken up. If the budget for investment is limited, not all opportunities will be able to be funded in a single budget period. Under these conditions it is desirable to discriminate among opportunities. It is proposed that cost-efficiency be used to express preference.

The proposed investment distribution system provides methods to determine harvest cost zones and cost-efficiency. It also suggests a method of assembling an annual investment program from information provided
by an incomplete inventory of opportunities. It integrates the time-frame and product goals from supply analysis with the methods used to determine stand treatment guidelines. Figure 1 is a schematic diagram of the flow of the system. The items that are starred involve procedures that have been developed to reflect current practices within the Forest Service. These will be described in subsequent sections. Information and analysis at the tail of an arrow contribute to decisions made at the head of the arrow. Harvest cost zone analysis is independent of timber supply analysis. All subsequent steps in the system use either the time-frame or the product goals, or both, derived through timber supply analysis.

3.3 An Important Caveat

The proposed system has been devised to assist decision-making within the context of public timber supply management. Its design reflects the current practices of the Forest Service in its operational mode. It has been proposed in an attempt to provide a bridge between the traditional orientation of the operative division in the Forest Service, the Silvicultural Branch, and the more "business-like" approach evident in new policy directions. It is needed because there is an urgency to invest in supply not felt under other circumstances. For convenience, investments made specifically for timber supply ends will be referred to as "social investments". They are assumed to contribute to the furtherance of social policy.

By contrast the forest also provides opportunities to invest in the normal business sense. Because of the long lags between investment and return these investments are characterized by a higher degree of risk than many other opportunities. Since normal business practices are the context for this type of investment they constitute venture opportunities.
FIGURE 1  SCHEMATIC FLOW DIAGRAM FOR THE PROPOSED SYSTEM

Items marked ° are developed in this thesis

STRATEGIC ANALYSIS

Timber Supply Goals

Product Goals \( \swarrow \) Time-frame °

Eligibility for Product Goals °

Potential Treatments

Costs of Treatments

Effects of Treatments

Managed Stand Growth Expectations

Annual silvicultural Budget

HARVEST-COST ZONE ANALYSIS °

Typical Growth Expectations

Location ° & Stand-types Eligible for Investment

Inventory of Eligible Opportunities (Chapter 5)

Assessment of each inventoried Opportunity ° (Chapter 6)

Selection of the most Efficient Alternative for each Product Goal °

Unfunded Opportunities

Assembly of the Annual Activity Budget °

OPERATIONAL PLANNING
In the long run the whole structure and health of the forest industry in British Columbia may depend on skillfull exploitation of venture opportunities.

The decision aids provided for both types of investment are likely to appear quite similar. Indeed, the aids developed for current management within the Forest Service are organized around factors similar to those likely to appear in guidelines developed for social and venture investment. The most recent Forest Service guidelines developed for stand treatment are appended for reference. It is important to realize that the content of such decision-aids reflects the purposes for which they are developed. Therefore the specifications that are derived through application of the proposed investment distribution system are quite specific to social investments as defined previously. Social investments can only exist in forest management units where short-term supply is limited to less than that required by regional supply policy. It is proposed that investment in these units has an absolute priority over venture opportunities because budget appropriations for silviculture are made with reference to short-term supply rates.
4.0 HARVEST COST ZONE ANALYSIS

Logs have value because they are used in subsequent productive processes. Timber stands have value because they are the source of logs. The unit of log production in the stand is the individual stem. The dimensions and properties of a stem determine the nature of the logs that can be manufactured from it.

It is proposed that, volume for volume, the relative value of a log is determined by its small-end diameter (s.e.d.). A log of small s.e.d. is presumed to be less valuable than one of larger s.e.d. This is a simplification made possible by the nature of social investments. They are likely to be undertaken within time constraints which preclude the adjustment of stand growth rates to reflect wood qualities that influence value.

The value of an individual stem, and of a timber stand, are simply the aggregate value of the logs derived from them. Larger stems produce a greater volume in a log size class and larger logs than do smaller stems. A stand which contains larger stems will provide more and larger logs than a stand with smaller stems.

Extraction of timber to the roadside is, in most cases, a batch process. Individual pieces have to be handled. Larger pieces are, on the whole, cheaper to handle than smaller pieces. The "piece" may change during extraction from a tree length to a log length. The cost of extracting all the timber from a stand is related to the average size piece the stand provides.

The marginally economic stem size is that at which the value of the stem is balanced by the cost of extracting it. As a stem increases in size its value and value per unit volume tend to rise, while the costs of
extraction tend to fall. A marginal stand is one within which aggregate stem value balances aggregate extraction costs.

It is proposed that marginal analysis be applied to the stem of average size within the stand. It is assumed that the distribution of stem sizes is consistently related to average stem dbh or average merchantable stem volume. This is an approximation, known not to be correct in detail, but acceptable for present purposes. In this case average stand value and average extraction costs are used to characterize a stand. A stand must be grown to at least the average dbh, or average piece size, associated with the marginal stand before it can be harvested.

4.1 Adjusting the Margin for the Effects of Utilization Policy

Total stand value and the costs of extraction are not distributed uniformly over the range of stem dbh represented in a stand. In general the largest diameter stems will have the highest per unit values, and the highest per stem values, and the lowest per unit extraction costs. Conversely, the smallest stems will have the lowest per unit values and the highest per unit extraction costs. If the value and costs of each dbh class in a stand are accumulated, a distribution like that shown in Figure 2 results.

Three points in the dbh distribution are of interest. The Forest Service, as part of its utilization policy, defines merchantable volume in terms of the stems larger than an administratively defined dbh. If harvesting proceeds by extracting the largest stems first and then progresses down the dbh distribution a profit-maximizing minimum dbh and a break-even dbh can be identified. The former represents the point at which the costs of extracting the next sized stem first exceeds the value of that stem. The latter occurs when the accumulated costs of extraction
The relationship shown in Figure 2 represents that of an immature stand. In economic terms, only the small proportion of the stand in stems larger than the minimum profit-maximizing dbh is attractive. A larger proportion of the stand, that in stems larger than the break-even dbh, could be extracted without incurring a loss but rather more than half the total number of stems would have to be left.

At present the Forest Service will not permit a stand to be harvested unless all the administratively defined merchantable volume is removed. This has implications for the timing of the earliest possible harvest for a stand. Consider the relationship between minimum dbh's as a stand range.
Figure 3 illustrates three successive observations of a stand. The relationship in period 1 is the same as that shown in Figure 2. By period 2 much more of the stand is extractable and all stems larger than the stand average dbh are economically attractive. However, the stand would not be permitted to be harvested since not all the merchantable volume could be removed. It is only in period 3, when the break-even and merchantable minimum dbh's coincide that the stand could be harvested without incurring a monetary loss. This then is the earliest that this stand could be
harvested.

In subsequent discussion and analysis minimum harvest ages and corresponding stand averages have always been predicated on the current administratively defined minimum merchantable dbh. There is, therefore, the possibility of earlier harvests if harvest rules should change. This would require a major change in the expression of utilization policy on the part of the Forest Service. Such a change is tantamount to changing the nature of public forest management and would lead to a redefinition of the forest supply system. The method to determine the break-even dbh in the existing management context will be described in subsequent sections.

4.2 Establishing Zone Boundaries

A zone contains all sites within a management unit that have similar harvest costs. A system developed by the Valuation Branch of the Forest Service for stumpage appraisals contains a very useful analysis of the factors affecting costs. This system can be used, by changing its interpretation, to identify and integrate the factors of the physical environment which contribute to total harvesting costs. It is proposed to define zone boundaries in terms of these integrated effects. The basic approach is known as the Logging Productivity Classification System (B.C.F.S., 1978).

4.2.1 The Logging Productivity Classification System

This system is used to assess the costs of harvesting a stand of timber at the time it is to be sold. The severity of individual cost factors is indexed by reference to standards. The factor indexes are then summed and the total used to place the stand in a logging productivity class (LPC). A standardized logging system is selected on the basis of the LPC and the magnitude of some of the factor indexes.
A logging system can be viewed as a series of tree and log handling phases. Each phase is characterized by a specific choice of machinery or method from the available alternatives. The logging productivity classification system provides an estimate of the productivity of a recommended method. Productivity is assumed to be strongly related to average piece size. A family of logging productivity curves, with average piece size as the ordinate, is drawn. The differences between the curves represent the effect of the logging productivity classes.

Once the recommended system and probable phase productivity have been determined the costs of harvesting can be calculated. The Forest Service provides a schedule of costs for rental equipment (B.C.F.S., 1979) for use in appraisals. This method can be used to evaluate harvesting costs over a wide range of environmental conditions. It is the use of consistent indexes which makes this system so useful for silvicultural planning. An index of, e.g., 15 will have the same effect on productivity for all cost factors. The indexes are under review and subject to refinement but are useable in their current form.

4.2.2 Adapting the System to Provide Zone Boundaries

In stumpage appraisal, stand conditions are taken as found. In silvicultural investment planning the stand conditions required under given cost conditions are of interest. The logging productivity system identifies average piece size as the stand quality that determines productivity, and hence cost. Average piece size can be related to other stand descriptive variables that can be manipulated by stand tending. The first step is to evaluate logging costs over the range of logging productivity classes likely to be encountered in an individual management unit. This is accomplished by working through the logging productivity classification
system. The result of this step is presented in Figure 4 for the range of LPC's likely to be encountered in lodgepole pine stands in interior management units. The Forest Service uses two sets of LPC's; one each for slopes less than or equal to 25% and greater than 25%. Slope affects the degree to which certain logging phases can be mechanized. Note that logging costs are more sensitive to the average piece size of the harvest than to the severity of the cost factors reflected in the site's LPC. Note also that the range of costs is considerable.

FIGURE 4  Relationship Between Logging Costs and Merchantable Average Piece Size for Recommended Logging Systems (1979 equipment costs, B.C.F.S. stumpage appraisal system)
Species does not affect the relations in Figure 4 except insofar as it reflects the range of environmental conditions likely to be encountered, or the logging systems likely to be employed. Lodgepole pine is a species typical of the interior of British Columbia where moderate slopes and gentle relief characterize the environment by comparison with the coast region. The Forest Service recognizes a total of ten logging productivity classes for slopes >25%; only seven are shown in Figure 4. It is assumed that the general shape of the relationship between cost and average piece size is the same for the three most costly classes.

The cost interval between classes is not constant. Some cost factors have relatively little effect on productivity in isolation, but in combination with certain levels of another factor, their effect is significant. The index sum of the two factors in such a case is enough to push the site into a higher productivity class.

The next step is to transform the cost-size relationships into a form useful for site classification. The objective is to identify features of the environment that determine the cost-class a forested site will occupy. Some of these features will be identifiable from study of aerial photographs and topographic maps. The cost-zone boundaries can therefore be superimposed on the forest environment in a form suitable for planning. A study of harvesting opportunities in British Columbia has used a similar approach but with derived slope and terrain classes (Hedin, 1978).

4.2.3 Transforming the Cost-Size Relationship

It is necessary to separate environmental effects from the effect of average piece size. The factors used for classification should be permanent features of a forested site which will not be affected by management. This is accomplished by evaluating the costs of harvesting at a specific stand.
condition. It is proposed that the smallest average piece size for operability be used. At this point the total value of the stand equals the total cost of harvesting it. A slightly larger average piece size will provide a positive net stand value, a slightly smaller one a negative stand value.

In British Columbia the value of public timber is its conversion return, a residual from the value of the products manufactured from the stand. The value of the manufactured products constitutes a pool from which the costs of manufacturing, transportation, and harvesting are drawn (Province of B.C., 1974).

It is possible to determine the value of logs at the mill-gate. There is an equivalent mill-gate stand value; the aggregate value of the log assortment from a stand. Unlike logging costs, there are value premiums that express species preferences. Each species or species group that provides products differentiated by price must be treated separately. Mill-gate stand value can be determined by applying the log value-size gradient to the log distributions of stands.

From mill-gate stand value the costs of harvesting and transportation must be removed to determine conversion return. Conversion return for a stand at the point at which it is first operable is zero; therefore, at this point, the combined costs of harvesting and transportation just balance the mill-gate stand value. As costs of harvesting rise, the pool of value available to cover transportation costs decreases. For a given stand value a more remote stand must be cheaper to log than less remote stands if it is to be operable. All cost factors, apart from average piece size, contribute to the accessibility of a stand. This classification follows that of Fries and Hagner (1970).
The procedure to define cost-zone boundaries can be best illustrated by example. The relationships presented here for lodgepole pine are from a study by Gasson (1979). They are highly generalized in nature and should not be used without modification.

The value gradient for lodgepole pine stems shown in Figure 5 was derived by considering the products likely to be manufactured from representative mill types described by Aune and Lefebvre (1975). Grade recovery information was obtained from Dobie (1978). Product yields were converted to the volume of logs from which they came through the use of standard conversion factors (Dobie and Wright, 1975). The distribution of log volume by log small end diameter was interpreted from taper tables in Lee (1966). These tables contain both height and dbh classifications. Stem value was obtained by aggregating the value of the logs a stem contained. For a given stem volume taller stems are more valuable than shorter stems because lumber recovery is better in stems of lower taper. The band of unit values in Figure 5 reflects this relationship.

Beyond a stem volume of approximately 0.4m$^3$ the value of each m$^3$ of wood remains fairly constant at a 1978 value of $145. Stems of this size and larger can provide all the products normally sawn in the interior of British Columbia. Stem total value increases because larger stems provide a larger volume of each product. The product output of smaller stems is dominated by studs and 2 x 4's. The very rapid increase in marginal value is associated with increasing product diversity. The net effect is to make total stem value directly proportional to stem volume over the range of volumes considered.

Assigning a value to a stand requires that the distribution of stem volume within the stand be known. Considering the rather gross nature of
FIGURE 5  Hypothetical Value Gradient of Lodgepole Pine Stems
based on 1978 lumber and chip prices

Increasing stem height

Total Value

Unit Value

Merchantable Stem Volume (to a 10 cm top) m$^3$

0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Total Value ($/stem$)

Unit Value ($/m^3$)
the stem value estimates, efforts to obtain this information are not justified. Assume that the values in Figure 5 are those of the merchantable stems. The value of a stand is then the number of merchantable stems multiplied by the total value of the average stem.

To obtain the stand mill-gate value the costs of milling the products must be subtracted from the stand value. Information about the marginal effect of log size on milling costs is, at best, sketchy in British Columbia. Costs appropriate to the mill-system used in manufacturing the products should be used. It is possible to substitute cost expectations developed on a regional basis, if necessary. Milling costs may be considered to be either fixed or variable with respect to log size. In general, they are considered to be effectively fixed because a mill cannot control the size distribution of the input stream. Aune (1979) has provided an average cost for a modern mill of the type that can handle the range of log sizes in Figure 5. The curve labelled Aune (1979) in Figure 6 shows the effect of removing this fixed charge from the average stand value. The residual value is the mill-gate average stand value.

The other curve Gasson (1979) is that of mill-gate values assuming variable milling costs. The milling charge is inversely proportional to log small-end cross-sectional area. The two milling charges are scaled to be equal at a log top-end diameter of 23 cm. The assumption of variable milling costs is justified because some element of control of log population is implied in stand tending. The mill-gate values under this assumption have been used in subsequent analysis.

The stand values shown in Figure 5 are for the stand volume on board a truck on the roadside. Those of Figure 6 are for the stand volume at the mill-gate. The difference between them is the amount that is available
to cover transportation costs at the earliest point of operability. Assuming average truck volumes and transportation speeds the cost per kilometer per m$^3$ of wood can be calculated. The maximum distance of a stand from the mill-gate is that at which the cost of trucking equals the stand residual value. A schematic representation of the relationship between maximum trucking distance and average stem volume for lodgepole pine is shown in Figure 7. All the curves for the logging productivity classes on slopes \( \leq 25\% \) are shown. For slopes \( > 25\% \) only the lowest and highest are shown. Representative curves for logging productivity classes (LPC) close to the lowest and highest are shown to emphasize the changes in the shape of the curves with changing LPC.

Figure 7 is the full expression of the relationship between operability, accessibility and average piece size. For any logging productivity class, a stand will be operable with a given average piece
size only within the radius indicated by the point on the corresponding curve. As accessibility decreases (trucking distance increases), larger average stem sizes are needed to make stands of a given logging productivity class operable.

Although each curve is shown as a narrow line the relationships are rather broad generalizations. It is proposed that, rather than using the full logging productivity classification, zones be based on two harvest cost classes on slopes \( \leq 25\% \) and on three classes for slopes \( >25\% \). If the actual cost per \( m^3 \) of delivered wood is plotted on the maximum trucking distance for operability, relationships like those shown in Figure 8 are obtained. The class boundary harvest costs are chosen to divide the expected range of costs into two, or three, bands. These boundaries should be drawn for each management unit; they define relative, not absolute, cost boundaries.

The cost-factor conditions associated with each logging productivity class are indicated by the sum of the factor indexes. These sums are shown in Table I. The factors that contribute to the total include those

<table>
<thead>
<tr>
<th>TOTAL INDEX</th>
<th>&lt; 13.1</th>
<th>21.1-29.1</th>
<th>37.1-45.1</th>
<th>53.1-65.1</th>
<th>65.1-80.1</th>
<th>≥</th>
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<tr>
<td>RANGE</td>
<td>13.0</td>
<td>21.0</td>
<td>29.0</td>
<td>37.0</td>
<td>45.0</td>
<td>53.0</td>
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<tr>
<td>LPC</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>V</td>
<td>VI</td>
</tr>
<tr>
<td></td>
<td>VII</td>
<td>VIII</td>
<td>IX</td>
<td>X</td>
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</tr>
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</table>

that are not permanent features of the site. The most significant site-related factors are:
FIGURE 8: Indicated Costs of Harvesting for Recommended Systems for Stands at Minimum Operability

(a) slopes \( \leq 25\% \)

(b) slopes >25\%

Total Cost of Delivered Wood ($/M^3)$ vs. Distance from Millgate (Km)
(1) The interaction of slope and terrain;
(2) The number and size of obstacles such as boulders, stumps and windthrow;
(3) The interaction between soil moisture, depth and type, and
(4) The amount of exposed rock.

It is proposed that the current values of the indexes of the other factors cannot be related to future conditions. Their contribution may therefore be ignored. The indexes for the individual factors to be considered are reproduced from the Forest Service standards in Table II.

The axes in Figure 8 can be transformed to put the logging productivity class on the y-axis. Since the LPC's are defined in terms of ranges of total index the y-axis can be shown as index totals. These axes are shown in Figure 9. Consider the low harvesting cost class in Figure 8, slopes \( \leq 25\% \). At a distance of 128 km from the mill-gate the maximum logging productivity class that can be harvested for $9.00/m^3$ is III. The maximum index for class III stands is 29 (Table I). An index of 29 thus represents a harvest cost boundary at a distance of 128 km.

At any distance from the mill, stands of logging productivity class IV lie in the high harvest-cost class. The minimum index for this class is 29.1. Therefore at any distance up to approximately 130 km from the mill-gate an index of 29 represents the low-cost boundary. At a distance of about 160 km no stands can be harvested for less than $9.00; this then is the maximum radius of the low harvest cost zone.

Between about 130 km and 160 km logging productivity class II costs rise above $9.00. This class is not shown in Figure 8 for the sake of clarity. The maximum index for LPC II is 21. From Figure 9 it can be seen that at a distance of 150 km an index of 21 costs $9.00 to harvest.
**TABLE II**

INDIVIDUAL FACTOR INDEXES FOR PERMANENT SITE FEATURES  
(Adapted from Forest Service Standards (B.C.F.S., 1978))

(a) The Interaction of Slope and Terrain

<table>
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<th>Slope %</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>&gt;95</th>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Even</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>17</td>
<td>23</td>
<td>31</td>
<td>39</td>
<td>48</td>
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<tr>
<td>Rolling</td>
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<td>1</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>14</td>
<td>20</td>
<td>27</td>
<td>35</td>
<td>44</td>
<td>52</td>
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<tr>
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<td>13</td>
<td>19</td>
<td>26</td>
<td>33</td>
<td>40</td>
<td>49</td>
<td>57</td>
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<tr>
<td>Broken</td>
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<td>6</td>
<td>8</td>
<td>13</td>
<td>18</td>
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<td>32</td>
<td>40</td>
<td>48</td>
<td>58</td>
<td>67</td>
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(b) Surface Roughness

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>&lt;.25 - .50</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>&gt;.50 - 1.0</td>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>13</td>
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<td>5</td>
<td>7</td>
<td>9</td>
<td>11</td>
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(c) The Interaction of Soil Moisture, Depth and Type

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<th>Moisture Depth (m) Type</th>
<th>All Dry</th>
<th>.1</th>
<th>.2</th>
<th>.3</th>
<th>.4</th>
<th>.5</th>
<th>.6</th>
<th>.1</th>
<th>.2</th>
<th>.3</th>
<th>.4</th>
<th>.5</th>
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<td>Cobble</td>
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<td>2</td>
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</table>

(d) Exposed Rock

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<tr>
<th>Exposure Code</th>
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<th>&gt;3.5</th>
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<tbody>
<tr>
<td>Factor Index Loading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Mid Point Values | 0 | 0 | 1 | 5 | 10 |
FIGURE 9  Graphical Determination of Harvest Cost Zonal Boundaries

(a) slopes ≤25%

- high harvest cost zone
- low harvest cost zone

(b) slopes >25%

- high harvest cost zone
- moderate harvest cost zone

Distance from the Millgate (Km)
The boundary mapped on the axes of Figure 9 shows the maximum factor index that can be harvested for a fixed cost. These are the descriptions of the harvest-cost zone boundaries.

There is a total index associated with a physical site description. For example, a site with 17% slope and rolling terrain, 6 obstacles/plot 1.2 m high, a wet organic soil 0.5 metres deep, and a rock exposure code of 3 (from Table II) would have a total index of 31. However, a total index is not exclusively associated with a stand description. For example, a site with 60% slope and rolling terrain, 3 obstacles/plot 1.5 m high, a wet clay soil 0.3 m deep, and a rock exposure code of 3, also has a total index of 31. Rather than attempt to specify maximum factor indexes (and the corresponding factor condition) for classification, the zoning should be applied at a stand level.

4.3 Using the Harvest Cost Zones

Consider the operability, accessibility and average piece size relationship for slopes ≤25% illustrated in Figure 7. For a site of logging productivity class I at a distance of 120 km from the mill to be operable, the average stem volume of the timber on it has to be at least 0.6 m$^3$. At the same distance a site of LPC IV has a corresponding minimum average stem volume of 0.86 m$^3$. It costs about $8.00/m^3$ to log the stand in the former case and about $11.00/m^3$ in the latter (from Figure 8). For sites of equal quality and stands of the same species, the stand of LPC I will require less time to reach a condition of operability.

Once a site has been classified the operability/accessibility relationship can be used to determine the average piece size the stand on it will have to reach before it becomes operable. If the stand is not likely to reach that goal within the time-frame required a stand treatment may be contemplated. It is proposed to use harvest-cost zonal relation-
ships of this nature to provide minimum growth goals to use in the social investment decision-making process. Using the full logging productivity system to provide growth goals would imply a much higher resolution in the basic data than is in fact available.

The harvest-cost zonal accessibility-piece size relationship is obtained by simply averaging the individual relationships of Figure 7 over each LPC in the cost zone. For example, for the low cost zone on slopes \( \leq 25\% \), at a radius of 50 km from the mill-gate LPC's I, II, and III contribute to the average (Figure 8). From Figure 7 the minimum average piece sizes for operability are 0.52 m\(^3\), 0.55 m\(^2\), and 0.61 m\(^3\) respectively. The low cost zone average for stands at 50 km radius is thus 0.56 m\(^3\). At 155 km radius only LPC I contributes to the zone average with an average stem volume of 0.68 m\(^3\). By proceeding across the whole range of Figure 7 the full zonal average relationships can be evaluated. The zone averages for slopes \( \leq 25\% \) are shown in Figure 10. These are not general relationships since the boundary between high and low costs is specific to a management unit. They are, however, typical of the type of relationship to be found.

These relationships ought to influence stand prescriptions. Consider stands A and B in Figure 10 at a radius of 120 km from the mill-gate. On average, stand B will have to have at least an average stem volume of 0.98 m\(^3\) when it is logged, while for stand A the corresponding stem volume is 0.75 m\(^3\). If both stands are to be harvested in the same period the rate of growth of stand B will have to be greater than that of stand A. If stand growth is to be manipulated through altering stand density the residual stand is not likely to be the same in both cases. It is proposed that under timber supply management, rotation lengths are pre-determined by the supply
plan. There is a common time-frame for alternative social investments with a common supply goal. Under these conditions the zonal accessibility/stem-volume relationships provide growth standards that can be used in decision-making.

The cost-zone definitions can be used to classify forest sites in preparation for an investment program. In this mode the forest estate is zoned to reflect the minimum growth goals. For example, between 100 and 120 km from the mill-gate forest sites with slopes ≤25% will have as minimum growth goals 0.73 m³ average piece size if in the low cost-zone, and 0.89 m³ if in the high cost-zone. Zoning should start by examining site conditions close to the mill-gate and proceed by working out to more remote locations.
Preliminary classification is accomplished by reconnaissance surveys of the harvest cost factors of Table II. The end result should be a map of a management unit showing the location and extent of areas with approximately homogeneous minimum requirements for operability. The map should be prepared as an overlay for forest-type maps. There will be overlays for each species within the unit that has markedly different manufacturing or marketing characteristics.

The zone boundaries do not have to be mapped at high resolution since no investment will be undertaken without more extensive ground survey. The zones are established to assist in silvicultural decision-making; if map areas can be excluded from the possibility of investment because of the age and nature of the timber, or because of policy, they need not be zoned. The zones themselves are designed as a temporary classification which should be replaced within a five or ten year period. If they are to be used for a longer period the boundary specifications and zonal relationships will have to be revised periodically. If future expectations of milling and harvesting practices and of real product values are incorporated into the zone analysis the basis for decision-making will be improved, and the need for frequent revision reduced.
5.0 DETERMINING INVESTMENT ELIGIBILITY STANDARDS

In the course of timber supply analysis the effect of a level of harvest on the performance of a variety of forest-growth variables is developed. One computer simulation model provides many variables including growing stock, average and minimum age at harvest, and forest increment as a percent of growing stock (Hall, 1979). This model has been used to develop a basis for evaluating the eligibility of an apparent opportunity for social investment.

The motivation for social investment is to permit a higher short-term harvest rate than would otherwise be possible. A short-term harvest rate influences future, longer term, rates through its effect on the structure of the forest estate. This effect is made evident through the performance of the forest variables to which management values are attached.

The need for social investment arises when, at some point in the planning horizon, the total supply of available timber is insufficient to meet the needs of the harvest. In this context the availability of timber is determined by regulation. In British Columbia regulation is by age class and it is the performance of the harvest age variable that provides information useful in investment planning. It is assumed that age class constraints will be relaxed at the time when stands that have been subject to investment are likely to be harvested. This is equivalent to applying one supply system in the process of running down the inventory of older age classes and then switching to another.

As harvesting progresses in a unit the average age of the stands in the harvest changes. At harvest rates close to the maximum sustainable the average age will approach, over the long run, the minimum permitted. At
rates above the maximum, at some point in the planning horizon, volume must be removed from age classes that are now closed to harvest. The period during which this happens may be limited if the age structure of the forest permits recovery.

If the minimum age of harvested stands is followed during a computer simulation of the effect of the required harvest rate on a forest unit a trace like that in Figure 11 can be obtained. During the period $T_1$ to $T_2$ years from present, supply is limited by the harvest age constraint since at least part of the annual harvest must be drawn from inaccessible stands.

**FIGURE 11**

Hypothetical Behaviour of the Minimum Age of Harvested Stands in a timber supply area for which a harvest rate is to be selected. The harvest rate is above the maximum sustainable.

Because stands that result from investment are not subject to a minimum age constraint the needed harvest volume can be drawn from them. However, any stand is subject to some constraints on the timing of harvest. The most basic are economic constraints of the nature discussed in Chapter 4. The earliest that a stand can be harvested, if utilization policy is maintained,
is when the average stem volume reaches the zonal average. Thus, in the unit from which Figure 11 is derived the goal for social investment is to provide yield in stands with zonal characteristics in the period T1 to T2 years from the present.

Eligibility standards are applied to stands in the inventory phase. They identify the class of stands that can be manipulated to a harvestable condition within the required time-frame. They serve the same function as, and will resemble, the treatment guidelines currently used by the Forest Service and shown in the Appendix. They differ, however, by being tailored to a specific management unit and objective. The types of treatment considered and their levels of application will be strongly influenced by the nature of the time-frame within which the benefits of investment must be realized. These will best be determined by computer simulation of the processes of stand development. If such models are not available the process of obtaining an informed consensus on the probable outcome of specified practices must be employed. The wider the base for consensus the better.

5.1 Using Zonal Goals to Predetermine Eligibility

An inventory of available investment opportunities is needed in the planning of an investment program. Such inventories are not generally available for the public forest estate. In this case inventory information must be acquired as investment progresses. It is necessary to have some preliminary inventory to permit the program to get underway.

In forestry, investment opportunities are likely to be characterized by many factors that influence the prospects of success. Much of this information may only be available through expensive and time-consuming ground surveys. It may be possible to keep survey costs low by operating
at a low level of resolution through low inventory intensities. An alternative approach is to restrict ground surveys to areas where the expectation of finding suitable opportunities is high. This can be accomplished with the help of zone boundaries superimposed on forest-type maps.

A stand is suitable for social investment if, through stand tending, it can contribute to short-term supply goals. It does so by being available for harvest during the time-frame imposed by supply analysis. Stands that meet zonal goals but are younger than the minimum harvestable age are not strictly available for harvest. This is a rather grey area of policy; it seems illogical to permit harvest of stands which have received investment but not of other stands in the same condition. The definition of availability is fundamental to the operation of a forest supply system. Until this issue is resolved it is proposed to regard stands that reach zonal standards as available, whatever their origin. Therefore, stand types that will reach zonal standards in the time-frame required without stand tending are not able to contribute to short-term supply goals and are not suitable candidates for social investment. The areas in which they occur may be eliminated prior to inventory.

Stands that cannot be made operable within the required time-frame may also be eliminated from consideration. However, since it is possible to "force" individual stem growth identification of these types is more complex. Forcing, in this context, means reducing stand density to a point where total volume production may be reduced. Even outside a supply context, forcing may be justified if economic gains accrue. Lee (1966), for example, demonstrated that in lodgepole pine, wide plantation espacements provided the best value recovery at harvest. In the supply
context apparent forcing is likely to occur when the lead time for the time-frame is short.

Smith (1973) has demonstrated that forest inventory data may be manipulated to show the effects of density on stand growth. His results can be interpreted to provide rough estimates of the ability of a species to contribute to supply goals. Gasson (1979a) has indicated some approaches to interpreting lodgepole pine data for this purpose.

An alternative approach is to seek an informed consensus. It is easier to structure the discussion around average stand dbh rather than average stem volume. The question to be resolved is how quickly a stand can be expected to reach a given dbh? The relationship between average stand volume and average dbh, of stems $\geq 17.5$ cm dbh, for lodgepole pine is shown in Figure 12. This relationship was derived for this study by analyzing 584 stand summaries from inventory reports.

**FIGURE 12**  
Relationship between Average Stem Volume and Average Stand dbh for Lodgepole Pine  
Source: BCFS. Inventory stand summaries

\[ y = -37323 + 0.123x + 33.347 \]
\[ R^2 = 0.88647 \]

close utilization standards
top dbh 10 cm
stump height 30 cm
all stems $\geq 18$ cm dbh
Approximately 89% of the variation in average stem volume can be accounted for by variations in average stand dbh. The formula expression was derived through regression analysis of the basic data.

For example, a stand in a low cost zone 100 km from the mill-gate has a zonal goal (from Figure 10) of 0.70 m$^3$. The minimum average stand dbh that has to be achieved during the required time-frame is 29.5 cm. Interestingly, at the same radius, but in a high cost zone, the goal average stand dbh is only 3 cm higher at 32.5 cm. This difference may be significant under some circumstances and not significant under others. In the high cost zone at 150 km from the mill-gate the minimum stand average dbh required has risen to almost 37.5 cm. This is a relatively high goal compared with the normal range of lodgepole pine dbh. Such a dbh may not be attainable by stands on poor sites or only after a period of competition-free growth on medium sites. Reasoning in this way the areas in which ineligible stand types are situated can be eliminated.

It should be recognized that stands that are ineligible for social investment may represent venture opportunities. It is likely that stands rejected because they will be harvestable when required will be of more interest than other rejected stands. All investment has implications for timber supply but the main focus of ventures is the opportunity to earn a return on investment. Stand values are therefore of interest. Stands that cannot, even with treatment, be expected to reach operability within a moderate time-frame are not likely to provide as good a return as those which could be harvested earlier if necessary. Therefore, three inventory zones should be mapped; one containing the areas where social investments are likely to occur, one containing areas rejected because they do not need social investment but may provide venture opportunities, and one for all
other rejected areas. The type of guideline represented by the Appendix could be applied within the second zone. The third zone would contain areas with low timber management potential.
6.0 ASSESSING INVENTORIED OPPORTUNITIES

Inventory is assumed to be an ongoing function. At any time it will have made available a list of forested sites that could, given suitable treatment, be made to provide harvestable yield during the time-frame required. Not all sites offer equally good opportunities for investment, however. Any investment may provide benefits at both the system and stand levels. In social investment the focus is on short-run system benefits but the other benefits are an integral part of an investment and also characterize it. Some opportunities for social investment may provide rather low system but high stand level benefits while others may offer the reverse. It is proposed that the "worth" of a social investment is related to the total benefit it can provide.

Assume that the total worth of investments A and B in Figure 13, and of any investments with system and stand level benefits on the line joining them, is 7 units. Similarly, investments C, D, and any with system and stand level benefits on the line between them, have total worths of 9 units. By definition the latter investments would be more satisfactory than the former.

It might seem that investments closer to A on line AB, or to C on line CD, should be more satisfactory than those closer to B, or D, since they provide a higher system benefit. However, all investment opportunities will have been identified through a process which expresses the requirements for system benefits. The stand level benefits considered here are provided by investment that would be undertaken for the system benefits alone.
It may be necessary to express preferences between alternative investment opportunities at two levels. The first arises in the process of selecting a treatment or level of treatment, for an individual forested site. The second arises in the preparation of an annual activity budget when more investment opportunities are available than can be undertaken. In both cases the first step is to characterize the alternatives in common terms that will allow them to be compared. In other words, the total "worth" of a social investment opportunity must be assessed. In this context an investment opportunity is provided by the ability to practise a silvicultural technique on a forest site or timber stand.

There has been a physical yield orientation associated with public timber management in British Columbia that has influenced decision-making
within the Forest Service. It has contributed to a failure to develop systems to handle economic analyses. The tendency has been to assign a nominal value to wood fibre whatever its source. Thus, for instance, a cubic metre of wood from 12 cm dbh stems would have the same value as the same volume from 40 cm dbh stems. In recognition of this bias a special definition of the worth of social investments has been developed for this study. It is the physical yield analogue of present net worth.

6.1 Measuring Stand "Worth"

The contribution of a stand to the long-run sustainable level of harvest for a management unit is related to its mean annual increment (m.a.i.) of merchantable yield at the age of harvest. Thus, for example, if all the stands within a unit are harvested at, or close to, the age at which m.a.i. culminates the long-run sustainable yield of the unit will be maximized.

If investments are made in order to permit early harvest of stands, as is the case for social investments, the mean annual increment at harvest of the treated stand is not likely to be the same as that of the stand if not treated. This change has implications for the supply plan for the management unit.

It is proposed to use the present "worth" of the m.a.i. of merchantable volume at harvest as the contribution of a stand to supply system benefits. Mean annual increment can be viewed as a series of annual volumes that can be harvested from existing stocks.

From the perspective of the present the volumes harvestable in the near future are more attractive than those available later. Society's preference for the distribution of benefits in time is expressed through the discount rate. There has been considerable debate on the correct inter-
pretation of this preference. A task force of the Provincial government has suggested a rate of 10% (Province of B.C., 1978). This apparently includes an allowance for continuing inflation. A more appropriate rate for the kind of analysis presented here is the real rate of return on municipal and government bonds over the long-term. This rate is between 2% and 4%. A rate of 4% has been used in the examples in this thesis.

The accounting formula for the present worth of a series of constant benefits available at yearly intervals is:

\[ PW = \frac{V(1-(1+i)^{-n})}{i} \]

where \( V \) = the annual benefit
\( i \) = the interest rate as a decimal
\( n \) = the number of years during which the benefit is received.

For the present worth of m.a.i. \( V \) is the m.a.i. at harvest in \( m^3/ha/yr \) and \( n \) is the number of years between the present and harvest. Table III shows the present worth of m.a.i. (or system benefit) of a stand that could be harvested in any decade from the 3rd through 8th from the present.

At the same time as a stand is contributing to the supply system it is accumulating volume that will be available at harvest. As before, society has a preference for early benefits that is expressed through the discount rate. It is the present worth of the harvest volume which contributes to stand level benefits. To satisfy the physical yield orientation of the Forest Service it is proposed to evaluate harvest "worth" in physical yield terms. To this end the concept of stand components defined by stem dbh has been developed.
TABLE III

PRESENT WORTH OF MAI (SYSTEM BENEFIT) FOR A STAND HARVESTABLE IN THE 3rd THROUGH 8th DECADES FROM PRESENT

<table>
<thead>
<tr>
<th>Years from Present</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume at Harvest (m³/ha)</td>
<td>50</td>
<td>150</td>
<td>215</td>
<td>265</td>
<td>310</td>
<td>350</td>
</tr>
<tr>
<td>MAI at Harvest (m³/ha/yr)</td>
<td>1.67</td>
<td>3.75</td>
<td>4.30</td>
<td>4.42</td>
<td>4.43</td>
<td>4.38</td>
</tr>
<tr>
<td>Present Worth of MAI (m³/ha) or System Benefit</td>
<td>28.88</td>
<td>74.22</td>
<td>92.37</td>
<td>100.0</td>
<td>110.75</td>
<td>104.75</td>
</tr>
</tbody>
</table>

6.1.1 Stand Component View of Stand Value

The value of a stem is derived from its ability to be manufactured into products for which there is a demand. Consumer preferences for certain types of products are expressed through premiums in the price paid for them. The price structure for sawn products is very complex with many types and grades of product identified. In the process of deriving stand values for the harvest cost-zone analysis (Chapter 4.0) average values for lodgepole pine sawn products were examined for the year 1978. There was a strong relationship between board width and unit value over the range examined. It is assumed that there is a similar relationship for products milled from other species.

The maximum width board a stem can provide is determined by the small end diameter inside bark at the top of the first log length. For a given species this is related to stem dbh and taper. On average a stem of larger dbh will provide a greater volume of larger logs than will a stem of smaller dbh. The value per unit volume of wood from a log of larger small end diameter is greater than that from a smaller log because (1) there is greater opportunity to manufacture a diversity of products and
thus exploit markets for explicit products, and (2) it costs less to manufacture the same volume of wood from larger than from smaller pieces. The net effect is to concentrate stand values on only part of the stand volume.

It is common to distinguish between stands managed to produce specific products. For example, the Forest Service guidelines in the Appendix refer to sawtimber stands. It is likely that, given the right economic conditions, almost any stem could be sawn through improvements in technology. Reference to sawtimber management is therefore rather empty without further qualification of size and quality specification.

It is assumed that veneer volume will always be more valuable than sawtimber volume which in turn will always be more valuable than volume that can only be chipped or pulped. This seems reasonable since, as the Forest Service guidelines in the Appendix point out, it is always possible to pulp sawtimber, or, if necessary, to saw veneer quality logs. It is also assumed that there is a log small-end diameter below which it is not economic to manufacture veneer or lumber. These minimum sizes are determined by the state of technology employed by industry. It is proposed that, failing a specific analysis of trends in the manufacturing industry, current practices can be used to guide silvicultural planning.

There is a minimum stem dbh that can provide at least one veneer or sawtimber size log. In a stand only those stems above this minimum will be able to contribute veneer or sawtimber volume. It is proposed to refer to these stems as the veneer or sawtimber stand component. Other stand components, defined in analogous ways, may be recognized. There is, for example, an implied operable stand component. This provides the value which permits the stems that are economically sub-merchantable but
administratively merchantable to be harvested. The volume in stems larger than the utilization minimum dbh may also be considered as a merchantable stand component.

Identification of the minimum dbh for a component is an expression of supply policy. Timber supply analysis can reveal the potential for shortfalls in supply of, not only merchantable yield, but also specific log products. The assumption made in the analysis about the development of industrial capacity should be carried into silvicultural planning.

A stand-level policy such as the production of saw-timber volume can be interpreted in the context of social investment. At harvest a stand contains stems distributed around the stand average dbh. To be operable the stand must have an average dbh at least that of the zonal goal. Management can influence the distribution of dbh to provide more or less volume in a specific stand component. Treatments are characterized by the degree to which they influence the specific component yield.

6.1.2 Total Present Worth of a Stand

The present worth of harvest yield is the volume of a specified stand component discounted to the present. Intermediate yields are treated in the same way. The accounting formula for the present worth of a benefit to be received n years in the future is:

\[ PW = \frac{V_n}{(1 + i)^n} \]

where \( V_n \) = the size of the benefit obtained in year \( n \)

and \( i \) = the discount rate (4%).

Thus, if the stand in Table III were to be harvested in year 80 the present worth of merchantable yield at harvest would be \( 350/1.04^{80} = 15.18 \text{m}^3/\text{ha} \).

The total present worth of the stand is simply the sum of the present worths of m.a.i. and harvest volume. For the stand in Table III at 80 years...
this would be \(104.75 + 15.18 = 119.93 \text{ m}^3/\text{ha}\). Thus the expression for total worth is \(\frac{V_n}{(1 + i)^n} + \frac{v(1 - (1 + i)^{-n})}{i}\).

6.2 Marginal Effects of Investment

The effect of investment in a stand is to cause a change in the development of the stand. It is the characteristics of the induced change which are subject to control through treatment design. The worth of an investment is the degree to which the change it induces satisfies the objectives of management. In the case of social investment changes are made in both the system and stand-level worths of a stand by treatments required by objectives related primarily to the supply system. It is proposed to characterize investments by the change they induce in both levels of worth of a stand.

6.2.1 System Benefits

In principle these are simply the change in present worth of mean annual increment over the life of the investment. However, for a stand which has not been subject to investment, the contribution to system supply is not the increment of the stand itself. The Production Forecast Method of the Forest Services relies on standard Forest Inventory yield data. These data are currently organized into species composition, region and site class groupings from which yield curves are derived. The contribution of an individual stand to system increment is actually the increment of the corresponding yield curve. These yield curves, known as Volume over Age Curves (VAC) were developed for yield control purposes under different circumstances than now exist and will gradually be replaced.
Until a new growth forecasting method is in operation they will remain in the timber supply analysis process.

To obtain the change in system contribution induced by investment the present worth of mean annual increment of the treated stand must be made net of the present worth expected from the stand had it not been treated. This latter value is the present worth of the mean annual increments of the appropriate VAC. Appropriate here means the VAC that would have been applied to project the growth of the stand if no investment had been initiated. The mean annual increment of the stand after treatment must be supplied from management tables, computer simulation or consensus of informed opinion.

The implication of introducing the VAC is to impute a standard for the effect of investment. VAC's are local empirical yield curves which express the growth of regional average stands. The stands eligible for social investment are likely to exhibit below average growth. Investment may improve stand growth which may still fall short of the average. The net present worth of mean annual increment, in such a case, would be negative. Such investments are, however, still desirable. Therefore no interpretation of the sign of a present net worth exists beyond its normal algebraic meaning, e.g., a present net worth of -3 is higher than one of -5 but lower than one of 3.

The expression for the present net worth of mean annual increment benefit of investment is:
\[ \text{PNW} = \text{PW}_T - \text{PW}_C \]

where \( T \) indicates the m.a.i. resulting from treatment
and \( C \) indicates the m.a.i. at harvest for the stand if no
treatment is applied.

6.2.2 Stand-Level Benefits

The expected yield at harvest of a stand is not considered a system
variable. The present worth of the harvest from a stand subject to invest­
ment is made net of the present worth of the harvest from the same stand
if not treated. In this case only the volume of a specified stand component
is considered. For example, the sawtimber benefit of investment is the
difference in net worths of sawtimber volume from the treated and non­
treated stand.

A stand may contribute to a specific product supply goal only if it can
produce volume in the appropriate stand component within the time-frame
set by supply analysis. This is because the rotation of the stand is
primarily related to the need for merchantable yield. The presence of a
time-frame within which benefits will be realized suggests a method for
determining the eligibility of an investment opportunity for a specific
product supply goal. If the stand type being considered for investment
cannot be expected under any conditions to provide a significant product
benefit in the time-frame required it is not necessary to modify treatments
to encourage product component growth.

There is assumed to be a trade-off between merchantable volume
production and component stand growth. The trade-off will be most severe
when a minimum component dbh is far from the minimum utilization dbh. An
exploratory examination of forest inventory sample data for lodgepole pine was conducted for this study. It indicates that maximum production of volume in stems $\geq 7.1''$ (17.4 cm) and in stems $\geq 11.1''$ (27.2 cm) dbh is found in stands with far fewer stems/ha than stands in which there is maximum production of volume in stems $\geq 5.1''$ (12.8 cm) dbh at almost any age up to 120 years. This indicates that volume production is directed into restricted dbh ranges in response to stand density. It is the volume in stems $\geq 12.5$ cm dbh which is considered merchantable. It is necessary, therefore, to adjust stand tending prescriptions when a stand is eligible for a product supply goal.

For any stand that is eligible for a product supply goal there are always at least two treatment alternatives. One will seek to maximize system benefits with the product component production considered as a constraint while the other will take the reverse view. A stand may be eligible for the production of more than one product component. For each the evaluation procedure is the same.

### 6.2.3 Determining the Time-Frame

The period during which harvest volume must be drawn from "closed" age classes provides the general time-frame for harvest. This can be obtained by evaluating the minimum age of harvested stands when the administratively determined age constraint is removed in a timber supply analysis.

Stands may become operable part-way through the general time-frame. There is, therefore, a "window" within the time-frame during which a stand will be able to contribute to short-term supply goals. This window can be defined in terms of years from present and translated into stand ages when
needed. As before, the minimum condition for harvest corresponds to the zonal average stem volume or average dbh. If a stand reaches this condition after the beginning of the time-frame, the years from present to the period in which operability is reached represent one side of the window. Otherwise this side of the window is determined by the earliest period in which volume would have to be removed from a "closed" age class. The upper side of the harvest window is always the end of the period indicated by supply analysis.

The harvest window for a stand that is treated is not necessarily the same as that for the same stand if not treated. Since stand-level benefits are only realized at harvest the number of years over which the harvest component volume is to be discounted will not be the same in both cases. Equally, system benefits cease when a stand is harvested; the period of contribution to system benefits may also be different for the treated and untreated stand. By the same token different treatments with common stand-level goals may have harvest windows of different lengths.

In general it is not possible to estimate when within the time-frame a specific stand will be harvested. This is a limitation imposed by the resolution of the data used in Production Forecasting. It is proposed that, from the supply planning viewpoint, it is an advantage to have flexibility in scheduling the harvest of stands. Therefore, the benefit of investment over the harvest window for an opportunity is of interest. It is proposed to characterize opportunities by the benefits of investment at both the upper and lower limits to the harvest window only.

6.2.4 Net Physical Benefit

The total net present worth of system and stand-level benefits of investment for a single opportunity, evaluated to the upper and lower limits
of the harvest windows, constitute the value of the investment for planning purposes. For ease of reference each of the two total net present worths will be referred to as the Net Physical Benefit (NPB) of investment.

NPB's are classified by the product component of the stand-level benefit. Since a single stand may provide more than one product opportunity the corresponding NPB's should be distinguished by subscripts. Every opportunity will have at least two NPB's for each potential product, one at each end of the harvest window. These should be distinguished by superscripts. Thus, for example, a stand which could be treated to produce either merchantable yield only or to produce sawtimber would have at least four NPB's which would be noted as $NPB_m^1$, $NPB_m^U$, $NPB_s^1$, and $NPB_s^U$. If several different treatments could be used to produce sawtimber the NPB's would be prefixed to indicate to which treatment they belong.

6.3 Cost Per Unit of Net Physical Benefit

The objective of planning the distribution of investment is to maximize the benefit obtained by that investment. Generally, planners face a fixed budget for investment. In the case of social investments this budget is likely to be determined on the basis of supply analysis. Under these circumstances the goal of planning is to provide for the maximum contribution to the predicted supply shortfall given the available budget. This implies that the efficiency of investment is a concern. This topic is the general area of cost-benefit analysis. Initially applied to engineering systems in a military context (English, 1968) it has been applied to public investment in forestry on a wide scale.

A rationale for a cost-benefit analysis has been developed by Massie (1972) and used by the Forest Service in stand-level guidelines for intensive management (Brett and Benskin, 1978). In this rationale the
marginal value increase attributable to investment can be exhausted by the cost of investment. That is, public investments in intensive management should be self-financing but need not provide a return over and above that level. This rationale has been adopted in the proposed distribution system. Its expression has had to be seriously curtailed because stand value is not explicitly considered.

An expression of cost-efficiency for social investments is the ratio of the costs of investment to the NPB which it realizes. This ratio, the cost per unit of net physical benefit (CNPB), is a variable of considerable utility in deciding among investment alternatives. Since part of any NPB contains system benefits, system costs must be included in the ratio. System costs arise from activities which benefit more than one investment opportunity. For example, in aerial fertilization the costs of the airstrip and access roads would be shared amongst all stands that are fertilized. It is the CNPB which characterizes an investment opportunity. There is a CNPB for each NPB associated with a stand. An extended example of the use of the CNPB as a decision variable has been prepared (Gasson, 1979b).

6.4 Assessing Inventoried Opportunities

In practice the silviculturalist will examine an area located by inventory and prescribe potential treatments for the area. His prescriptions will be guided by the proximity of the supply time-frame, by the zonal stand goals, and by the physical attributes of the site and of the stand on it. In this respect the proposed investment distribution system provides guidelines that have the same function as those in the Appendix. The efficiency of each proposed treatment will then be assessed by calculation of all the appropriate costs per unit of net physical benefit. At this
stage choices between treatments with the same product supply goals can be made.

The general principle is to choose the alternative with the lowest CNPB. A low CNPB implies a relatively high cost-efficiency within a common product goal. However, the behaviour of the CNPB's across the time-frame must be considered. Treatments that provide early benefits may not be as attractive if the stand is permitted to develop for a longer period. The exact rotation of a stand within the limits set by its harvest window is assumed to be unknown and unknowable. This sets the problem of making decisions that involve the rotation length in the realm of uncertainty.

The scientific discipline of decision theory has developed in response to the need to recognize the effect of chance processes on the consequences of decisions. There are three environments under which decisions are made: certainty, risk, and uncertainty. For a discussion of the basis for decision-making under these environments see, for example, Smith (1967). The approaches to decision-making under uncertainty useful for forest management have been summarized by Fight and Bell (1977). It is proposed that, of the procedures they discuss, the minimax decision rules are most appropriate in the context of social investment.

The minimax procedure requires that decisions be made on the basis of their likely outcomes under the worst conditions. The actual procedure proposed in the minimax regret criterion. This seeks to reduce the potential loss of benefit if the rotation length does not permit harvest when the benefit is at its maximum within the harvest window. It is proposed to use only the CNPB's at the lower and upper limits of the harvest window of an investment in the procedure. Table IV contains the CNPB's for four
hypothetical alternatives which will be used to illustrate the procedure.

**TABLE IV**

SAWTIMBER COSTS PER UNIT OF NET PHYSICAL BENEFIT FOR FOUR HYPOTHETICAL TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yrs. from present of 1, u limits</td>
<td>60</td>
<td>55</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>CNPBs $/m$</td>
<td>7.50</td>
<td>13.25</td>
<td>1.25</td>
<td>3.75</td>
</tr>
<tr>
<td>C</td>
<td>12.50</td>
<td>6.25</td>
<td>5.00</td>
<td>6.25</td>
</tr>
</tbody>
</table>

The first step is to plot the appropriate CNPB's on a time axis to provide an overview of the situation. Note that the lower limit of the harvest window is not the same for all alternatives. There are 10 years in which alternative 2 and 5 years in which alternative 1 could contribute to supply goals but the other could not. It is proposed that this period not influence the decision between alternatives. The "effective" harvest window is thus from year 65 to year 90. If the period within which a single alternative is the sole opportunity to contribute to supply goal exceeds 20% of the total harvest window of that alternative it is proposed that it be preferred.

The circled points in Figure 14 represent the CNPBs in Table IV. The solid lines joining pairs of points are for clarity and do not represent the behaviour of the CNPBs over time.

Under no rotation length within the adjusted harvest window will treatment 1 be the most efficient. It is dominated by the other treatments and may be rejected. Treatment 2 is the most favourable between year 65 and year 66, treatment 3 between years 73 and 90 and treatment 4 between years 67 and 72. The next step is to prepare a table of "regrets". The regret for a treatment is the difference between its CNPBs at one of the harvest
window limits and the lowest CNPBs at the same limit offered by one of the alternatives. For this example the minimum CNPBs at the lower limit is that of treatment 2 at $4.50/m^3$, and at the upper limit it is that of treatment 3 at $3.75/m^3$. The regret table is shown in Table V. For this example a straight line extrapolation has been used to find the CNPBs for treatment 2 at 65 years from the present. In practice CNPBs will not vary linearly with time. When for this analysis, harvest windows have to be adjusted the CNPB concerned must be recalculated.

The $1.75$ regret, for example, of treatment 3 at 65 years from present is simply interpreted. It is the amount by which the CNPB is increased by failing to choose the most efficient treatment if the benefits are realized in year 65. The minimax criterion calls for the selection of the treatment which provides the minimum regret from amongst the maximum regrets. The maximum values are $8.75$ for treatment 2 at 90 years, $1.75$
TABLE V
REGRETS FOR SAWTIMBER ALTERNATIVES AT THE
ADJUSTED HARVEST WINDOW LIMITS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years from Present</td>
<td>65</td>
<td>90</td>
<td>65</td>
</tr>
<tr>
<td>Regret</td>
<td>0</td>
<td>8.75</td>
<td>1.75</td>
</tr>
</tbody>
</table>

for treatment 3 at 65 years and $2.50 for treatment 4 at 90 years. The preferred treatment would be 3.

Once the most efficient treatments for the products for which the stand is eligible have been determined the assessment phase is complete. The next phase is the assembly of the annual activity budget. For this a record of the details of the stand, of the most efficient treatments, and of the relevant CNPB values needs to be made. It is suggested that a standard assessment form be developed. The form should be compatible with other stand assessment and silvicultural inventory documents and with any information handling systems in use.

6.5 An Extension to Components: Species Preference

The opportunity often arises, in stand tending work, to increase the proportion of a preferred species in a stand at harvest. Expressing this preference is equivalent to pre-empting supply management goals. Consider a stand containing an overstory of lodgepole pine and an understory of Douglas-fir that is eligible for juvenile spacing. There is often $\frac{1}{2}$ to 1 metre difference in height between the stories in these types of stands because of the rapid juvenile growth of lodgepole pine. Presently, Douglas-fir is more highly valued than the pine and there is a tendency to
sacrifice the growth advantage of the pine in the spacing operation. This, of course, puts the stand onto a Douglas-fir, rather than a pine growth curve.

If species was a strong element in supply strategy there would be an effort to sustain yield by species working circles. Because this is not the case, from the social investment viewpoint, the species of the yield delivered in the required time-frame is not important. However, in the same way that product components represent stand values, species contributes to stand-level benefits. In this sense species is the same sort of factor in analysis as the minimum component dbh.

If either species in a stand could form a fully stocked residual stand and both can contribute harvest yield within the time-frame then the choice between the "alternative treatments" can be based on the expected relative price of both. The procedure is to determine the relative per unit price that would make the cost to present net worth ratio of both alternatives equal. The ratio of prices sets a lower bound against which price expectations can be judged.

Consider the lodgepole pine - Douglas-fir example. The relevant data are shown in Table VI. Without considering species except as a treatment label, the pine alternative dominates the fir. At the lower limit (1) of the harvest window the CNPBs of the pine alternative is $10/m^3$, and of the fir is $14/m^3$. To convert these to ratios of present net worth it would be necessary to multiply the denominators by the unit value of wood at the time of harvest. Let $P$, $D$ be these values for lodgepole pine, Douglas-fir respectively. Then for the alternatives to be of equal efficiency in the production of stand values.
### TABLE VI

**BASIC DATA FOR DETERMINING RELATIVE SPECIES WORTH FOR THE LODGEPOLE PINE - DOUGLAS-FIR EXAMPLE**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lodgepole Pine</th>
<th>Douglas-Fir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit of Harvest Windows</td>
<td>1</td>
<td>u</td>
</tr>
<tr>
<td>NPBs m³</td>
<td>25</td>
<td>16.7</td>
</tr>
<tr>
<td>Cost $</td>
<td>250</td>
<td>300</td>
</tr>
</tbody>
</table>

\[
\frac{P_1 \text{ NPBs} \times P}{C_p} = \frac{D_f \text{ NPBs} \times D}{C_d}
\]

where \( P_1 \text{ NPBs}, D_f \text{ NPBs} \) are the NPBs for pine, fir alternatives respectively

\( P, D \) are as prices as described

\( C_p, C_d \) are the treatment costs for pine, fir respectively

from which

\[
\frac{D}{P} = \frac{C_d \times P_1 \text{ NPBs}}{C_p \times D_f \text{ NPBs}}
\]

substituting the lowest limit harvest window values

\[
\frac{D}{P} = \frac{300 \times 25}{250 \times 21.4} = 1.4
\]

Similarly the ratio of \( D/P \) at the upper limit to the harvest window is 1.2

The interpretation of these ratios is straight-forward. At the lower limit to the harvest window the value of Douglas-fir must be more than 1.4 times that of lodgepole pine to make the fir alternative more cost-efficient than the pine. By the time the harvest window closes the minimum ratio is 1.2. The analyst must ask himself whether it is likely that premiums for species will be at this level at that point in the future? Is it likely that current premiums will continue unchanged, or increase, in the future?
6.6 An Extension to the CNPB: Other Resources

The economic objectives of resource management in British Columbia include increasing employment opportunities. (Province of B.C., 1978a). Intensive management programs provide employment opportunities in silviculture and stand tending. If the potential for creating short-term employment is part of the justification for undertaking social investments, the benefits of investment should include the employment created.

Other resources in addition to investment funds may limit the size of a program in a budget period. For example, there may only be a certain number of hours in a season that special machinery may be available to a management unit. Maximizing efficiency in the use of a resource is equivalent to husbanding it. The need to husband a resource should influence decisions about investments that employ it.

In principle, the CNPB indexes efficiency in the use of one resource, dollars, for the production of another, wood yield. Employment and limiting resources can be included in the CNPB by modifying the definitions of physical benefit and cost. The result, an extended CNPB ratio, can be used to aid in the choice between alternative investment opportunities.

6.6.1 Extended Benefits

It is proposed that the short-term employment benefit of an investment opportunity is the total number of man-hours/ha needed to accomplish the task. The contribution of supervisory, "non-productive" workers should be pro-rated.

The extended investment NPB is the product of the yield NPB and the short-term employment benefits. The units are $m^3 \cdot \text{man-hours/ha}$. Note that these are not commensurate with NPB's calculated without reference to
employment benefits.

6.6.2 Extended Costs

The limiting resource should be identified. For example, the availability of a mechanical crusher may be limiting in an investment program that includes many opportunities for juvenile spacing in lodgepole pine. The consumption of the limiting resource by an investment should be measured in appropriate units. For example, if the total availability of the mechanical crusher is expressed in operating hours per year, its use in individual investments is in hours per hectare. The total extended cost of investment is the product of investment cost and consumption of the limiting resource.

6.6.3 Selecting Preferred Alternatives

As with the CNPB ratio, the lower the extended CNPB the more efficient is an opportunity in the production of combined benefits, and in the use of combined resources. Therefore, when considering the treatment alternatives for an individual stand, the extended CNPB's are treated in exactly the same way as before. It is likely that different treatments will be preferred if other resources are allowed to influence the choices than if only yield and dollar costs are considered.

6.6.4 An Example Showing the Influence of Other Resources on a Decision

Consider the four investment alternatives for which the sawtimber CNPB are shown in Table IV. Recall that the preferred treatment is 3 on the basis of its CNPBs regret at year 65. Assume that employment benefits are part of the justification for investment and that a machine needed for all alternatives is in limited supply. The man-hours needed and the machine hours used for each alternative are shown in Table VII. The extended CNPBs are found by multiplying the CNPBs of Table IV by the ratio of limiting
resources to employment. The extended CNPBs are shown in Table VIII and have been plotted on a time axis in Figure 15. As before, treatment 1 is dominated by the other alternatives and can be rejected. The minimum

\[\text{TABLE VIII:}
\]

EXTENDED CNPBs FOR SAWTIMBER ALTERNATIVES

\begin{tabular}{|c|c|c|c|c|}
\hline
Treatment & 1 & 2 & 3 & 4 \\
\hline
Employment Man-Hours/ha & 5 & 8 & 10 & 7 \\
Limiting Resource Machine hours/ha & 2 & 1.5 & 4 & 3 \\
\hline
\end{tabular}

extended CNPB at the lower limit is that of treatment 2 at $0.90$-hrs./m$^3$-man-hrs., and at the upper limit is that of treatment 3 at $1.50$/hrs/m$^3$-man hrs. The regrets for the three non-dominated alternatives are shown in Table IX. The maximum regrets are 0.85 at 90 years for treatment 2, 1.60 at 65 years for treatment 3 and 1.25 at 65 years for treatment 4. The preferred treatment would thus be 2.
Consider a fixed budget of $100,000 and 1100 hours of machine use. Assume that the stand for which treatments 2 and 3 are investment alternatives is 500 hectares in extent and represents the only opportunity for investment. Assume the costs of treatment are $250 and $350/ha for treatments 2 and 3 respectively. Table X shows the total resource use of, and benefits from, employing one of the alternatives. A greater area can be treated and more employment created by favouring treatment 2.
### TABLE X

**COMPARISON OF TREATMENTS 2 AND 3 IN A FIXED BUDGET**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Machine Treated</th>
<th>Yield Benefits $m^3$ @ 65 yrs.</th>
<th>@ 90 yrs.</th>
<th>Total Man Hours</th>
<th>Total Machine Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>400</td>
<td>22,222</td>
<td>8,000</td>
<td>3,200</td>
<td>600</td>
</tr>
<tr>
<td>3</td>
<td>275*</td>
<td>15,400</td>
<td>25,667</td>
<td>2,750</td>
<td>1,100</td>
</tr>
</tbody>
</table>

* limited by machine availability: Budget is exhausted by an area of 286 ha.

It is not possible to say which treatment will provide the greatest contribution to system benefits since the situation changes through the harvest window. The average contribution of treatment 2 is 15,111 $m^3$ and that of treatment 3 is 20,533 $m^3$. The difference, 5,422 $m^3$, can be viewed as the "price" of creating the additional 450 man-hours of employment. The marginal yield cost of creating employment is minimized by choosing between alternatives on the basis of the extended CNPB.
7.0 ASSEMBLING THE ANNUAL ACTIVITY BUDGET

The approach to operational planning proposed here has been suggested by the assumed budgeting method for intensive management within the Ministry of Forests. Provincial budget appropriations are made on the basis of strategic analyses of the need and potentials for intensive management on a regional basis. It is assumed that these appropriations will actually be distributed to the regions. The intensive management budget for a region is therefore "fixed" from the point of view of implementing opportunities inventoried under the proposed investment distribution system. It is further assumed that the annual regional budget is lost if not used in the same budget period as it is appropriated.

The goal of planning social investments is to maximize the benefit obtained from the annual regional budget. It is assumed that the lack of an inventory of management opportunities is a serious obstacle to an efficient distribution of the available budget. The objective of the activity budget assembly phase is to identify the program of assessed opportunities which approaches one of maximum benefit.

In principle the most efficient program that can be assembled from the inventory at any time is that which contains the number of most efficient opportunities that exhausts the available budget. This can be obtained by ranking the opportunities by their relative efficiencies. If the inventory of opportunities is small compared with the need for investment the absolute efficiency of the resulting program may not be high. It is for this reason that the generation of alternatives is to be encouraged.

The inventory and assessment phases of the investment distribution system are ongoing activities. They will provide a list of opportunities
which increases in length over a period of time. Once in each budget period, sufficiently ahead of the beginning of the field season to permit operational planning, the investments to be funded must be chosen. To this end all the opportunities available at this time must be ranked by their relative efficiencies. In the proposed investment distribution system the criterion of efficiency is the cost per unit of net physical benefit. The CNPB ratios used to choose between stand treatments for a specific product goal are not suitable for this purpose.

The primary objective of social investment is to permit the short-term rate of harvest required by timber supply policy. Efficiency of investment with respect to this objective is indexed by merchantable volume CNPB ratios only. The rank of an opportunity within the annual activity budget must therefore be determined on this basis. The budget should be selected so that production of other stand components is maximized within the investment program when possible.

7.1 Ranking Opportunities by Merchantable Volume CNPB

The CNPB ratio used to select a stand treatment may be extended by considering other resources. These other resources may include employment in the denominator and limiting resources in the numerator of the ratio. If employment is used in this way it is an expression of policy in the same way as volume benefits are. All opportunities should, therefore, have been discussed on the basis of an employment---extended net physical benefit.

It is unlikely that the same resources limit the scope of all treatments. Not all opportunities will, therefore, have been assessed on the basis of extended investment costs. There is no policy to use limiting resources, only that, if used, they be husbanded. The consumption of
limiting resources should therefore not appear in the merchantable volume CNPB ratio used to rank an opportunity.

The most efficient treatment for a product goal is associated with a merchantable volume growth curve, as well as with the product component growth curve. There is, therefore, a CNPB of merchantable volume corresponding to the most efficient CNPB of product volume. Recall that net physical benefit of volume is the sum of the system and stand-level benefits. The system benefits of a product opportunity and its corresponding merchantable volume production are the same. The stand-level benefit of the latter is the difference in merchantable volume discounted from the limits of the harvest window between the stand when treated and when not treated.

If a stand is eligible to contribute sawtimber or veneer supply it is also eligible to contribute to the supply of merchantable volume. It is assumed that the most efficient treatments for each product would be different from each other. There are therefore at least two CNPB of merchantable volume ratios for each stand which is eligible for other product goals. It is necessary to dedicate a stand to only one product before assigning its rank for the budget.

7.1.1 Identifying the Most Suitable Product for a Stand

It is proposed that the relative values of product and merchantable volumes be used to guide stand dedication. The procedure is best illustrated by example. Figure 16 shows the volume growth curves corresponding to the most efficient sawtimber and merchantable volume treatments for a hypothetical stand. Both treatments provide volume in
the sawtimber component. The present worths of the harvest volumes and costs of treatment are shown in Table XI. The present worth of merchantable volume can be resolved into merchantable and sawtimber components. For the cost efficiency of the two treatments for dollar benefits to be equal

\[
\frac{(sBS \times Vs) + ((sBm-sBs) \times Vm)}{Cs} = \frac{(mBs \times Vs) + ((mBm-mBs) \times Vm)}{Cm}
\]

where  
- \( sBS \) = sawtimber treatment present worth of sawtimber volume  
- \( Vs \) = value of sawtimber $/m^3  
- \( sBm \) = sawtimber treatment present worth of merchantable volume
V_m = value of merchantable volume $/m^3

C_s = cost of sawtimber treatment

mBs, Vs, mBm, V_m, C_m are the equivalent values for the merchantable volume treatment. This relationship can be solved for the ratio Vs/V_m. In the example the ratio is 13 and 11.25 at the lower and upper limits of the harvest window respectively.

### TABLE XI

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Present Worth of Harvest Volume (m³/ha)</th>
<th>Costs of Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sawtimber Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Sawtimber</td>
<td>7.39</td>
<td>8.35</td>
</tr>
<tr>
<td>Merchantable Volume</td>
<td>4.77</td>
<td>5.57</td>
</tr>
</tbody>
</table>

The interpretation of the ratios is that the value of wood in stems larger than the minimum stand component dbh must be between 11 and 13 times greater than that in stems less than the minimum. It is proposed that a stand be dedicated to the production of the highest value product for which the cost efficiency of dollar benefits is not likely to be less than that of the most efficient merchantable volume treatment. If the relative value of a product necessary for equal cost efficiencies is much higher than can be expected the stand is not suited to the production of that product.
The actual values of the components of present worth of merchantable volume will depend on the average characteristics of the stems in each component. Some guidance about future relative values can be obtained by considering present relative values. Information of this type can be derived from the Harvest-Cost Zone Analysis (Chapter 4.0). Assume that the example given in this section is for lodgepole pine and that the minimum sawtimber component dbh is 21 cm. Assume that the minimum stand dbh at harvest is 25 cm. The distribution of stem numbers by dbh class for an average stand dbh has been tabulated for dense, natural stands of lodgepole pine in Alberta (Johnstone, 1976). At an average stand dbh of 25 cm the average diameter of stems larger than 21 cm is likely to be approximately 32 cm, while that of stems less than 21 cm but larger than 12 cm is likely to be about 18 cm. From Figure 13 the average stem volumes for these components would be $0.9 \, \text{m}^3$ and $0.15 \, \text{m}^3$ respectively. From Figure 5 the per unit value of the larger stems is $143/\text{m}^3$ and of the smaller is $105/\text{m}^3$. The current relative value of the sawtimber component is thus 1.36. It is not likely that in 70 to 90 years the relative value will have risen to that required to favour the sawtimber treatment in the example.

7.1.2 Ranking Dedicated Stands

Once stands have been dedicated to a product they can be represented by a single product investment opportunity. The opportunity is characterized by the CNPB of merchantable volume, extended by the employment created, if necessary, at the lower and upper limits of the harvest limits. The characteristic CNPB ratios of all opportunities are commensurable. However, the opportunities cannot yet be ranked. Firstly, the harvest
windows of the opportunities are not likely to all be coincident with the beginning of the time-frame for yield benefits. Coverage of the whole period of the time-frame is assumed to be a system benefit, but this does not imply automatic preference to opportunities that are operable early in the period. Secondly, there are two CNPB ratios for every opportunity which would provide inconsistent ranks if used separately.

It is proposed that the available opportunities be segregated by the decade in which yield benefits are first available. Thus, for example one group would contain all opportunities in which the stand becomes operable either before the beginning of, or up to 10 years, into the time-frame. The next group would contain these opportunities that are first operable from 11 to 20 years into the time-frame, and so on.

Within any group, ranks are based on the minimax regrets, assuming all opportunities start and end at the same points. As before, all dominated opportunities must first be eliminated. In this case there will be subgroups of dominated opportunities. Within a subgroup none of the opportunities will be dominated. Starting with the subgroups with the lowest generalized CNPBm ratios, the first rank is assigned to the opportunity with the minimax regret. The second rank is assigned to the second smallest maximum regret, and so on to the end of the first subgroup. Ranking continues in subsequent subgroups until all the opportunities have been ranked within a decadal group.

It is proposed to characterize each subgroup by the average CNPB of the opportunities within the subgroup. This ratio is then used to assign a rank to the subgroup as a whole. The first rank is assigned to the subgroup with the lowest average CNPBm of all subgroups for all decades. The
second rank is assigned to the subgroup with second lowest average CNPB and so on.

When the annual investment budget is to be distributed, the opportunities in the first ranked subgroup are selected for funding first. The funds are distributed in subgroup rank order. If this does not exhaust the investment funds the second ranked subgroup is selected. Funds are distributed in subgroup rank order, and so on until the funds are exhausted. Operational planning for the selected opportunities can then begin. Stands offering opportunities which are not taken up in this budget period are left on the books but must re-enter the system at the opportunity assessment phase. The opportunities a stand offers should be re-evaluated whenever silvicultural techniques, yield estimates, or supply goals change. As stands age the treatments for which they are suitable change, and the degree to which they will respond to a treatment also changes. Opportunities cannot therefore be held indefinitely. As inventory continues, opportunities will be displaced and the stands that provide them will no longer be suitable for treatment.

Among the selected opportunities will be those that use a limiting resource. A check must be made that total consumption of a specific limiting resource does not exceed the available supply. Care must be taken to observe the original circumstances under which the resource is limiting. For example, if the resource is distributed to a management unit then the opportunities within the unit that use the resource must be checked even though the Regional budget is not developed on this basis. If total consumption is greater than can be supported, enough opportunities must be dropped to balance consumption and supply. The opportunities with the highest CNPBm ratios should be dropped first. Compensating oppor-
tunities should be selected from the next ranked opportunities in the last subgroup funded or from the next ranked subgroup.
8.0 SUMMARY AND DISCUSSION

It is proposed that public policy requires a supply orientation for the management of the public forest estate. This orientation has to be expressed within the administrative environment that governs forest management. Several environments exist within British Columbia to reflect the degree to which industry accepts management responsibility. The Forest Service is the sole agency responsible for silvicultural investment, or intensive management, over a significant portion of the total estate.

Under a supply orientation, investments are undertaken to support supply goals. In the management environment provided by the Forest Service alone these goals may be interpreted in terms of the physical supply of wood fibre. In this environment the economics of forest investment are not central to decision-making in the planning and execution of investment programs. And yet, distributing investment among the available opportunities is essentially an economic problem.

There is likely to be a transition period during which the Forest Service will shift its philosophy from physical to economic wood supply. It is proposed that there is a class of investments, here called social investments, which must be undertaken before this transition is complete. The urgency for social investment springs from the short-term component of timber supply policy. The scope of these investments is quite limited and is defined by strategic timber supply analysis. The nature of this analysis prevents identification of the opportunities within the forest estate that must be exploited by social investment. It does, however,
provide information which can be used to characterize the type of opportunities that can contribute to short-term supply goals.

Interpretation of the information from strategic analysis in a form useful for silvicultural planning requires a system to integrate inventory, prescription and programme planning. The function of the system is to ensure the passage of objectives required by public policy through the planning chain to the type of stand treatments implemented. The objective of planning investment, in this context, is to obtain the maximum benefit from the investment.

The benefits of social investment need not be limited to their effect on short-term harvest rates. Longer term goals include those that would justify investments from an entrepreneurial viewpoint but which are difficult to express within the Forest Service environment. There is likely to be conflict between the short- and long-term goals of social investment. Since neither, alone, represents the public interest trade-offs among them are desirable.

A silvicultural distribution system has been proposed that interprets basic economic relationships from a physical yield orientation. It uses information from the timber supply analyses of the Forest Service to provide a time-frame within which the benefits of investment must be realized. It provides a description of the forest estate which defines areas in which suitable investment opportunities are likely to be found. It provides a means to choose among alternative treatments for a suitable stand. Finally, it provides a method to assemble an annual activity budget which contains those opportunities that can best contribute to short-term supply policy. This method has been designed to maximize, as far as possible, the entrepreneurial benefits of investment.
The system can be used at many levels of precision determined by the quality of the information it uses. The precision required depends on the degree to which stand prescriptions can distinguish among stand growth goals.

As a system the proposal offers a means to incorporate changes in the management environment into the decision-making process. The general approach is to adjust the relationship expressed by curves in the preparation of inventory zones. It would be better, however, to use the long-term trends to estimate future values for these relationships.

8.1 Using the System

Intensive management is a cooperative venture between industry and government. Even in that part of the forest estate for which the Forest Service is responsible for operational planning the active cooperation of industry is sought. The system can provide a means of communication between government and industry in this situation.

It is proposed that the system be implemented at the Resource Region level. That is, it is the Regional intensive management budget which is to be distributed through the system. Harvest cost zone analysis would also be accomplished with Regional input. Mapping of zones and the inventory of opportunities should, however, be Forest District responsibilities. This is to make best use of local knowledge. Assessment should be carried out by the person who made the prescriptions.

Control is exercised in the system by providing growth estimates and regional economic information. It is proposed that sufficient control can be exercised by this means to allow a great deal of freedom in the inventory, prescription and assessment phases of the system. Once the
rules for establishing zonal boundaries have been formulated these phases could be contracted out to industry. That is, industry will be able to determine, for itself, which opportunities are likely to be most suitable for investment.

It is proposed that the documentation for a proposed investment, whatever its source, should contain all the information needed to determine its rank in the budget distribution phase. If the opportunity is selected for funding, this document will become the contract for the operation. In particular, since the growth estimates will already have been approved, the cost of investment used to calculate the CNPBs will be the costs allowed, with the usual tolerance.

The approach inherent in the proposed system differs from that currently taken by the Forest Service. At the moment the relationship between silviculture and timber management does not receive the explicit attention it should. Existing guidelines for investment do not contain as much economic input as is required for rational distribution of resources. The new system provides a means to align timber management and silvicultural planning while rationalizing the way in which resources are distributed.

Regional development of the cost-zone boundaries should be undertaken as soon as possible to facilitate testing and implementation of the new system. When in use the system will improve the quality of investment decisions needed to increase both short- and long-term wood supplies in British Columbia.
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Benskin, Henry. 1980. Address to a fourth year class in the Faculty of Forestry, U.B.C. (Mr. Benskin is associated with the preparation of resource programs for the Ministry of Forests, Victoria).


Hall, T. 1979. Wood Supply and Forest Productivity Model WOSFOP. The card deck and documentation for this computer model were provided by Dr. Hall and adapted for U.B.C. computing facilities by staff in the Faculty of Forestry.


CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Definition of Treatments</td>
<td>3</td>
</tr>
<tr>
<td>Coast -</td>
<td></td>
</tr>
<tr>
<td>Stand Tending Priorities by Treatment</td>
<td>8</td>
</tr>
<tr>
<td>Criteria for Setting Priorities within Treatments</td>
<td>9</td>
</tr>
<tr>
<td>Southern Interior -</td>
<td></td>
</tr>
<tr>
<td>Stand Tending Priorities by Treatment</td>
<td>16</td>
</tr>
<tr>
<td>Criteria for Setting Priorities within Treatments</td>
<td>17</td>
</tr>
<tr>
<td>Northern Interior -</td>
<td></td>
</tr>
<tr>
<td>Stand Tending Priorities by Treatment</td>
<td>20</td>
</tr>
<tr>
<td>Criteria for Setting Priorities within Treatments</td>
<td>21</td>
</tr>
<tr>
<td>Protection Guidelines</td>
<td>26</td>
</tr>
<tr>
<td>Guidelines for Licensees</td>
<td>35</td>
</tr>
</tbody>
</table>
BACKGROUND

Silviculture staff from the six Forest Regions and Headquarters met in Victoria on January 31 and February 1, 1979 to develop a set of first approximation guidelines for establishing stand tending projects conducted under the intensive forestry program. For the purpose of guideline development, the province was divided into three broad regions: (i) Coast, being all of the Vancouver Forest Region and the coastal portion of the Prince Rupert Forest Region; (ii) Southern Interior, being all of the Nelson and Kamloops Forest Regions and the Interior Douglas-fir zone of the Cariboo Forest Region; (iii) Northern Interior, comprising the Prince George Forest Region, the interior portion of the Prince Rupert Forest Region and the rest of the Cariboo Forest Region.

After review of the first approximation guidelines, representatives from each of these three regions met again with Headquarters staff on May 14-15, 1979 to standardize guideline format as much as reasonably possible and to further review the included material.

INTRODUCTION

An analysis of market demands done for Planning Branch suggests markets could absorb an annual production of 35 million cunits from B.C. by the year 2000. This level of production could not be sustained without a major intensive forest management program. Projected demand, in conjunction with the established pattern of manufacture in the forest industry, suggests that we should aim our intensive forestry program to primarily produce sawlogs since pulpwood will always be available as a by-product of lumber production.
A rational intensive management program can not be developed until the provincial timber supply analysis has been completed, defining the wood supply situation by TSA and identifying needs, opportunities and alternatives for enhancing that wood supply. At present we must develop regional programs based mainly on best estimates and a fair amount of intuition. For these reasons, we should beware of large-scale ad hoc projects until we know with some certainty where our efforts are needed and what particular activities should be emphasized.

A comprehensive, carefully considered program is currently needed to gain experience and cost data across a range of forest types for many stand tending activities. This will provide us with a solid footing on which to build when the timber supply analysis has more closely defined the major program needed.

Given our current state of growth and yield knowledge we do not have the basis for critical cost-benefit evaluations of many types of treatments. All we can reasonably hope to do is to be as cost-effective as possible in carrying out stand tending projects.

These guidelines are intended to help in establishing priorities for treatments and in setting limits, both on stand or area selection and on costs. The guidelines are strictly interim in nature and substantial evolution or modification is to be expected.

Although we have developed guidelines for planting and juvenile spacing densities, we have not thought through the entire sequence of stand development to the end point of final harvest. Although the desired final stands at
rotation, target stands, can be expected to vary somewhat by species and according to local wood production objectives, all final stands can with certainty be expected to contain far fewer stems than years earlier at time of juvenile spacing. If we intend to capitalize on the early fast growth rates stimulated by juvenile spacing, possibly also accompanied by fertilization, and really shorten rotations substantially, then some additional reduction in stand density will be necessary between the time of juvenile spacing and final harvest.

Where markets for small wood exist, and where other factors such as access and topography are favourable, commercial thinning will be possible. Where there are no small wood markets, or where access and topography are limiting, we will have to waste-thin managed stands or face up to the prospect of stagnation, lengthened rotations and the wasting of earlier investments in stand tending projects.

**DEFINITION AND PURPOSE OF TREATMENTS**

1. **Juvenile Spacing**: the reduction in number of stems per hectare to control stocking, to prevent stagnation, to increase tree quality and thus end-product quality and value, to increase growth rates and provide for later interim harvests of useable wood, to reduce final harvest and milling costs and to reduce rotation length. Pre-commercial thinning and thinning-to-waste (waste thinning) are other terms included in this category. A project is currently classed as juvenile spacing when the majority of cut trees are not merchantable.

Methods used for spacing may be: (i) manual, using a wide range of tools including powersaws; (ii) manual, applying chemicals to individual
trees; (iii) mechanized crushing or slashing; and (iv) combinations of these methods.

2. **Brushing and Weeding**: the elimination or reduction of competition from brush and weeds to recently planted seedlings or natural regeneration to enhance survival and provide better nutrient, moisture and light conditions for early stages of growth. Brushing and weeding projects apply particularly to young stands which are in danger of being substantially lost to brush and weeds.

   Methods used include manual techniques using hand tools or chemicals and aerial spraying.

3. **Conifer Release**: to release established coniferous trees overtopped by shrubs or other undesirable trees. These projects are mainly for promoting growth, rather than survival, of overtopped conifers.

   Methods used include manual and chemical techniques, separately and in combination.

4. **Seed Tree Control**: to reduce or prevent the seeding of undesirable trees.

   Methods used involve treatment of individual trees either by powersaw, girdling or chemical application.

5. **Sanitation Spacing**: to improve the growth and health of young stands by removing overtopping pole-sized, or larger defective stems (usually remaining after selective logging) and by controlling the density, species composition and disease level of advanced growth or new regeneration through spacing.

   Methods used are similar to those for juvenile spacing.
Several situations come under this category. However, although undoubtedly a sanitation spacing measure by definition, mistletoe control warrants distinction as a separate category. The following treatments should be considered as belonging within sanitation spacing.

(a) Residual falling, where trees left unwanted after logging are felled because of poor form, poor genetic quality and minor disease infection. If, however, prevention of mistletoe spread is the major aim then check-off mistletoe control as the appropriate treatment category.

(b) Decadent stem falling in cedar-hemlock stands where no additional treatment other than the spacing of advanced regeneration is required. If the felling is followed by broadcast burning or other site preparation measure, then use a rehabilitation label, rather than sanitation, for the treatment.

(c) Quality slashing of I.U. spruce-balsam. This is a local term used in the north Kamloops region.

(d) Dry-belt Douglas-fir sanitation. If the treatment involves falling pole-size or larger residuals and understory spacing, use the sanitation label. If the area has already undergone salvage or normal logging and no large residuals remain, assign the project to juvenile spacing instead.

6. Mistletoe Control: to reduce or eliminate the spread of mistletoe, which causes volume and quality losses in conifers, by eliminating infected trees. In current logging situations, mistletoe control should be regarded as a basic forestry function, not as stand tending, and all infected trees should be felled during logging operations. There are, however, substantial backlog areas where young stands have been or are being infected with mistletoe due to infected trees having been left standing after logging.
7. **Rehabilitation**: to convert productive land occupied by undesirable stands or brush back to a condition appropriate for establishing desired conifer species. Rehabilitation projects differ from basic site preparation in that they normally include a combination of treatments (such as salvage logging, knockdown, bunching or windrowing slash, burning and planting) while site preparation is usually a single treatment, immediately after logging, that is necessary for basic crop re-establishment. Stump removal treatments to reduce or eliminate root-rot infection centres are classed under rehabilitation.

8. **Commercial Thinning**: to gain an interim harvest of merchantable trees, and fell any residual non-merchantable stems, in an immature stand so as to leave a pre-determined number of high-quality trees per hectare in order that volume and, more especially, value production will be increased when the remaining stand is eventually harvested.

Commercial thinnings should, by definition, yield a positive return over operating costs. There may be pressure in some areas to carry out thinnings with yield in stands that are submarginal commercially. Such partial subsidization will require a very clear definition of expected benefits to justify the investment.

9. **Fertilization**: to promote a rapid acceleration in growth on sites deficient in one or more soil nutrient elements, particularly nitrogen in the Pacific Northwest. Response to fertilizer is usually far greater when it is applied in conjunction with thinning rather than when used alone - a synergistic effect is often obtained. The use of fertilizer may be particularly advantageous to obtain a rapid and increased response in thinned
stands that have been under a heavy degree of competition and where live
crown mass is insufficient to provide a response without some extra stimu-
lation.

10. Pruning: to improve the market value of the final wood product by
removal of the lower branches of crop trees, producing clear, knotfree wood.
This practice should be limited to young stand on good sites where trees are
of such a size that the knotty core will be minimized to about 10 to 15 cm.
Stand Tending Priorities by Treatment

(a) High Priority

There are two broad priority categories, high and low, but within each of these categories there is no implied priority related to the order of treatment listing.

(i) Juvenile spacing
(ii) Brushing and weeding
(iii) Conifer release
(iv) Fertilization
(v) Commercial thinning
(vi) Rehabilitation

(b) Low Priority

(i) Mistletoe control
(ii) Seed tree control

In most cases, the best opportunities for return on money spent lie with the high priority treatments. Individual P.S.Y.U.'s, T.S.A.'s, or Ranger Districts will have differing priorities depending on species present, age classes, access, local timber supply and other forest uses. Local managers will have to select projects according to local opportunities but the distinctions between high and low priority treatments for each region must be borne in mind when developing a program - that is, the priority guidelines are there to be used.
With time, as objectives become more clear and more locally specific and suitable inventory and growth and yield data become available, priorities and stand selection criteria may be modified.

**Criteria for Setting Priorities within Treatment Categories**

When comparing alternative stands for most treatment categories, they are given priority rating numbers by factor. These numbers should be totalled and the stand with the highest total is assigned first priority and so on, for the remaining candidate stands. Other factors may be used subjectively to decide between two otherwise equal stands.

These factors need individual consideration, they cannot easily be broken down into priority categories. They are location, total size of area, size of blocks for contracts, commuting time, distance to manufacturing plant, protection aspects, and disease (root-rot and mistletoe).

1. **Juvenile Spacing**
   (a) **Stand selection**

   Candidate stands should be evaluated for preferred species selection according to the Tree Species Selection Guide or equivalent. If more than one acceptable species is present, preference should be given to the more valuable species.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>Low</th>
<th>1</th>
<th>0 (No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td></td>
<td></td>
<td></td>
<td>31+</td>
</tr>
<tr>
<td>Site Index (50 yrs, metres)</td>
<td></td>
<td>16-20</td>
<td>21-25</td>
<td>26-30</td>
</tr>
<tr>
<td>Stand Density/ha</td>
<td>2501-7500</td>
<td>32-35</td>
<td>27-31</td>
<td>21-26</td>
</tr>
<tr>
<td>Topography</td>
<td>1501-2500</td>
<td>Under 20%</td>
<td>Over 7500</td>
<td>751-1500</td>
</tr>
<tr>
<td>Access</td>
<td>2WD, Immediate</td>
<td>4WD, Immediate</td>
<td>4WD, Needs repair</td>
<td>Walk, under 1 km</td>
</tr>
<tr>
<td></td>
<td>2WD, Immediate</td>
<td>4WD, Immediate</td>
<td>4WD, Needs repair</td>
<td>Walk, over 1 km</td>
</tr>
</tbody>
</table>
(b) Selection of method for juvenile spacing

(i) Density.

Up to 15,000 stems/ha - manual, using power saw, shears, circular saw, pulling, chemical.

- machine, affected by tree size, terrain, ground cover, alright if there is no dominance expressed.

Over 15,000 stems/ha - machine, choice of machine affected by factors as above.

Over 30,000 stems/ha - consider alternative program such as crush, burn and replant.

(ii) Tree size.

Over 5 cm - power saw, hack and squirt, machine

Under 5 cm - pull, shears, girdle, circular (brush) saw.

(iii) Topography.

Machine - maximum slope approximately 20%.

Manual - maximum slope approximately 40%.

(iv) Ground cover. Machines are limited by slope, tree size, obstacles such as stumps, rocks and windfall.

(v) Protection. A protection plan is mandatory.

(vi) Stand structure. If more than one story is present then some other treatment is usually required.

2. Brushing and Weeding

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High → Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Brush closure</td>
<td>3 2 1</td>
</tr>
<tr>
<td>Seedling quality</td>
<td>Healthy, Uniform</td>
</tr>
<tr>
<td>Stocking</td>
<td>80-100%, 50-80%, Under 50%</td>
</tr>
<tr>
<td></td>
<td>Healthy, Questionable, Poor</td>
</tr>
<tr>
<td></td>
<td>Uniform, Patchy, Scattered</td>
</tr>
</tbody>
</table>
Access, site index and topography are rated as for juvenile spacing. Candidate plantations or single species natural stands should be ranked according to the Tree Species Selection Guide or equivalent. Mixed natural stands should be ranked according to the major species present. If more than one acceptable species is present, preference should be given to the more valuable species.

Several other aspects should be noted. A stocking survey is required before treatment approval will be given. All brushed-in stands that are adequately stocked (750-1000 stems/ha) should be treated. Where stocking falls short of these levels, weeding projects will only be considered where fill-planting in unstocked patches follows as soon as possible. Mechanical site preparation should be considered where fill-planting is required in unstocked brushy patches.

Chemical, manual and mechanical methods may be used. Chemical treatments should be used where possible for cost-effectiveness. Forest managers must be prepared to treat areas more than once if necessary.

3. Conifer Release

Candidate stands should be ranked for preferred species according to the Tree Species Selection Guide or equivalent.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Canopy closure</td>
<td>80-100%</td>
<td>50-80%</td>
<td>Under 50%</td>
</tr>
<tr>
<td>Understory quality</td>
<td>Healthy</td>
<td>Questionable</td>
<td>Poor</td>
</tr>
<tr>
<td>Stocking</td>
<td>Uniform</td>
<td>Patchy</td>
<td>Scattered</td>
</tr>
<tr>
<td>Topography</td>
<td>Under 20%</td>
<td>20-40%</td>
<td>Over 40%</td>
</tr>
<tr>
<td>Years to self-release</td>
<td>Over 10</td>
<td>5-10</td>
<td>Under 5</td>
</tr>
</tbody>
</table>
A stocking survey is required before treatment approval will be given. Candidate stands should have a minimum stocking level of 750 stems per hectare. In areas of Sitka spruce weevil infestation, when treating stands of Sitka spruce, 50% overstory cover should be left after treatment to prevent weevil infestation.

Chemical, manual and mechanical methods may be used with chemical often being most cost-effective.

Conifer release projects may be combined with other stand tending activities in some cases, such as juvenile spacing. It is also an acceptable follow-up treatment to underplanting.

### 4. Fertilization

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Ranking, High</th>
<th>→ Low</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>and type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercial thinning</td>
<td>Juvenile spacing</td>
<td>Juvenile spacing (under 20 yrs)</td>
</tr>
<tr>
<td>i) Nutrients</td>
<td>Poor (B)</td>
<td>Medium (C)</td>
<td>Rich (D)</td>
</tr>
<tr>
<td></td>
<td>Rapidly (2) and well (3) drained</td>
<td>Moderately well (4) drained</td>
<td>Imperfectly (5) and poorly (6) drained</td>
</tr>
<tr>
<td></td>
<td>Helicopter (1200+ kg payload)</td>
<td>Fixed-wing aircraft</td>
<td>Manual</td>
</tr>
<tr>
<td></td>
<td>Mid September to snow fall.</td>
<td>Spring after snow melt, before growing season.</td>
<td>Wet snow up to 15 cm over unfrozen ground slopes under 30%</td>
</tr>
<tr>
<td>ii) Moisture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor (B)</td>
<td>Medium (C)</td>
<td>Rich (D)</td>
</tr>
<tr>
<td></td>
<td>Rapidly (2) and well (3) drained</td>
<td>Moderately well (4) drained</td>
<td>Imperfectly (5) and poorly (6) drained</td>
</tr>
<tr>
<td></td>
<td>Helicopter (1200+ kg payload)</td>
<td>Fixed-wing aircraft</td>
<td>Manual</td>
</tr>
<tr>
<td></td>
<td>Mid September to snow fall.</td>
<td>Spring after snow melt, before growing season.</td>
<td>Wet snow up to 15 cm over unfrozen ground slopes under 30%</td>
</tr>
</tbody>
</table>

The bracketed letters and numbers associated with soil nutrient and moisture factors are from the Tree Species Selection Guide. Soils with nutrient levels of very poor (A) and very rich (E) should be rejected. Soils with moisture levels of excessively (0), very rapidly (1) and very poorly (7) drained should be rejected.
Fertilizer applications should not be made during summer because of urea volatilization or on snow deeper than 15 cm, especially on steep slopes or over frozen ground because of losses in run-off.

Because of the limited knowledge on response to fertilization, treatments should be directed to Douglas-fir-and Sitka spruce forest types. Applications should be made as soon as possible after commercial thinning or juvenile spacing.

When considering candidate stands, helicopter or aircraft ferry time between stands and landing sites must be weighed in relation to the cost of application. Long ferry distances rapidly reduce the economic accessibility of stands.

Until further research data suggests otherwise, nitrogen fertilizer as urea (46-0-0) should be used at the application rate of 200 kg nitrogen per hectare. Monitoring for uniformity of application should be carried out.

To simplify flying patterns and improve uniformity of application, areas to be treated should be laid out in rectangular or square blocks if possible.

Fertilizer applications should be repeated at 5 to 7 year intervals if maximum growth rates are to be sustained.

Because of the far more rapid breakdown of thinning slash after fertilization, this treatment substantially accelerates the reduction of fire hazard.
5. Commercial Thinning

Commercial thinning will be evaluated on an individual project basis. In the Vancouver Forest Region, first priority will be given to Douglas-fir types, second priority to hemlock types.

No commercial thinning operation will be considered unless the end result is silviculturally beneficial to the stand, providing for high volume and value yields at rotation.

The minimum economic standard for commercial thinning is that there should be an average of 100 m³/ha of merchantable wood available for extraction over a thinning area. There is no arbitrary upper limit on volume that can be extracted. As long as 200 to 250 well-formed dominant Douglas-fir can be selected to remain per hectare, or 250 to 300 similar hemlock, any surplus merchantable volume may be removed. The important point is to ensure that volume and value expectations are realized by leaving the appropriate target number of trees for rotation.

Operations should be timed to exclude most of the growing season to avoid excessive and unnecessary bark damage to leave trees. In general, operations can take place in hemlock stands from mid-September to mid-April and in Douglas-fir stands from mid-August to mid-April, although local discretion should be used. Stumps of cut trees should be treated immediately with an acceptable fungicidal agent to prevent infection by root-rot spores (*Fomes annosus*).

6. Rehabilitation

Rehabilitation treatments will require individual project justifi-
cation. Projects will be considered in alder and non-commercial brush on good and medium sites only due to relatively high treatment costs.

Both chemical and mechanical treatment methods are acceptable, although girdling will not normally be considered.

Treatments must be closely co-ordinated with sowing requests to ensure the provision of proper stock types. Forest managers should be prepared to follow up rehabilitation projects with a brushing program to ensure seedling survival and growth.

In *Phellinus weirii* areas, special treatment will be necessary for control of the root-rot when establishing new stands. Where a susceptible species is to be re-established, the stumps of susceptible species in the previous stand must be removed.

7. **Mistletoe control**

This treatment will be considered and justified on an individual project basis in residual backlog areas. Treatment will be mechanical and should be carried out only in areas where hemlock is the preferred species.

8. **Seed tree control**

This treatment also will be considered on an individual project basis and only where such control is clearly beneficial. Alder is the only species to be treated, either by chemical or manual techniques.
There are two broad priority categories, high and low, but within each of these categories there is no implied priority related to the order of treatment listing.

(a) High Priority

(i) Juvenile spacing - emphasis should be on lodgepole pine and other intolerant species such as Douglas-fir and larch.

(ii) Rehabilitation - chiefly in decadent hemlock stands.

(iii) Sanitation spacing - old I.U. timber sale areas.

(iv) Brushing and weeding - plantations in wet-belt areas, subject to rapid and heavy brush growth.

(v) Mistletoe control.

(b) Low Priority

(i) Conifer release - e.g. plantation with deciduous overstory.

(ii) Seed tree control - to reduce the spread of unwanted deciduous trees.

(iii) Commercial thinning.

(iv) Fertilization - to be undertaken only as trials, not operationally.

(v) Pruning.

In most cases, the best opportunities for return on money spent lie with the high priority treatments. Individual P.S.Y.U.'s, T.S.A.'s or Ranger Districts will have differing priorities depending on species present, age classes, access, local timber supply and other forest uses. Local managers will have to select projects according to local opportunities
but the distinctions between high and low priority treatments for each region must be borne in mind when developing a program - that is, the priority guidelines are there to be used.

With time, as objectives become more clear and more locally specific and suitable inventory and growth and yield data become available, priorities and stand selection criteria may be modified.

Criteria for Setting Priorities within Treatment Categories

Having separated treatments into high and low priority groups, it is expected that few, if any, projects in the low priority category will be carried out in the early years of the intensive forestry program. Any that may be selected because of unique local conditions should be critically examined and justified on an individual project basis.

For high priority treatments, guidelines have been developed to assist in ranking candidate stands or areas so that funds available might be spent to best advantage. Key factors in stand selection have been listed, with relative priorities assigned to graduations within the factors.

When comparing alternative stands for most treatment categories they are given priority rating numbers by factor. These numbers should be totalled and the stand with the highest total is assigned first priority and so on, for the remaining candidate stands. Other factors may be used subjectively to decide between two otherwise equal stands. These factors need individual consideration, they cannot easily be broken down into priority categories. They are location, total size of area, size of blocks for contracts, commuting time, distance to manufacturing plant, protection aspects, and disease (root-rot and mistletoe).
1. **Juvenile spacing (P1, F, S and L types)**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>50%-70%</th>
<th>20-30</th>
<th>8,000-12,000</th>
<th>Medium</th>
<th>Minor repairs</th>
<th>Slightly expressed</th>
<th>Moderate</th>
<th>Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent live crown</td>
<td>70% +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, (years)</td>
<td>10-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stand density/ha</td>
<td>6,000-8,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Class</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>Immediate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of area</td>
<td>Over 50 ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominance</td>
<td>None expressed</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damaging agents</td>
<td>None-light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground cover</td>
<td>Bare-light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Rehabilitation of Decadent Stands**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>Nil</th>
<th>Light</th>
<th>Medium</th>
<th>Poor</th>
<th>New access needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-merchantable volume</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Class</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>Immediate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of area</td>
<td>Over 100 ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting stock available</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of machine movement</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Sanitation Spacing**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>Medium</th>
<th>Poor</th>
<th>New access needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Class</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>Immediate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of area</td>
<td>Over 50 ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overstory</td>
<td>Heavy defective tree stocking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young stand - as for Juvenile Spacing</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Whatever the species composition, this treatment applies where two stand components are found: (i) a vigorous young crop in need of spacing; (ii) defective residuals from previous logging.
4. **Brushing and Weeding**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>Priority Rating, Medium</th>
<th>Priority Rating, Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent brush closure</td>
<td>80-100%</td>
<td>50-80%</td>
<td>Under 50%</td>
</tr>
<tr>
<td>Good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seedling quality</td>
<td>Under 10 cm</td>
<td>10-25 cm</td>
<td>Over 25 cm</td>
</tr>
<tr>
<td>Under 10 cm</td>
<td>Fair</td>
<td>Patchy</td>
<td>Scattered</td>
</tr>
<tr>
<td>Seedling leader growth</td>
<td>Uniform</td>
<td>Minor repairs</td>
<td>New access needed</td>
</tr>
<tr>
<td>Under 10 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stocking</td>
<td>Immediate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. **Mistletoe Control**

This treatment cannot be separated into priority categories as readily as other treatments. Appropriate action will depend on:

(i) silvicultural characteristics of host species, e.g. can fire be a useful treatment as in larch, ponderosa pine or old-growth Douglas-fir;

(ii) site, tree growth on high sites can outstrip the growth of the parasite;

(iii) degree of infestation on overstory and on regeneration;

(iv) size of the stand and extent of infestation.
Stand Tending Priorities by Treatment

There are two broad priority categories, high and low, but within each of these categories there is no implied priority related to the order of treatment listing.

(a) High Priority

(i) Juvenile spacing - emphasis should be on lodgepole pine, Douglas-fir and spruce.

(ii) Sanitation spacing - spruce and balsam types in old IU logging areas, mostly on good site.

(iii) Brushing and weeding - spruce plantations.

(iv) Rehabilitation - spruce, balsam, lodgepole pine and wet-belt cedar/hemlock types.

(b) Low Priority

(i) Conifer release - deciduous types with substantial spruce and Douglas-fir components.

(ii) Fertilization - low operational priority, high research priority.

(iii) Commercial thinning - wet belt Douglas-fir, operational trials.

(iv) Seed tree control - to reduce the spread of undesirable deciduous species.

(v) Pruning.

(vi) Mistletoe control - lodgepole pine.

In most cases, the best opportunities for return on money spent lie with the high priority treatments. Individual P.S.Y.U.'s, T.S.A.'s, or
Ranger Districts will have differing priorities depending on species present, age classes, access, local timber supply and other forest uses. Local managers will have to select projects according to local opportunities but the distinctions between high and low priority treatments for each region must be borne in mind when developing a program— that is, the priority guidelines are there to be used.

With time, as objectives become more clear and more locally specific and suitable inventory and growth and yield data become available, priorities and stand selection criteria may be modified.

**Criteria for Setting Priorities within Treatment Categories**

The table following is an amalgamation of all the factors to be considered for every treatment category. When using it to determine relative priorities between stands in the same category, e.g. juvenile spacing, use only those factors that are relevant and disregard those that are irrelevant.

When comparing alternative stands, they are given priority rating numbers by factor. These numbers should be totalled and the stand with the highest total given first priority, and so on for the rest of the candidate stands. Unrated factors below the table may be used subjectively to decide between two otherwise equal stands.
<table>
<thead>
<tr>
<th>Factor</th>
<th>Priority Rating, High</th>
<th>Priority Rating, Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Pl 10-15,000</td>
<td>15,000-20,000</td>
</tr>
<tr>
<td></td>
<td>All others -</td>
<td>2,000</td>
</tr>
<tr>
<td>Stocking</td>
<td>Homogeneous</td>
<td>Scattered</td>
</tr>
<tr>
<td>Site</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Age *</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Crop Quality **</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Access</td>
<td>Immediate</td>
<td>New Access Needed</td>
</tr>
<tr>
<td>Distance ***</td>
<td>Under 50 km</td>
<td>100 km +</td>
</tr>
<tr>
<td>Machine Trafficability/</td>
<td>Flat to easy</td>
<td>Steep slopes</td>
</tr>
<tr>
<td>Topography</td>
<td>rolling 0%-20%</td>
<td>Over 40%</td>
</tr>
<tr>
<td>Slash Profile</td>
<td>Light slash</td>
<td>Heavy slash</td>
</tr>
<tr>
<td>Size of Area</td>
<td>Over 100 ha</td>
<td>25-50 ha</td>
</tr>
<tr>
<td>% Live Crown</td>
<td>Over 70%</td>
<td>40-55%</td>
</tr>
<tr>
<td>Preferred Species Ratio</td>
<td>Over 50%</td>
<td>Under 20%</td>
</tr>
<tr>
<td>(restricted to San. Spacing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciduous Canopy Closure</td>
<td>80-100%</td>
<td>Under 50%</td>
</tr>
<tr>
<td>(restricted to B&amp;W, Con. Rel.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Age criteria will be higher for species suppressed in the understory

Crop quality includes vigour, defective stems, presence of damaging agents (disease, insects, wildlife)

Distance includes both commuting distance for project crews and distance to manufacturing centre for harvested products. If these distances are different, i.e. the crews base and the mill are in different towns, then use this factor twice - for each separate distance included.

Some other factors need individual consideration, they cannot easily be broken down into priority categories. These include location, size of blocks for contracts as opposed to total treatable area, commuting time and protection aspects. These factors can be used to decide between two or more apparently equal stands. For example, with location, distances may be equal but one stand may be at low elevation, another high or roads to one stand may be good, to another very rough.
Justification for treatment

1. **Juvenile Spacing**

**Lodgepole Pine Types:** - this species exhibits the worst overstocking problem;
- responds very rapidly in growth, particularly in early years (up to age 30), to juvenile spacing;
- it is the second major commercial species in the northern interior;
- many extensive stands exist that are accessible and in close proximity to manufacturing centres;
- sites occupied by this type have high potential for easy treatment and future mechanized logging.

**Dry Belt Fir:** - grows as a suppressed overstocked understory;
- terrain conducive to easy, inexpensive access and mechanized logging;
- located close to manufacturing centres;
- high wood value - preferred species;
- requires spacing for eventual understory regeneration to perpetuate the stand;
- capable of good response upon release.

**Spruce Types:** - utilizing an established crop of a preferred species;
- early plantations may be overstocked by natural regeneration occurring amongst planted trees;
- responds to treatment over wide age range;

2. **Sanitation Spacing**

**Spruce - Balsam and Balsam - Spruce Types:** - extensive areas of old I.U. logging virtually all on good sites with remaining stems
exhibiting a poor rate and quality of wood production;
- spruce is a preferred commercial species;
- considerable volumes already exist that can be effectively enhanced through crop tree selection and density control;
- readily accessible and close to utilization centres;
- responds to treatment over wide age range.

3. Brushing and Weeding

**Spruce Plantations:** - many productive sites display severe brush competition;
- need to protect initial investment of planting;
- relatively accessible.

4. Rehabilitation

**Spruce, Balsam, Lodgepole Pine, Wet-Belt Types (Cedar, Hemlock):**
- extensive areas supporting little or no merchantable volumes are occupying sites with some of the highest growth potential;
- no alternate treatments possible both biologically as well as cost-effectively.

5. Conifer Release

**Deciduous Types with Spruce and Douglas-fir:** - considerable areas of spruce and Douglas-fir under deciduous species;
- existing volumes have potential to be increased;
- cost-effective aerial application of herbicides is possible;
- species are preferred commercial species;
- lower priority due to location and lack of expertise for operational work.

6. Mistletoe Control

**Lodgepole Pine:** - most severe infestations are on poor and low sites, hence lower priority;
marginal gains expected in wood volume and quality;
- control should be a contractual or basic forest management function;
- control difficult to maintain within project boundaries due to surrounding infestations.

7. Fertilization

**Lodgepole pine, Douglas-fir, Spruce**: 
- insufficient quantities of spaced stand media available to operationally fertilize;
- due to shorter growing season, a less response to fertilizer expected than on the Coast;
- no data exists on nutrient requirements for the area.

8. Commercial Thinning, Pruning, Seed Tree Control:

These remaining treatments are grouped at a low priority rating and will be considered only in the future on an operational trial basis. Such treatments require further collection of expertise and data before being promoted on a wide-scale basis. However, this is not to pre-suppose that these treatment types are to be completely ignored. As intensive forest management practices broaden, proposals will be welcomed and given favourable consideration.
PROTECTION GUIDELINES

Protection considerations are inherent in the planning and carrying out of stand tending projects, especially those, such as juvenile spacing, that may produce a substantial amount of slash. Projects resulting in such slash production should have an individual protection plan.

The ability to protect investments in stand tending must be of concern in selecting areas for treatment. Particular attention should be paid to the fire climate of each candidate area. Some general principles can be readily applied, with local modification to suit conditions, that will reduce fire hazard and risk without incurring major costs. Where local protection measures are required of a contractor that will put the basic contract price over the maximum level, the protection cost will have to be justified to the Regional Manager.

Spacing Slash as a Fire Hazard

The amount of slash fuel produced by juvenile spacing with power saws and the duration of increased fire hazard depends on a number of factors. Species differences can be quite pronounced. Some examples follow:

- **Douglas-fir** - produces an extremely hazardous thinning slash which retains extremely flammable cured foliage on the branches for one or two fire seasons, depending on time of year of spacing. Also fir has a branching habit which resists compaction from winter snow, tending to keep an elevated fuel bed for longer than some other species. Fine twigs remain on the slash for longer than most other species, resulting in less reduction in fire hazard after needle drop than in other species.
Fir stands of average Dbh greater than 10 cm and stand height greater than 10 m can be expected to produce a thinning slash of extreme fire hazard until needle drop occurs, which should happen after one winter in spring spacing or two winters in fall spacing.

If more than 2000 stems per hectare are cut in these larger size stands, fuel beds will be deep and continuous, fire spread rates and intensities such that fires will be uncontrollable while in slash.

Hazard would be rated high in such fir stands during the second and third year, once needle drop has occurred. Fine fuels and medium slash begins to break down significantly during the fourth and fifth years, and hazard could be considered moderate. During the sixth year, slash break-down should have proceeded to the point where the hazard will have been abated.

Smaller sized fir stands of less than 7 cm average Dbh and less than 7 m in height produce light slash loadings. Such slash presents a shallow fuel bed, generally with discontinuities in slash coverage.

Hazard would be rated high in such stands until needle drop. By the second year hazard should have dropped to moderate, and should be effectively abated after three years.

Western red cedar is perhaps the next most hazardous species for spacing slash. Its foliage remains on the branches for a year longer than fir and even when detached from the branches, the foliage tends to form highly flammable suspended fuel mats up off the ground where they dry quickly and carry fire rapidly.
A significant cedar component (20% of the basal area or more) would add one hazard class to the descriptions for fir.

Lodgepole pine - forms an extreme hazard slash when large size stands are spaced (tree size greater than 10 cm Dbh and 10 m height), and as with cedar, the lodgepole retains foliage for two to three years. However, the branching habit of lodgepole is such that the fuel complexes settle very rapidly after the first winter snow, speeding up slash decomposition.

Slash from large size trees will remain an extreme hazard until needle drop occurs. By the third year such fuels would be rated high, moderate in the fourth year and abated after five years.

Smaller lodgepole stands (less than 7 cm Dbh and 7 m high) will form shallow but continuous fuel beds if more than 10,000 stems per hectare are cut. Such slash is an extreme hazard until needle drop but should become moderate by the third year and abated after four years. If slash breakdown is hindered by elevation of the slash bed due to old remnant dead and down fuels, as will be the case on many lodgepole spacing operations, hazard abatement will be somewhat slower and snow will be less effective in quickly compacting the fuel bed.

Smaller lodgepole stands where density is such that less than 5000 sph are cut should result in discontinuous slash which should satisfactorily abate after 3 years.

Western hemlock - loses its foliage so quickly (after one winter or one fire season whichever comes first) that it is not usually a major spacing slash problem. Fine hemlock twigs drop quickly, usually after two years
and checking of bark, branch and bolewood also occurs within two years so that hemlock spacing slash should be only a moderate hazard during the second year and abated after three years.

Western larch - needle fall is rapid, fine twig detachment and disintegration into small fragments occurs after one or at the most two winters so that larch is one of the lowest hazard-producing species. As with hemlock, larch slash should be a moderate hazard by the second year and abated after three years.

In mixtures with fir, larch tends to break up the fuel continuity and generally reduce the hazard rating produced by pure fir.

Fertilization - should generally improve the speed and degree of hazard abatement, both from the point of view of increasing rate of crown closure after spacing and in terms of its causing increased vegetation growth in the area of the slash bed, thereby creating a more favourable micro-climate for slash deterioration and assisting in creation of slash fuel discontinuities.

Directional Falling

A general specification in juvenile spacing operations should be consideration of directional falling, particularly in such species as fir and lodgepole where longer needle retention adds more time to the extreme hazard period. Directional falling is especially effective in getting the maximum possible benefits from snow compaction of the fuel bed to speed up slash decomposition. Even where a substantial dead and down fuel bed exists on the area prior to spacing, directional falling will minimize slash height, maximize rate of slash deterioration and make traversing the area by wildlife and domestic stock much easier. Trampling of spacing slash by wildlife
and cattle is a very effective aid in speeding up natural reduction of hazard without resorting to other expensive mechanical means.

### Block Layout Considerations

#### Block Size

Restrictions on block size may be necessary in areas of high lightning risk so as to avoid very large areas of continuous high or extreme hazard fuels. Treatment blocks should not exceed 100 ha without adequate separation of blocks by adjacent areas of untreated stands or abated slash in areas of high lightning fire occurrence. If larger stands are being treated, then 50 ha would be a better maximum block size for high lightning zones.

#### Staggering of Blocks

Area layout should take into account the duration of high hazard discussed under species, to ensure that adequate time for natural hazard abatement is allowed before an adjacent block is treated. Such staggering of blocks to avoid large continuous areas of high and extreme hazard fuels should be done wherever significant man-caused or lightning fire risk exists. Topographic breaks and fuel type changes, e.g. deciduous stands, swamps etc. should be utilized for their protection value as fuel breaks in block layout.

#### Buffer strips

Leave strips as buffers along public roads and public use areas such as recreation sites are very important prevention measures which can be taken with little cost.
Several approaches to buffer strips as fuel breaks are possible. They can be simply untreated strips of the stand being spaced. They can be spaced but with the slash pulled out and disposed of, usually by roadside burning in the safe season. They can be strips spaced with the slash pulled back into the spaced area and piled or windrowed. They can be clear-cut strips left to natural vegetation growth patterns or with low hazard vegetation seeded or planted or with semi-permanent fire retardant applied along the roadside.

Of these many options, probably the best buffer strip along public travelled roads through juvenile spacing areas is an untreated strip of the stand being spaced. The width of this strip must be adequate to modify the microclimate beneath the stand so as to lower the ease of ignition, rate of spread and difficulty of control opposed to the treated area. In some types, such buffer strips may need no treatment at all or perhaps pruning of dead branches from tree boles to a height of 2.5 m to remove vertical fuel continuity. Keeping unspaced buffers will tend to hinder vegetation growth under the stand, eliminating as much fire-carrying fuel as possible.

A closed canopy buffer strip of unspaced young timber should be of sufficient width to suit the man-caused risk pattern along the roads through the area, and the detection and initial attack response time and capability. The buffer strip should give lead time on any fire occurring along roads before it spreads into spacing slash fuel. This makes guidelines on necessary widths difficult to prescribe because each development area will have different protection capability. Minimum effective widths are easier to define. A 5 m strip is clearly not much more than a cosmetic feature
to screen spacing slash from public view. Such a strip does not provide effective shade for maintaining a cooler moisture micro-climate than in the slash. A minimum buffer width for any significant protection benefit is 15 m where slope is less than 35% and 30 m for steeper slopes. No falling of trees into buffer strips can be tolerated.

An exception could be made for small size stands (less than 7 m height) where the best compromise in a buffer strip may be a 10 m strip spaced and the slash pulled out to the road and disposed of. Slash disposal is preferable to slash being pulled into the spaced block and piled or windrowed. This practice creates large fuel concentrations and impedes access by cattle and wildlife which have a beneficial effect on fuel hazard reduction through their trampling action during grazing and browsing. This is another case of interrelationships being considered between silvicultural goals, protection of the investment, cost of the treatment and impact on other resources.

**Other Fire Protection Measures**

**Public Information:** on-site signs explaining the stand tending treatment, cautioning about fire hazard and advising that special campfire and access restrictions may be applied.

**Campfire restrictions, access restrictions:** in stand tending areas where a long period of high and extreme fire danger combines with high public use or travel and/or high lightning fire risk, then special restriction formulae for campfire bans, public travel and use and industrial operation restrictions may have to be developed.
Such restriction formulae should be based on weather and fuel flammability factors related to ease of ignition, rate of spread, and difficulty of control of fires starting in or spreading into slash fuels typical of the bulk of juvenile spacing being carried out in the area. Special ratings are needed for large areas of spacing slash because, not only does this fuel represent more hazardous conditions than accounted for by normal Fire Danger Rating classes, but spacing slash, tending to be continuous and un-compacted during the years up to needle drop, even results in guidelines for clearcut logging slash under-estimating the ease of ignition and Rate of Spread.

Detection

A stand tending development area will probably need more fixed-point and mobile patrol detection and possible adjustments in aerial patrol routes and scheduling. Such detection measures must be taken to minimize fire reporting time primarily to keep man-caused fires out of spacing slash where they will quickly become uncontrollable and also to ensure the quickest possible attack on lightning strikes in these most highly flammable and rapid-drying fuels that occur in the province.

Initial Attack

The need for rapid initial attack capability for extensive areas of red needle spacing slash is evidenced by the potential spread rates of such fuels. Spacing in larger stands creates a red-needle slash which will spread at a rate of 25 m/min where the Initial Spread Index of the Canadian Fire Weather Index is 15 or higher. Such burning conditions, which occur for significant portions of the fire season in most of our areas except the
coast and, to the lesser extent, the interior wet belt, produce fires of such tremendous free burning growth potential (135 ha after 1 hour) that the importance of immediate detection, reporting and quick initial attack capability is obvious.

Fuel Management Considerations in Juvenile Spacing Contracts

Lopping to a particular height specification is difficult to administer and in many spacing operations in larger stands and in stands having a significant dead and down fuel loading, lopping may be too expensive and will not achieve significant protection benefits.

Directional falling can be more effective at no additional cost and should be considered in most conditions due to its benefits both in speeding up hazard abatement and easing access by both animals and later by men and either thinning or harvesting equipment.

On blocks where high old stumps are prevalent, providing high points for jack-potting of fuels, in addition to directional falling, avoidance of falling trees over such stumps should be specified as a protection measure.

Creation of a mosaic of treatments in an extensive even-aged stand resulting from an old burn can have beneficial protection advantages as well as silvicultural age class distribution advantage. Clearcutting or machine clearing blocks or strips through or across juvenile spacing developments, burning the clearcuts if necessary and planting a new stand can have important advantages in breaking up the fuel mosaic into different hazard classes as well as different age classes.
GUIDELINES FOR LICENSEES

Stand tending projects will be carried out by licensees under credit to stumpage procedures. Licensees thereby become contractors to the Crown and subject to appropriate regulations and constraints. Inherent in this are the following considerations.

1) The licensee will submit a plan for his proposed activities to the Regional Manager for approval for budget and technical purposes.

2) The cost of the proposed projects may not exceed the expected revenue from that licensee.

3) Guidelines for Forest Service projects will apply to licensees. This applies particularly to costs which should be clearly indicated in proposals.

4) Licensee projects will be subject to Forest Service inspection.

5) The licensee must use the same final reporting forms for all projects as are used by the Forest Service.

6) Monitoring by the Forest Service should be mainly concerned with technical aspects of the work. The financial statements will be subject to audit.

7) The licensees' projects should be tied in with their own working plans so that treatments will be sequential with their over-all operations.

Stand tending projects are not necessarily a basic right or responsibility for licensees. Proposed projects must be compatible with needs identified by the timber supply analysis program. Any licensees' basic silviculture program must be completely up to date and up to required standards before any stand tending projects will be considered for approval under the intensive forestry program.