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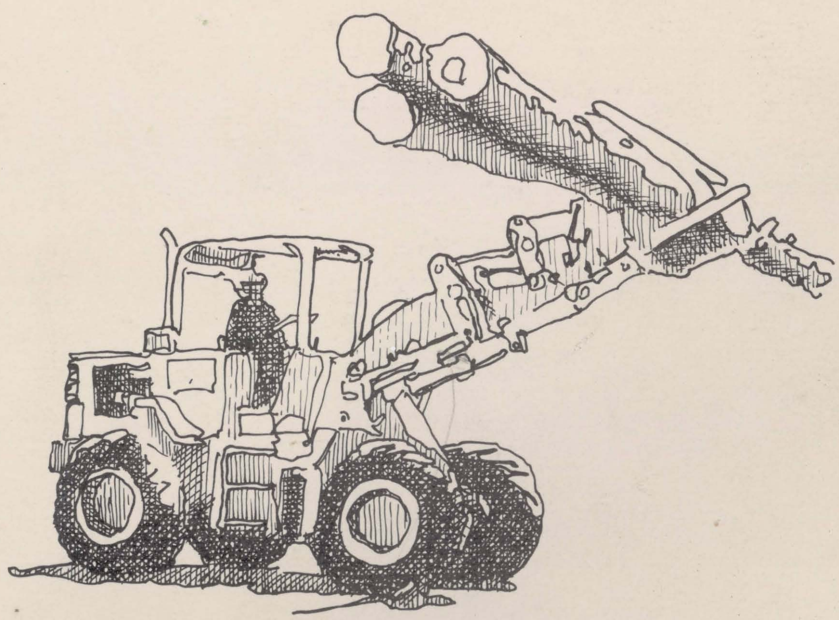
Impact of Timber Production Practices on Forest Resource Values in British Columbia

A Situation Appraisal and Summary of Research Needs

Pacific Forest Research Centre
Victoria, British Columbia
October, 1973



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IMPACTS OF TIMBER PRODUCTION PRACTICES ON FOREST RESOURCE VALUES IN BRITISH COLUMBIA

A situation appraisal and summary of research needs

by

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CANADIAN FORESTRY SERVICE

RESEARCH CENTRE

VICTORIA, B. C.

INTERNAL REPORT BC-47

DEPARTMENT OF THE ENVIRONMENT

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Foreword

This report is a situation appraisal. It is designed to contribute some background and thinking to future co-operative discussions, analysis and joint action by appropriate resource management and research agencies. The immediate goal is the sound allocation and use of limited research resources to solve some of the more important current and foreseen resource use and management problems.

The appraisal is in reponse to a recommendation of the Pacific Forest Research Centre Regional Advisory Committee* circa May, 1972 calling for research inputs into the management and utilization of forests for purposes other than wood production. At that time it was recognized that work of the nature called for had definite "Environmental Quality" orientation and might be undertaken with resources that were expected to be available for Environment Canada programs.

A research group comprised of a silviculturist, forest hydrologist, forest pathologist, ecologist, and an economist was formed and following organizational meetings was given broad terms of reference including the task of producing this appraisal. Their approach has consisted of visits to most of the Forest Districts, interviews with management staff and field tours, discussions and interviews with industrial representatives, officials of various resource management agencies and the universities, participation in workshops and seminars, acquisition and study of current research and

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* PFRC Regional Advisory Committee is chaired by the Director, PFRC, and comprised of senior representatives of the BCFS, Industry and U.B.C.

resource management data and strategies. The appraisal has been broad, and of necessity has included consideration of the institutional framework within which necessary ameliorative action would be taken. The group has not, however, restricted comments to generalities but has also cited specific impacts, estimated degrees of these impacts and has summarized the most important short- and long-term problems.

In this report the basic objective of Environmental Forestry research is seen as the promotion of forest management practices directed towards optimization of multi-resource usage. Therefore, while the many, positive effects of existing timber management operations receive some attention, the main emphasis is on the adverse effects of such practices and how they can be ameliorated in the interests not only of future wood production but also other resource values.

The goal of integrating resource management and satisfying the many demands that are made of the forest, while difficult, is not an earthshaking task. Forestry has always been an environmentally aware profession. Silviculturalists were among the first applied ecologists and forest policy frequently has been in the hands of far-sighted individuals appreciative of the many values of the forest. Indeed, an enormous amount of activity relative to integrated resource management has been generated since the formation of the appraisal group. Notable examples are the rapidly developing Provincial Environment and Land Use Committee and its Secretariat, the initiation and use of resource management policies and manuals by some elements of industry and the Province alike, the establishment of a number of large, well-funded multidiscipline and multiagency research projects throughout the Province, and the accelerated development of the British Columbia Forest Research Board.

This appraisal will be directed to the Forest Resources Use Committee of the British Columbia Forest Research Board. By this action it is expected that the necessary process of discussion, addition, alteration, analysis and decision by a broader, more comprehensive study team will be promoted. In this manner a clear set of research recommendations representative of a cross-section of resource management and research agencies can be provided.

C. P. Brett,
Head,
Forestry and Environmental Services.

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INTRODUCTION

The management of the forest landscape of British Columbia is under attack. Public concern, expressed through environmental groups and the news media, has built up and many conflict situations have developed, taking such forms as wilderness park demands, "save our salmon" campaigns and public condemnations of current resource management practices. In response, the forest industry companies have employed the first environmental foresters and initiated forest management advertising campaigns; the provincial forest service has issued environmental guidelines (7); and, professional forestry groups have emphasized the need for integrated resource management plans. In short, the environmental crisis has arrived on the British Columbia forestry scene.

This situation is but one example of the uncomfortable position of resource managers throughout North America and the industrialized countries of the world. Like the forestry community in British Columbia they have been surprised by the swift rise of environmental concerns to a position of respectability on the public scene and disconcerted by the startling intensity of attacks on their operations and, directly or indirectly, on their integrity. Despite complaints and criticisms in the past, 1970 was the first year in which public concern over the deterioration of environmental quality had any significant influence on resource policies of government (59). This delay has perhaps led to the dramatic rhetoric employed by environmental groups to publicize their cause.

It is inevitable that in British Columbia public criticism would be directed mainly toward the forest industry and the forestry community generally. The industry is a success and tremendous economic and social benefits have flowed from forest development policies. These policies ensured that an efficient administrative framework was set up to supervise the utilization of the public timber resource and to organize its protection and renewal. In a short space of time over half the land area of the province has been brought under management. However, these accomplishments have not been achieved without cost. Timber harvesting and other management practices can result in obvious environmental modifications and impacts on the non-timber resources of the forest. This has led to severe criticisms of provincial forest policies which are alleged to be oriented towards timber production at the expense of other resources.

In conceptual terms, at least, these criticisms, which have been advanced by more than one environmental group, have no basis. The many "influences" of the forest have long been recognized by foresters. In 1945 the Chief Forester of the province stated with regard to sustained yield:

> "Too often it is taken for granted that the "yield" will be so much wood and nothing else. This is a costly misconception. Other values in items such as fish, game, water, recreation, scenery and erosion control may exceed the value of the wood produced. Sound forest management cannot overlook these values" (47).

Management planning today includes all the values of the forest and the recently stated aim of provincial forest policy is as follows:

"The responsible administrators (of British Columbia's forest lands) are genuinely striving to strike an even balance and cater fairly to the economic, social and environmental objectives. Their aim is the optimum use of our forests for all concerned" (6).

Yet, if foresters have long accepted the validity of demands for non-wood resources, why have the forest policies in the province proved so vulnerable to environmental criticism? More than one answer to this question can be suggested:

1. Planning for multiple-use has been neglected until very recently. The multiple-use policies of the forest managers have consisted mostly of rhetoric with little action and responses to environmental conflicts have been dominated by the timber production viewpoint.

2. Forest managers by virtue of past concentration on wood production have become "technologically oriented" rather than "people oriented" (28,50).

3. Harvesting practices can have severe effects on the forest ecosystem and are quite evident to forest visitors. Little or no effort has been made to limit or explain the visually unattractive aspects of logging.

4. The demand for higher standards of environmental quality in forest management has coincided with a marked increase in wood production activity in the province. Logging has never been more conspicuous. It may also be that for many critics their "margin of tolerance" to the effects of wood

production activities has been exceeded, and they have suddenly become aware of the effects.

5. Demands for increased public participation in resource management have accompanied the demand for higher standards of environmental quality. These demands have not been met as indicated by the following quote:

> "Resources management and environmental quality policy-making in Canada is thus faced with a dilemma. On the one hand, rapid technological advances, coupled with increasing population growth and growing economic aspirations, are leading to massive alterations in the environment. Many of these alterations are beyond the comprehension of the average individual and so reliance is placed upon a technical elite to identify the problems and propose solutions. On the other hand, an increasingly alienated public is chagrined at major errors that have been made in assessing public preferences, and the failure to take into account values other than those stemming from the experts' technical training and experience. How this dilemma can be overcome remains an open question. It is clear, however, that there must be a considerable improvement in the means used to ascertain public preferences." (57, p.126).

6. The intellectual viewpoint in resources management has shifted radically and suddenly from a concern for optimization of the values gained from the management of a particular resource such as the forest, to man-environment interrelationships at a planetary level. As Boulding expresses it, we must now concern ourselves with "the economics of the coming spaceship earth " (2).

These points force one single inescapable conclusion. The forestry community in British Columbia should reappraise the objectives of forestry in the province and make appropriate adjustments:

> "Can we (foresters) point out the way to assure the fulfillment of our future needs for wood fibre in such a manner that the other values of the forest, both tangible and intangible, will be enhanced" (61, p.699).

This task which represents what might be called "environmental forestry", can only be accomplished by pursuing a wide range of strategies. Such strategies include new information systems (62) to collect and organize environmental inventories, the monitoring of impacts of various forestry activities over time, and the assessment of social consequences of these impacts. Management planning must be adjusted to reflect this new information and to evaluate alternative methods for promoting environmental forestry and for ensuring the application of new policies. These policies will have financial implications for both the government and private sectors which cannot be ignored.

Research is another important strategy that can be used to improve forestry practice. This paper outlines a framework for assessing impacts of timber production activities upon forest environments in British Columbia. The possible impacts are appraised to indicate what is known about their effects. From this, management and research initiatives to ameliorate adverse impacts are suggested.

SECTION I

ENVIRONMENTAL FORESTRY CONCEPTS

Actions to maintain or improve environmental quality in British Columbia forests must be governed by an astute awareness of the complex interrelationships between man and environment. Even immediate actions to rectify gross forms of environmental damage such as major stream blockages or to reserve forests pending best-use studies should be based on a holistic perspective.

For example, current efforts to improve stream protection during logging on the British Columbia coast also require consideration of the aesthetics of streambanks, otherwise general recreation groups may judge management as inadequate. Similarly, if environmentalists force a ban on slash burning they may intensify the risk of wildfires and catastrophic environmental damage.

An appreciation of the man-environment relationship in a forest setting requires more detailed knowledge of the impact of present and future timber production practices on the forest ecosystem. Research programs from simple ecosystem studies to large-scale watershed experiments will be necessary. At the same time, socio-economic assessments are equally important to provide the necessary value judgements. Like ecological research the socio-economic assessment must span a wide range from management accounting costs to large-scale regional studies.

The remainder of this section sets out some ecological and socio-economic factors basic to environmental forestry.

ECOLOGICAL FACTORS

THE ECOSYSTEM CONCEPT

Life within a closed global system comprises many interdependent and intricately linked ecosystems. Each ecosystem has four major components; the physical resources including energy input and loss, water, oxygen, carbon dioxide and minerals; the producers or photosynthetic organisms; the consumers - parasites, herbivores and carnivores; and, the decomposers - saprophytes and scavengers (Fig. 1). These components are interlocked in a dynamic system and modification of one component causes changes within that ecosystem and other ecosystems linked to it. The systems are resilient and except in the case of major natural disturbances such as fire, are, in the absence of modern man, relatively safe from destruction. However, man's technological developments can induce changes in the cycling of matter, energy flow, biotic communities and the basic physical resources on which all life is dependent. Some changes are beyond the range of normal, fluctuating natural conditions. For example, large-scale clearcutting will modify nutrient cycling, solar energy input, water relations and plant and animal communities. An understanding of ecosystem dynamics and the adoption of a biophysical systems framework will help to ameliorate the effects of these changes.

Some components of ecosystem dynamics; namely, the hydrologic and nutrient cycles and vegetative succession, warrant a more complete description at this time.

Hydrologic Cycle

Water interacts with all aspects of the natural landscape. It is the thread which links the various components of the ecosystem and through them forms the hydrologic cycle. For any given ecosystem the hydrologic cycle can be described by the water balance equation

$$P = D + R + E_T + S_M + M$$

where P is precipitation, D is drainage from the soil mass, R is surface runoff including temporary ponding in surface depressions, E_T is evapotranspiration, S_M is soil moisture storage change and M is precipitation storage by the vegetation. In addition, evapotranspiration is also linked to solar radiation, the driving force of the ecosystem, via the energy balance equation

$$R_N = E_T + H + G + V$$

where net radiation (R_N) the sum of solar and long wave radiation components, is partitioned into evapotranspiration (E_T), sensible (atmospheric) heat (H), soil heat (G) and vegetation heat storage (V), assuming no net advected energy. A brief discussion of water and energy balance components within the forest environment will provide a basis for understanding the subsequent enumeration of forest management impacts on the water resource.

For a given storm, the amount of rainfall reaching the ground can vary from near zero to near 100 percent of incoming rain depending

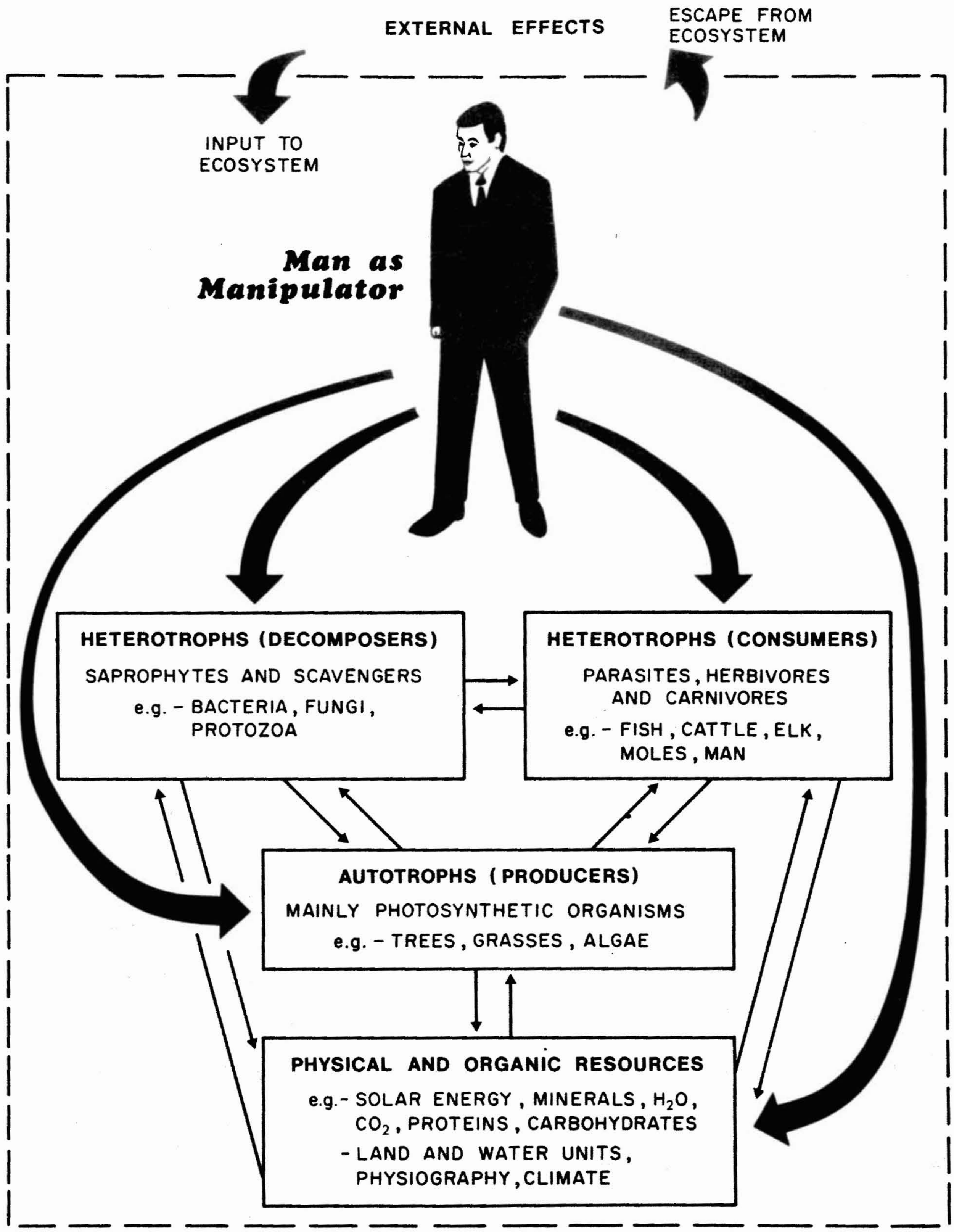

Fig. 1. Components of the ecosystem and man as manipulator.

on its intensity and the capacity of the forest canopy and lesser vegetation to store intercepted water. Snow may remain trapped in the canopy for long periods and thus be subject to considerable redistribution by subsequent winds. Along the coast and at high elevations, forests intercept fine fog or cloud droplets. This action results in an increase in soil moisture and runoff either by direct water input or indirectly by a reduction in transpiration losses of soil moisture.

Once precipitation has reached the ground surface, it will infiltrate into the soil, flow over the surface, remain temporarily stored on the surface as ponded water or snow or evaporate. Most forest soils have a protective layer of litter which permits rapid entry of water into the soil. Consequently, in many regions there is little or no surface runoff except locally where the soil has become saturated, such as in marshy areas, near streams or in depressions where drainage is restricted, where the surface is impermeable as a result of frost, clay content or extreme dryness, exposed bedrock or compact glacial till. Evaporation losses directly from the soil surface are usually relatively small within forest stands. Subsurface water movement is conditioned by the ground slope and the ability of the soil to transmit water, which is a function mainly of its texture, porosity, presence of root channels, depth to an impermeable layer, water content or degree of saturation and temperature. The existing soil water content is largely related to the ability of the soil to retain water and to the amount and rate of water removal by transpiring trees.

The energy budget of a forest ecosystem plays an important role, particularly in transpiration and snow-melt processes. If soil moisture is freely available to tree roots, most of the net radiation energy will go into evapotranspiration. Otherwise, this energy will be mainly partitioned between this process and warming up the air, with relatively little being used to heat vegetation or soil. Beneath the forest canopy, the shaded microclimate is usually cooler and more humid than in the open. The implications of this difference are two-fold. Firstly, evaporation and transpiration rates from minor vegetation are reduced. Secondly, the rate and amount of snow melt is lower within the forest stand than in the open.

Water also serves as a medium for the movement of materials through the ecosystem. Nutrients are washed from foliage by intercepted precipitation. More important, however, is the interaction between water and soil. Water absorbs or dissolves nutrients or other constituents, as it passes through the soil. Some of these elements will be recaptured by trees or redeposited within the soil matrix while some will be lost to the system when the water drains into streams or lakes. If water is permitted to run over the soil surface it may gain sufficient energy and volume to detach soil particles and initiate erosion. Eroded soil will be removed from the system once it reaches a stream. In addition, mass soil movements are often initiated by water. Saturated soil may literally flow, slump or slide downhill depending on soil type, topographic position and presence of binding agents, including tree root networks.

Streamflow in defined channels represents the integration of water-flow components which have moved via various pathways into and through the forest ecosystem. Between rain storms or snow-melt periods, streamflow is derived solely from slow drainage of unsaturated soil or ground water outflow. Stormflow or quick runoff from a rain event, on the other hand, is developed from subsurface drainage, overland flow and direct precipitation input to the stream. Recent research has demonstrated that stormflow is produced from expanding and shrinking source areas which include saturated zones adjacent to the stream, intermittent and ephemeral channels. It is not, then, generated from an entire watershed. In fact, the total source area for stormflow may vary from as little as one percent of the basin area for small storms up to 50 percent or more for large storms.

Vegetation Succession and Nutrient Cycling

Vegetation succession and nutrient cycling are closely related. The amount and kinds of nutrients in circulation depend greatly on the numbers and species of organisms being supported by the soil. Succession may be defined as changes in plant and animal composition which occur in time as a result of changes in the quality or balance of the resources on which the organisms live. It may proceed from primary stages, e.g., either very dry (rock) or wet (ponds), over a very long period of time during which soil is formed from the rock and the pond is filled in with organic and mineral debris. The direction of this long-term succession is from the extreme (either dry or wet) to a relatively stable (climax) mesic condition (31). Realization of this mesic condition is in terms of thousands or hundreds of thousands of years.

Short-term vegetative succession occurs on recently exposed material such as alluvium or glacial outwash, in which progress toward a relatively stable condition does not depend on the time-consuming development of a completely new soil base. Similar but more rapid successional patterns are initiated when existing vegetation such as a forest stand is removed from a site. This removal of vegetation immediately changes the microclimate and reduces competition for water, minerals, nutrients and space. It also disrupts nutrient cycles. Assuming that much of the vegetation is killed but not removed (e.g., branches, foliage, roots), there is an increase in available nutrients. This is due to actual increases in dead organic matter and to the greater amount of solar energy available for organic matter decomposition as a result of removal of the tree layer. Released nutrients are susceptible to leaching out of the soil profile and losses will occur unless new vegetation is established quickly. Reestablishment of vegetation is accomplished by plants which are prolific seed producers, disseminate their seeds over long distances and flourish in exposed areas. These pioneer species dominate cut-over sites and succession toward a climax begins again. Many of the pioneer species are not timber producers and their vigorous growth on some sites frequently leads to difficulties in reforestation. Occupation of the site by non-commercial species does not in itself reduce the ecosystem's potential capacity to produce timber. However, by removing protective vegetative cover, disrupting surface soil horizons, constructing roads and slash burning, certain timber production practices may damage or lead to damage of the basic soil resource through erosion or by raising the water table. Such damage forces the site back toward the primary successional stage--bare rock or water. This retrogression may occur over a very short period, or, in cases where revegetation is slow, over a longer period. In either case, a reduction in productivity is likely. The closer the original ecosystem is to the primary stages of rock or water, the greater will be losses in productivity and the longer will be the time needed to return to the original state (31). For a shallow soil reduced to bare rock because of erosion after clearcutting, this may well run into the thousands of years mentioned previously. No practical means exist to shorten this period of recuperation.

ECOLOGICAL MAPPING AND FLAGGING CRITICAL SITES

Identifying, classifying and mapping forest types and ecosystem units is essential for natural resource management. The main objective of such efforts is the delineation of map units which have fairly similar basic characteristics in terms of landform, soil, vegetation and animals and which thus respond fairly similarly to disturbance, including timber management practices such as clearcutting, slash burning, and scarification. In this way, ecological classification provides a foundation for management interpretations. Productivity in terms of site index for trees is one important interpretive measure. Others include erosion and windthrow hazard, slope stability, species suitability and probability of natural regeneration. These interpretations can and should be continually improved as more on-the-ground knowledge is gained concerning the relationships of the basic ecological units to specific management practices.

Because of the vast and topographically complex nature of British Columbia's forests, mapping of ecological units has generally been carried out with the aid of aerial photography with emphasis on geology, landforms and soils (29,60). The units recognized often contain a complex or mosaic of types not readily distinguishable on aerial photographs or easily mapped at the normal scale of 1:15,000 (39). For this reason, a good understanding by foresters on the ground of forest associations (36,38) and their relationships to the mapped ecological units will improve day-to-day planning and execution of operations.

Ecological classification should permit managers to designate or flag sensitive or fragile sites which are likely to be affected adversely by timber production practices or may be critical in terms of fish, wildlife, recreation and watershed values.

A main objective in identifying sensitive sites is to determine whether they should be included as part of the timber-growing base (68), and, if included, whether modified practices are needed to reduce adverse effects of timber management activities. In British Columbia, there are whole zones or subzones (35,38, Appendix A) in which the macroclimate severely limits the establishment and growth of trees. These include the dry Ponderosa Pine Zone, the cold Boreal White and Black Spruce Zone and the upper portions of the Mountain Hemlock and Engelmann Spruce - Subalpine fir Zones. Timber management practices used successfully in moderate climatic zones can cause environmental damage when employed in extreme zones.

Also, and within productive zones, areas of extreme topography or fragile soils will occur. These should be delimited on ecological inventory maps. Examples are the Lichen, Salal-Lichen and Dry Moss ecosystem types (64) which occur on shallow soils in most zones, the Skunk Cabbage and Sphagnum Bog types which occur on wet, largely organic soils in most zones, and extremely steep slopes in all zones.

Other critical sites are winter feeding areas for wild ungulates, animal migration routes or wet habitats for waterfowl. For general recreation, such areas might include river, lake and road edges, particularly in cases where revegetation after clearcutting is slow.

SOCIO-ECONOMIC FACTORS

In the end, ecosystem knowledge while extremely important can not tell man where to go. This, he must decide for himself. This is not an outright rejection of Commoner's (11) fourth law of ecology—'Nature knows best'. It represents a small but significant philosophical shift to Dubos' (16) viewpoint that the interplay between man and nature is a form of true symbiosis and that while nature and ecology have much to teach man, his activities can improve upon nature.

The move toward environmental forest management, therefore, is in essence one of social choice. It is no different in this respect from the beginnings of forest management in North America when public concern about future timber supplies, abetted by strenuous efforts on the part of conservation groups, resulted in the establishment of public forest management institutions.

Social choices depend on the values that are at stake in the pending decision and are conditioned by the institutional means for making such choices. In environmental policy-making generally, both values and institutions give rise to many difficulties some of which are discussed as follows.

VALUES

What distinguishes environmental decisions from earlier public policy decision is the sheer complexity of the problems posed by so many indeterminate social values. For example, environmental forestry is concerned with the production, protection and enhancement of the six familiar forest products:

- timber
- fish
- forage
- wildlife
- recreation
- water

to which must be added:

- clean water at the tap and in the forest
- clean air over the city and in the forest
- aesthetic beauty of the landscape
- low noise levels
- preservation of natural assets such as rare geomorphological phenomena and rare species of plants and animals
- wilderness preservation
- ethical concern for ecosystem integrity and diversity

Many of these values can not be measured easily. There are, as a consequence, few means of judging whether management is either efficient or equitable. This situation comes about because many of the environmental resources are public not private property resources and there is no market or exchange price to measure value.

Good management under these conditions would be difficult enough, but the inevitable prospect of resource conflicts adds more problems of a political nature. In either/or decisions some of those affected by the decision do not get what they would choose. When this is done outside the bounds of the price-exchange system, the disaffected can claim political bias. This is already a problem in environmental decision-making procedures.

INSTITUTIONS

The alleged failure of North American society to respect fundamental requirements for a high level of communal environmental quality and individual amenity rights is regarded by many analysts as a result of inadequacies in social institutions. Economic and industrial institutions have borne the force of such criticism, but legal, religious, educational and political institutions have received their share. Again, the criticisms stem from recognition that most environmental values are the product of public property resources whereas many of our existing institutions are best suited to management and control of private property rights and resources. This has resulted in a situation where "within the framework of existing social institutions, there is no tendency toward optimal use of the environment" (15). Measures to alleviate this problem include economic inducements and government regulations. The former approach is experimental but seems to offer much potential in the fields of air and water pollution. Its relevance for environmental forestry has yet to be explored. Government regulation in forestry is very common since in Canada and British Columbia the forest resource is publicly owned. The problems with the latter approach have been described by Haefele (25 p.284) who points out that traditionally social choices are made in isolation by technicians or small groups of politicians who try to 'balance' the interests of affected parties.

The difficulties of arranging suitable financial or regulatory measures to provide for many environmental resources have led to a third approach which calls for much greater public participation in resource management. How this might be accomplished is still not clear and it seems apparent that much social science research is required in this area.

SECTION II

TIMBER PRODUCTION, OTHER FOREST LAND USES AND PROBABLE AREAS OF CONFLICT

TIMBER PRODUCTION AND TIMBER PRODUCTION PRACTICES DEFINED

The total area of forest land in British Columbia is about 134 million acres of which 95% is owned by the Province. Nearly all of this forest land south of 57° N latitude excluding urban, park and agricultural areas is under some form of forest management. Sustained yield timber production is planned as a major activity on these lands and is directed at the removal, renewal and protection of the timber resource for the wood conversion and manufacturing industry.

The flow of timber from forest lands has great importance for the citizens of British Columbia and Canada. The forest industry employs 10% of the labour force and is responsible for a large proportion of the Provincial exports. It is a major contributor to economic development in the Province.

HARVESTING

Harvesting is the most important phase of timber production and receives the greatest attention from the public because of its conspicuous nature and potential for damage to other forest resources.

It is an important source of government revenue through royalties and stumpage fees.

The annual cut has tripled in British Columbia in the past 30 years:

Year	Volume cut (thousands of cunits)
1940	6,155[a]
1950	7,600[a]
1960	11,790[a]
1970	19,326

[a] Converted from fbm using 1 cu ft = 6 fbm

With the rise in volume cut there has been a shift in the proportion of species cut. In 1950, Douglas-fir made up the largest proportion of the cut but by 1970 it had dropped to third place behind hemlock and spruce. Most of the increased production of spruce has come from the Interior. Total timber production in 1971 from the Interior almost equalled timber production from Coastal areas. Also increasing rapidly is the utilization of lodgepole pine, from less than 2% of the total cut in 1950 to about 10% in 1970—most of this from the Interior. Logging both in the Interior and on the Coast is being carried on at increasingly higher elevations. Operations over 5,500 feet elevation are common in the southern Interior. The greater visibility of these high-elevation clearcuts compared with valley bottom operations, and their large size, have contributed greatly to public concern about overcutting and environmental effects.

Clearcutting is the most common logging system except in dry Interior areas where selective logging is generally practiced. Yarding on the Coast is mainly by some form of high-lead system and in the Interior by wheeled or tracked skidders. Jammer or access logging is one variation which has come under close scrutiny because of its dense road network.

ROAD CONSTRUCTION

Roads are required for timber harvesting and a variety of other timber management practices such as tree planting and thinning. They also provide access for fire control and for recreational use. Adamovitch (1) states that, "B.C. now has almost 40,000 miles of forest roads built since the war, of which more than 10,000 miles are high standard main raods. Each year, close to 3,000 miles are added to this total". In general, a larger percentage of the roads built in the Interior are of a temporary nature (10:1), than on the Coast (3:1).

SCARIFICATION

Scarification is employed to create a favorable mineral soil bed for natural and artificial reforestation. Also, it enables planting crews to work more efficiently and temporarily removes vegetative competition to seedling growth.

Scarification by blade and drag scarifiers is a common practice in lodgepole pine and spruce-alpine fir stands of the Prince George and Williams Lake Forest Districts where over 100,000 acres have been scarified since site preparation practices were initiated (4).

Scarification research projects and a few operational trials are being conducted in lodgepole pine stands in the Nelson and Kamloops Districts. Scarification is not common on the Coast and usually is restricted to fairly deep, fresh soils on gentle slopes (30).

WEED CONTROL (HERBICIDES)

Herbicides provide a wide spectrum control of unwanted vegetation usually at a lower cost than mechanical treatment. Their use on forest land in British Columbia is confined to the Coast in plantation operations, roadside brush control and pre-commercial thinning or juvenile spacing.

The most common plantation use is in alder control, either by "hack and squirt" on individual trees or by aerial or ground spraying. Other species treated are big leaf maple and occasionally grass when it competes with young seedlings.

The main objective of roadside brush control is safety in terms of increased visibility. The herbicides 2,4-D and 2,4,5-T are commonly used.

Juvenile spacing using MSMA (monosodium methanearsonate) has been carried out on over 16,000 acres within the past four years. It has the advantage over saw-thinning in hemlock stands in that the root rot, *Fomes annosus*, is not able to colonize cut stump surfaces (40). However, since the development of lightweight chain saws, saw-thinning has become increasingly attractive and has been conducted on large acreages.

Simazine, a pre-emergence herbicide applied to the soil, is commonly used for weed control in forest nurseries. In addition, contact herbicides such as Gramoxone and Dalapon are used to control grass and mineral oil is used as an all-purpose weed suppressor.

DRAINAGE

Drainage is not a regular forest practice in British Columbia. However, wetlands are common both on the Coast and in the Interior and a considerable potential exists for such land rehabilitation. Rayonier Canada (B.C.) Limited are planning an exploratory drainage project near Port McNeil, Vancouver Island. Ditching was slated to begin in the spring of 1973.

DIRECT SEEDING

Direct seeding includes hand and aerial seeding and seed spotting. Seed has usually been treated with the rodent repellent Endrin, a chlorinated hydrocarbon, and with Arasan, a fungicide, and may be colored to discourage eating by birds. Aerial seeding is the cheapest artificial regeneration method and eliminates the problem of employing large planting crews. Some pilot projects and a few full-scale operations have been conducted in British Columbia, but at present there is no regular, operational direct seeding in the Province, because of inadequate seed supplies and low survival rates, particularly on the Coast.

PLANTING

Planting is the surest way of restocking desired tree species at the desired spacing. It includes the use of 2-0 and transplant bare root stock, and container-grown seedlings. It is the only operational means of artificial reforestation in British Columbia and is used in clearcuts and burned areas which are too large for adequate natural seeding from bordering uncut stands. As the distance seed will travel from a timber edge may average only 3 to 5 chains (200-300 ft), clearcuts over 20 acres, excepting strip cuts, theoretically require artificial restocking in their centre portions. Whether this is true depends, of course, on many other factors such as topography, wind direction and speed, and species. The presence of hard-packed snow may aid seed dispersal by allowing seed to be swept along on top of the snow by wind.

The area planted in British Columbia has increased greatly in the last 10 years (Table 1), but is still only a small fraction of the acreage logged, particularly in the Interior. For instance, in the Prince George Forest District about 7,500 acres were planted while 103,000 acres were logged in 1971.

TABLE 1. Number of trees and acreages planted in British Columbia in last 30 years.

Year	Trees planted (millions)	Acres planted
1940	1.3	1,497
1950	6.9	7,400
1960	6.7	18,185
1970	33.9	85,336

Source: B.C. Forest Service Annual Reports

The objective by 1975 is a production of 75 million trees annually and plans are in hand to increase this total substantially.

SLASH DISPOSAL

Slash burning is conducted primarily for reduction of fire hazard and for silvicultural reasons such as improved conditions for reforestation (artificial and natural), removal of insect breeding areas, and removal of residual trees infected with dwarf mistletoe. Burning may be broadcast, or may entail spot burning concentrations of slash on landings, in windrows or piles. Slash burning has been a widespread practice on the Coast for many years. Over 50 per cent of logged areas in the Vancouver Forest District were burned from 1943 to 1969 (45). In the three Interior Districts and the Prince Rupert District, there was very little slash burning before 1962. In 1956, burning had increased considerably in these four Districts reaching 107,169 acres in 1970, about 40 thousand acres more than in the Vancouver Forest District (5). The rapid increase in slash burning in the Interior resulted from an increase in clearcutting and the extension of slash burning regulations (53, Section 116) to all areas of the Province in 1967.

Slash burning guidelines include an evaluation of the slash hazard, timber type, expected mode of regeneration, degree of slope, exposure, depth of duff, soil and percentage of exposed mineral soil. Where a conflict occurs between requirements for hazard abatement and silvicultural considerations, alternatives to broadcast burning are considered, for example, slash dispersal and "walking" a crawler tractor over the slash and breaking it down.

FIREBREAKS

Firebreaks are strips of green timber left unlogged to provide a barrier to slow or stop the spread of wildfire from adjacent slash or young growing stock.

FIRE CONTROL

A general principle of forest management in British Columbia is to reduce timber losses due to wildfire. Because of differences in weather from year to year, the effectiveness of fire control is difficult to assess. There is no doubt, however, that large areas of forests have been saved from wildfire and that the area saved is increasing with improved detection and suppression methods. The average annual cost of fire control in British Columbia is about $3,000,000, about 8 times the costs in the early 50's.

Fire control usually involves considerable land disturbance because of the requirement of access trails for crews, machinery and fireguards. The latter are constructed by removing trees, minor vegetation and surface debris down to mineral soil. Even when aerial means of suppression are available, ground crews are usually required for mop-up operations.

INSECT CONTROL (INSECTICIDES)

Forest insecticides have not been used extensively or in repeated applications in British Columbia. Spraying with DDT by aircraft began in 1946 for hemlock looper control on Vancouver Island. The largest area treated in British Columbia was a 156,000-acre operation in 1957 on northern Vancouver Island to control the black-headed budworm. Treatment was 10% DDT in fuel oil at a rate of one gal. per acre. The same chemical was used on a smaller scale in Lower Mainland park areas to control the Phantom hemlock and green-striped loopers. Other DDT operations were carried out in 1961 on 10,500 acres near Kitimat (saddle-back looper) and 1,500 acres in the Cameron Lake area, Vancouver Island (pine butterfly). Phosphamidon, an alternate to DDT, was tested as early as 1961 and again in 1964 on 1,600 acres in the Queen Charlotte Islands (26,32). In spring 1973, fenitrothion, an organo-phosphate, was applied to approximately 28,000 acres near Pt. Alice to control an outbreak of black-headed budworm.

Ambrosia beetles have been controlled in logs by spraying booms in the water and decks on land with BHC (Lindane), a chlorinated hydro-carbon. In the late 1960's, however, Methyl Trithion, an organo-phosphate, was being substituted because of its lesser impact on fish. More recently the same results have been obtained using water sprays on both fresh-water booms and on dry-land decks (54). Since 1970, no chemical spraying of water-stored logs has been allowed.

DISEASE CONTROL (FUNGICIDES)

Use of fungicides for control of forest diseases in British Columbia has been mainly experimental. Examples include trials of anti-biotics in the control of white pine blister rust and Rhabdocline needle cast of Douglas fir. Borax is recommended after thinning in hemlock stands to prevent infection of freshly cut stumps by *Fomes annosus*, a root- and butt-rot fungus, but is seldom used.

Disease control in nurseries is more common than in forests and is considered essential. Common treatments include Captan and Thiram to control damping off disease; methyl bromide, Vorlex and Vapam as soil fumigants; and, Difolatan for the control of Sirococcus tip blight.

JUVENILE SPACING

Juvenile spacing or pre-commercial thinning gives an opportunity to select the better formed, fastest growing and healthiest trees from a larger population and to direct the growth potential of a site toward these selected trees. Spacing is carried out by chemical means or by mechanical felling. The practice is almost exclusively limited to Coastal forests.

COMMERCIAL THINNING

Thinning allows removal of merchantable trees thus reducing mortality due to excessive competition. It results in a saving of wood volume which otherwise might be lost to decay. At this point in time, only a small portion of the annual cut in British Columbia comes from commercial thinning. However, thinning will undoubtedly increase in the future as second-growth stands reach merchantable size and mature timber becomes increasingly expensive as logging moves into more remote areas.

FERTILIZATION

Several hundred thousands of acres have been fertilized in the Pacific Northwest. At present, fertilization has been used only on an experimental scale in British Columbia and only on the Coast. Pacific

Logging Company has applied 2,300 tons of fertilizer, mostly urea, on 16,000 acres through 1972. MacMillan and Bloedel Company has applied about 100 tons. Other applications have been in small-scale ground-applied operations. The Canadian Forestry Service is presently conducting a comprehensive fertilizer study on southern Vancouver Island and the B.C. Forest Service Productivity Committee has established thinning - fertilizer studies throughout Douglas fir and hemlock stands in southern coastal British Columbia.

FOREST RESOURCES AND USES AFFECTED BY TIMBER PRODUCTION ACTIVITIES

FUTURE TIMBER PRODUCTION

Timber management has already been discussed, however, it should be noted that future timber production may itself be adversely affected by present timber management practices.

WATER PRODUCTION

Water is an integral component and important natural product of all forested watersheds. In addition to controlling the rates and types of vegetation growth, its uses include domestic and industrial supply, irrigation, domestic animal and wildlife consumption, power generation, maintenance of fish and wildlife habitat, and water-based activities such as swimming, canoeing, boating, sport and commercial fishing. Water also has value simply for aesthetic appeal.

Forested watersheds generally produce high quality water and moderate streamflow regimes. Watershed features which result in these desirable characteristics include an adequate forest cover, a landscape free from excessive sediment-producing erosion, shaded streams, channels free from excessive debris and disturbance and an absence of chemical contamination. Timber management activities which change any of these features may adversely alter otherwise acceptable water attributes for particular uses.

Watershed management, has the basic goal of producing adequate quantities of water of a quality suitable for use. In British Columbia, watershed management is generally synonomous with watershed protection. Watershed rehabilitation is usually undertaken on a small scale where adequate protective measures have not been applied or where protection has not been successful. Prescribed watershed improvement practices are rare although beneficial results might occur simply from tree harvesting regardless of the objective. The need for water-yield improvement is restricted mainly to water-deficit areas of the southern Interior and possibly to municipal watersheds in other areas. On the other hand, needs for flow regime modification are more extensive.

FISH PRODUCTION

The fresh waters of British Columbia support an important and valuable fisheries resource. In addition to lakes, almost any stream is a potential fish stream or is tributary to a potential fish stream or lake. Anadromous fish of commercial value which spawn within forested watersheds include the five main species of salmon: sockeye, pink, chum, chinook, and coho. Chinook and coho as well as steelhead are prized for their recreation fishing value. Sport fishing involving resident species, mainly trout, grayling and char, is also a highly valued recreational activity. For these species of fish, small streams provide important habitat for both spawning and at least early rearing stages of their life cycles. Any change in the quality of the stream environment will thus inevitably affect fish populations or fish production.

Land management objectives and practices associated with fisheries management are really the same as those outlined for watershed management. Major considerations are protection and maintenance of high quality water and stream environment, which includes channel spawning and rearing habitats, stream banks and streamside vegetation.

Fish production may also be aided through the use of artificial spawning channels and hatcheries. However, for the anadromous fish resource Narver (46) has stressed that these two practices are not a satisfactory alternative to natural stream production but have a limited role to play in special situations. For some species, spawning channels are not acceptable because of needs for in-stream rearing habitat. Further disadvantages of both spawning channels and hatcheries for salmon production in particular, are cost and the possibility of long-term genetic damage. On the other hand, stocking of lakes with trout for sport fishing by the Provincial Fish and Wildlife Branch has been successful.

DOMESTIC AND WILD ANIMAL PRODUCTION

The forested landscapes of British Columbia support a natural abundance of diverse wildlife forms and a significant livestock industry. Wildlife species are highly valued by those members of the public who hunt or fish or whose enjoyment of the outdoors is enhanced by the sight of soft-eyed deer and the sound of song birds. Some individuals devote large portions of their leisure time to the scientific study of wildlife species, while for others the knowledge that the species are alive and well is sufficient. The livestock industry is valued in a much different way through a well developed market. However, there can be little doubt today about the high value of its products. Ranches also possess certain aesthetic and recreational values for they are an essential part of a frequently admired landscape of rolling grasslands and forests, and provide opportunities for specialized forms of outdoor recreation.

OUTDOOR RECREATION AND NATURAL AMENITIES

In the last twenty years outdoor recreation in British Columbia's forests has boomed. More and more people are travelling and holidaying in the forests of the Province. As they do so, they pursue a wide range of activities from rock climbing through camping to bird watching. For many people, old growth forests are a national heritage. Others wish to escape from the daily grind into the wildness of the forest and some go specifically to learn about ecological processes and marvel at nature. For still others trees simply shelter a multitude of places where pleasurable activities can take place (63).

Natural amenities such as clean air, clean water, scenic beauty and low noise levels are essential for high quality outdoor recreation experiences. Indeed the strong demand for outdoor recreation opportunities and the experience of recreationists have contributed much to the political demands for improvements in general environmental quality.

IRREPLACEABLE NATURAL ASSETS

The world of nature has always been a source of wonder and astonishment for man. Geological phenomena like the Grand Canyon, the Fraser River Canyon and Valley, the Rockies and Niagara Falls are visited or otherwise appreciated by millions each year and some have been institutionalized as National Parks. Among the ecological phenomena of the world, trees, and in particular the ancient groves of redwoods, western red cedar and Douglas-fir and the areas of exceptional fish and wildlife production hold a similar fascination for man and have provoked a similar protective response. Yet it is not only the grand features of the landscape that elicit wonder. Anyone who has observed a naturalist explaining to a group of children how, without the intervention of man, salmon spawn and die and are recycled in the ecosystem of the stream, cannot fail to be aware of the interest that nature stimulates. Thus it is that many small wild areas out-of-doors have been set aside for the enjoyment of local populations and for educational purposes.

IDENTIFYING SPECIFIC INTERACTIONS

Impact matrices were used to provide a checklist of possible interactions between timber management practices and forest resources and values, thus reducing the chance of missing important ones. Several impact matrices have been published (42,43).

This report lists a number of timber management practices in a generalized matrix (Fig. 2). These would normally occur under more than one major heading, but to avoid duplication each practice is included only once. For instance, slash burning is a part of both regeneration and protection but is included only under protection. Salvage logging has not been included in the matrix as it might be represented by any of the listed harvesting practices. Examples of salvage operations resulting in adverse impacts comparable to continuous clearcutting are the large-scale salvage of bark beetle-damaged and killed spruce in the Interior and timber killed by wildfire. In the matrix, insect and disease control only include the use of chemical pesticides. Sanitation measures such as salvage and slash burning associated with insect and disease control, e.g., bark beetles and dwarf mistletoes, are covered under harvesting practices and slash disposal.

Forest resource and resource value parameters have also been kept to a minimum in this general matrix. The magnitude of effects on water and fish were so similar that the two were combined. Relatively minor resource values have been omitted. Examples are the use of forest greenery (salal, false box, evergeen huckleberry) by the florist industry, and the use of huckleberries and other edible woodland crops.

In any matrix scheme there will be a great deal of subjectiveness in rating the magnitude and importance of an interaction. In addition, any rating will depend greatly on the type of forest ecosystem concerned, the actual logging method (as opposed to logging system) used, time of year of harvesting, and many other factors. For this reason, the generalized matrix only suggests where interactions may be of significance in magnitude (actual effect) and not in importance (overall impact taking into account such criteria as duration, frequency and extent of damage). In expanding individual portions of the matrix in later sections, there will be greater opportunity for discussing the importance of interactions and for considering details such as harvesting methods and regional factors.

The ratings represent maximum adverse impacts possible. They are not necessarily intended to be a measure of good forestry practice, but rather to identify those areas in which the potential for environmental damage is high. Because the ratings are subjective, some explanation of the reasoning behind them is provided.

All harvesting practices were deemed to potentially affect future wood production on the basis that reforestation may not be successful after harvesting. Selection cutting was expected to have a moderate effect on future wood production, more because of the effect on composition and quality of the future crop than on its yield. Clear-cutting and seed-tree harvesting in large blocks leave little residual cover and were thus rated as potentially highly damaging to water and fish resources. Patch and strip cutting were considered less damaging

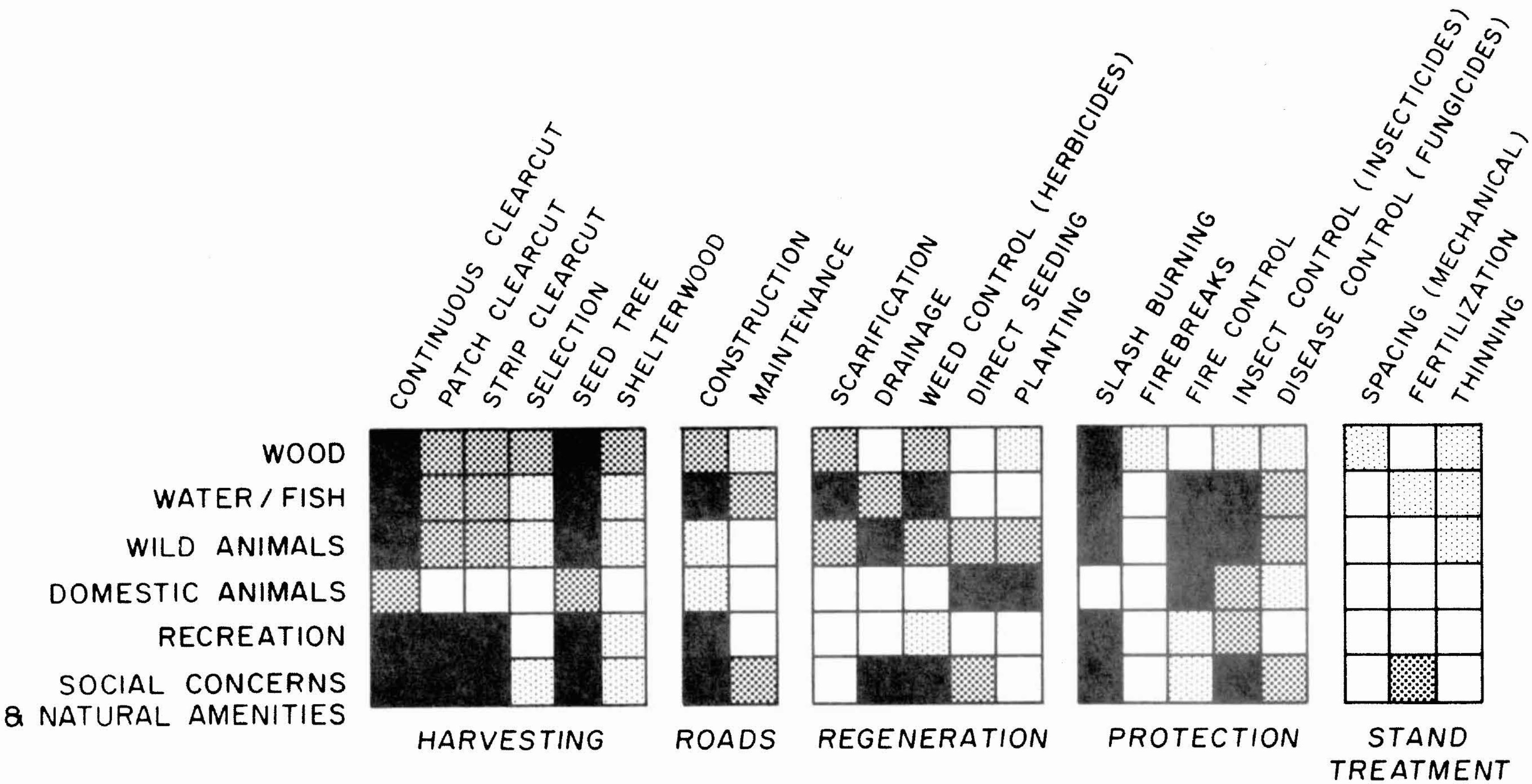

Fig. 2. Areas of potentially adverse interactions between timber management practices and major forest-land resources and public concerns.

Level: ☐ = none, ░ = low, ▒ = moderate, ■ = high

than clearcutting in that a smaller percentage of a given area is affected. Continuous clearcutting was rated as having a potential moderate impact on domestic animals particularly in dry forest zones where grass production may be optimum under the open stands and where large clearcuts, rather than being advantageous, would remove protective shade and cover for range animals. All clearcutting practices were judged to decrease aesthetic values and increase public fears of overcutting. Thus they were rated high in the social concerns category.

Road construction has a high potential impact on soil stability and therefore on water and fish and a moderate impact on future wood production through loss of productive area and site deterioration. Recreational values may be greatly lowered as a result of increased accessibility and impairment of the wilderness experience. Roads are often aesthetically displeasing and tend to engender on the part of the public the same fears of overcutting as harvesting. Road construction thus received high ratings for potentially adverse recreational and social impacts.

Scarification was considered socially acceptable once clearcutting had occurred but with a potentially high impact on water and fish. Drainage, on the other hand, is opposed in principle by many people and thus was given a high rating in the social concerns category. It is also potentially destructive to certain wildlife habitats.

Artificial regneration practices may have an adverse impact on animals in that forage areas may be more quickly succeeded by closed-canopy forests than when left to natural regneration. Direct seeding engenders public concern as a result of the use of chemicals in seed treatment and baiting.

Weed control includes the use of chemicals for control of shrubby vegetation, weed-tree control and in juvenile spacing. The use of herbicides and insecticides evokes considerable public concern and is potentially highly damaging to water and fish if improperly handled.

Slash burning was rated high in potential impact on future wood production because of the chance of escapes into surrounding timbered stands and site deterioration. There is a potential high impact on water and fish by reason of increased erosion and decreased shade, and on animals by direct kill and by destruction of habitat. Recreational values are lowered when slash burning destroys wildlife habitat. Smoke pollution is a major public concern in the autumn months.

Fire control was considered to include both the actual fire fighting and the ultimate effect of successful control, i.e., a lower proportion of burned-over areas. Thus, it is believed that fire control might adversely affect water because of the actual control operation, and wildlife and agriculture because of the loss to the animals of potential grazing lands.

Spacing and thinning by mechanical means have generally low potential adverse impacts while fertilization has a moderate potential impact in respect to public concern over pollution of water bodies.

One problem in considering adverse impacts is that a greater adverse impact could occur if a particular practice is not performed.

For instance, planting may have a low adverse impact on wood production in terms of monoculture, but if not carried out, the impact could be much more serious. Further, slash burning may have adverse effects of a fairly high magnitude, but the adverse effects of not burning could well be greater due to the high fire hazard of the unburned slash. An assessment of the benefits resulting from specific timber management practices would have to be included in any investigation into the need for corrective procedures.

SECTION III

IMPACT OF TIMBER PRODUCTION PRACTICES ON FUTURE TIMBER PRODUCTION

DIRECT LOSSES

REGENERATION

Clearcutting is the most common and often the most silviculturally sound system of logging in British Columbia (Plate I). At the same time, heavy reliance is placed on natural regeneration in reforestation plans. The Prince George District may be used as an example. In 1971, 103 thousand acres were logged primarily by clearcutting in patches over 100 acres in size. In the same year, 194 thousand acres of mature and immature timber were burned by wildfire. Using current figures for logged acreages and the ten-year average for timbered acres burned, the denuded area amounts to 150 thousand acres annually. In 1971, 7.5 thousand acres were planted and while this acreage will be increased to 25,000 in 1975, the percentage of denuded lands dependent upon natural restocking will still be over 80 per cent.

There are many examples in British Columbia showing that because of the size of the clearcuts, limited distance of natural seed dispersal, periodicity of seed crops, seedbed and microclimate problems, natural regeneration has not been adequate. For example, spruce seed is carried only about 250 to 300 ft from the timber edge, is produced abundantly only every 5 to 7 years and requires a seedbed with exposed mineral soil. The prospect of spruce clearcuts over about 40 acres becoming naturally and adequately restocked is not promising. Apart from lodgepole pine, the same general principles regarding the relationship between clear-cut size and amount of natural regeneration applies to all other commercial tree species. The larger the clearcut the greater the impact. For example, salvage logging in southern Interior spruce-alpine fir stands attacked by bark beetles has resulted in inordinately large clearcuts (Plate 1). The current small planting program does not provide the flexibility to deal with such emergencies. It seems, therefore, that there is little chance of adequate, prompt regeneration--natural or artificial. The adverse effect of inadequate restocking of burned and logged lands on the future sustained yield of forest products should be clear.

WINDTHROW

Harvesting methods such as strip cutting, which are intended to achieve natural regeneration and thus reduce reforestation costs, tend to increase the amount of timber lost by windthrow when compared with large, regular-shaped clearcuts. Glew (21) felt that much of the blowdown associated with strip cutting could be prevented by proper placement of the strips. However, definitive information on the amount of windthrow in strip-cut areas and the effectiveness of this practice in obtaining natural regeneration is lacking in British Columbia. Information is also lacking on windthrow in leave strips along streams. Such strips are often resisted by forest managers on the premise that residual trees will blow down.

Windthrow in small clearcuts is probably greater than in large clearcuts because of the greater amount of exposed edge per volume of timber harvested. Small clearcuts are, however, probably less liable to windthrow than strips because of the lower wind speeds attained.

Partial cutting of various kinds has often been condemned on the basis of a potential increase in windthrow (27). However, the opposite effect has also been noted in which partially cutover ponderosa pine stands suffered less windthrow than virgin stands (34). Roads alone will increase the rate of windthrow in adjacent stands. Finally, in addition to direct wood loss, windthrown timber can promote the build-up of bark beetle populations (17).

Susceptibility to windthrow depends on a number of factors such as logging method, species, age and health of the tree, soil type and topography (22,56). Thus great variation can be expected in the extent and significance of windthrow and ameliorative action will be dependant upon improved knowledge and a better appreciation of underlying causes.

TREE DAMAGE AND WASTE

Thinning, selection and diameter-limit felling, pre-harvesting scarification and road construction to greater or lesser degrees depending upon the quality of the operation, can result in damage to unharvested trees. Such damage directly will reduce the value of the lower bole for forest products, or, provide entrance courts for decay fungi (Plate 2) wherever the damage occurs. Decay losses resulting from root and bole scars can be particularly serious in thin-barked, decay-susceptible species such as western hemlock (67), spruce and subalpine fir (49). In thicker-barked species such as Interior Douglas-fir losses may be as much from direct deformation of the butt log and from growth retardation as from decay (13; Plate 2).

Tree injury may occur after stand opening as a result of sunscald. Further, sunscald may allow entrance of decay and canker organisms (18,20).

The rate of disease development can be increased by thinning and other forms of partial cutting. For example, dwarf mistletoe intensifies more quickly after thinning, selective logging or incomplete "clearcutting" because of its requirements for good light conditions. Such stand openings encourage a greater dispersal distance for mistletoe seed. In addition, the root rot Fomes annosus is spread by means of infection of cut stumps and partial cutting in stands of susceptible species will expose living trees to subsequent infection through root contacts (66).

Tree injury may occur as the result of misapplied herbicides and fertilizers although such damage is rarely experienced. For example, Walker (65) has reported severe damage on jack pine where spraying with a herbicide occurred too early in the growing season.

There are many examples of how timber management practices will increase the effect of injurious insects. Under certain conditions, logging slash provides ideal breeding grounds for bark beetles. In heavy slash, these populations may build up to the point where live trees are attacked and killed. Many bark beetle infestations can be traced to logging disturbance (41).

Waste of wood during logging operations has decreased significantly over the last decade. However, winter logging on snow is still common and considerable high value bole wood is left in the forest in the form of high stumps (Plate 3).

FIRE HAZARD

Fire may occur at any time throughout the life of a stand. While fire hazard may increase as stands become overmature due to the greater fuel load and increase in the number of snags, the most hazardous period occurs immediately following clearcut harvesting. Unless this hazard is reduced by controlled slash burning, logging increases the chance of wildfires burning adjacent unlogged timber. Thinning and spacing also temporarily increase fire hazard as does the creation of slash along new roads.

DIRECT FIRE LOSSES

Fires may occur as a direct result of timber management operations in addition to an overall increase in the fire hazard. Table 2 illustrates the magnitude of fire losses resulting directly from timber management operations including escaped slash fires (Plate 4). These fire losses represent from 10 to 20 per cent of total fire losses over the past five years.

TABLE 2. Fire losses due to logging and lumbering[a]

Forest District	Acres burned		Volume lost-M cu.ft.		Value $	
	1972	5-yr.av.	1972	5-yr.av.	1972	5-yr.av.
Vancouver	9,513	5,568	2,551	2,227	575,559	374,255
Prince Rupert	162	2,049	7	749	2,591	74,856
Prince George	2,700	5,429	243	804	42,293	50,746
Kamloops	754	4,669	206	524	31,528	42,982
Nelson	398	2,029	88	309	4,470	25,441
Cariboo	179	8,406	5	1,554	1,731	107,562

a/ Source: B.C. Forest Service

LOSS OF PRODUCTIVE AREA

It is estimated that roads including landings, fills and backslopes make up 10-15% of harvested areas (Plate 5) and the percentage may reach 20% or more with systems such as access logging. Much of this area may be permanently removed from production while some of the areas occupied by spur roads and landings may be brought back into production. The success of restocking old roads and landings depends mainly on soil condition, particularly the degree of soil compaction and topographic exposure. On steep slopes, the area covered by sidecast material can be substantial (Plate 6). End hauling of road-cut material reduces the amount of sidecast but increases construction costs. There has been at least one report that the productivity of trees growing adjacent to road right-of-ways is increased, probably due to the reduced competition (52).

SITE DETERIORATION

Site deterioration refers to changes in the forest ecosystem which are expected to adversely affect future forest productivity. Timber management practices such as clearcutting alter natural ecosystems, though not necessarily their ecological function, trees being but one component of forest ecosystems (30). Clearcutting plus slash burning comes closest to completely upsetting natural ecosystem processes, albeit temporarily, by removing above-ground animal and plant life and disrupting life in surface soil horizons. Evapotranspiration is temporarily halted, runoff increased, water tables raised, erosion increased, microclimatic extremes increased and nutrients leached out of the soil profile. The seriousness of the disruption depends principally on the duration of adverse effects, which, in turn, depends much on the rate at which revegetation occurs. Evidence of past catastrophic events such as wildfires, indicates that revegetation does occur even though serious soil disturbance is evident in the soil profile, but at rates varying with climate and local site. However, there must be a concern with the time factor and with the composition of the resulting plant cover - for timber managers, grass is not a reasonable alternative to trees.

The possible interactions of forest management practices and site deterioration are shown in Fig. 3. Site deterioration is characterized by 8 elements, 5 pertaining to soil, 1 to vegetation, 1 to microclimate and 1 to runoff pattern as it affects soil erosion. In rating the magnitude of these interactions, reference is made only to effects on future wood production. Effects on other uses are dealt with in later sections. The assumption is that maintenance of forest growth is a prime objective in the management of forest lands. The rating given is an estimate of the maximum expected magnitude of adverse effect of the interaction in a given situation and does not include any estimation of its overall importance.

Some explanation of the environmental parameters included in Fig. 3 is offered. Soil physics refers mainly to properties such as bulk density, porosity and structure. Thus scarification, which involves disruption of the surface soil layers of a high percentage of areas treated, was considered to have a high potential adverse impact on soil physical properties. Soil chemistry refers mainly to nutrient levels and soil biology to soil organisms. Slash burning was considered to have a high potential adverse impact on both soil chemistry and biology due to rapid release and therefore possible loss of some nutrients and destruction of surface layers high in biological activity. Soil erodibility is a factor of both physical soil properties and of amount, kind and distribution of protective vegetation. Scarification and slash burning, which remove vegetation and disturb soil, including the creation of hydrophobic substances during burning, were therefore rated as having high potential adverse impacts in terms of soil erodibility. In the context of site deterioration, serious adverse soil moisture effects are most likely to result from clearcutting by raising of the level of water tables or by surface-soil drying. Microclimate is drastically affected by clearcutting, and vegetation by clearcutting, slash burning, scarification and weed control. Surface runoff refers to overland flow which can lead to sheet erosion and gullying. By diverting natural drainage patterns, road construction has a high potential adverse impact in this respect.

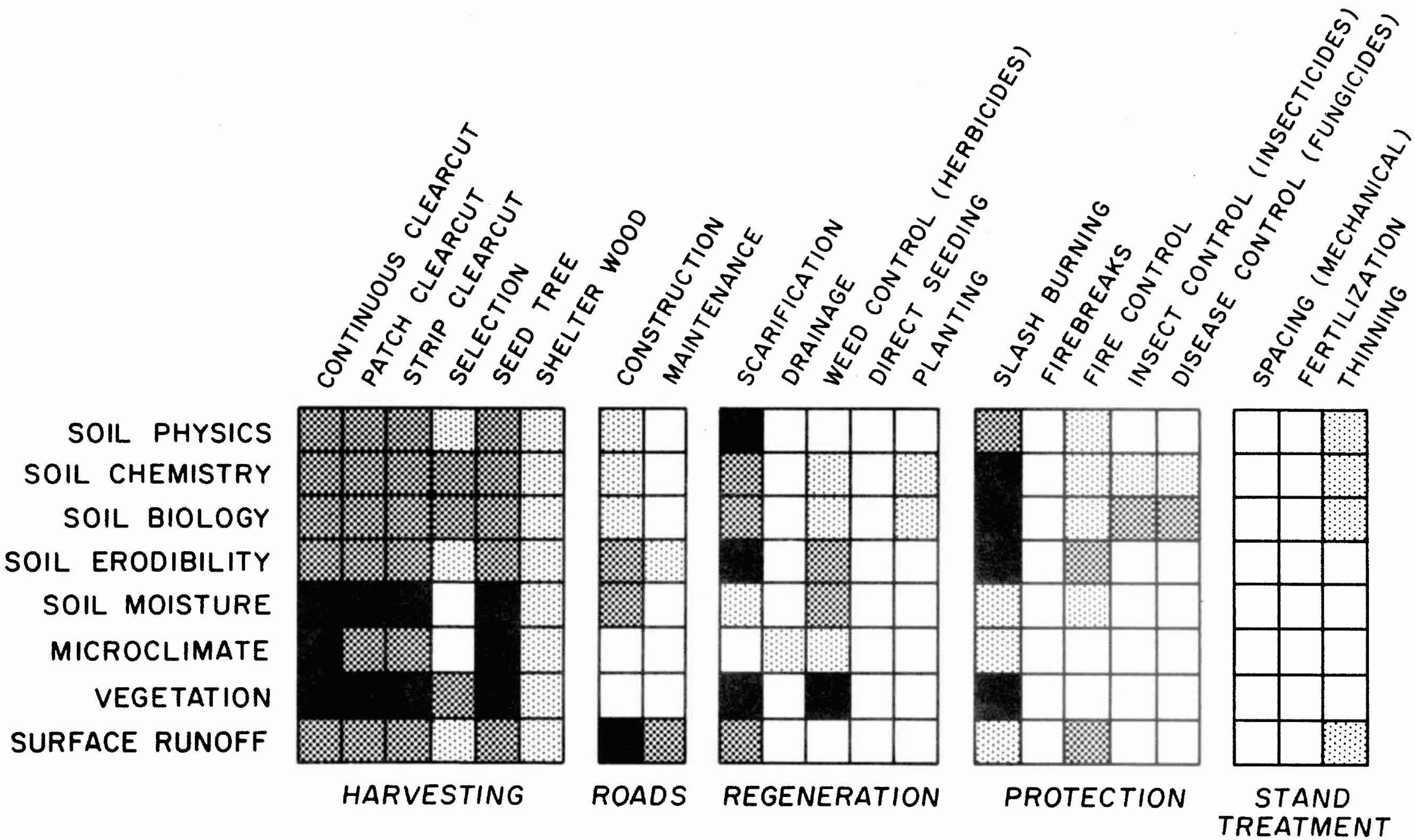

Fig. 3. Areas of potentially adverse interactions between timber management practices and site deterioration-related parameters.

Level: ☐ = none, ░ = low, ▒ = moderate, ■ = high

MANAGEMENT AND RESEARCH INITIATIVES

In this and succeeding Sections (III, IV, V and VI), important interactions are grouped in three ways on the basis of information known and required to document the interaction and recommend corrective procedures.

1. <u>Timber management practices which have a predictable adverse impact and for which corrective procedures exist</u>

    a) Inadequate stocking and therefore reduced sustained yield capacity will result when reliance is on natural regeneration without regard to such factors as species, size, arrangement and timing of clearcuts, and site preparation practices.

    b) Various harvesting systems, site preparation procedures, inadequate protection practices and road construction can result in damage to unharvested trees or accelerate insect and disease development.

    c) Clearcutting by access logging on moderate to steep slopes is unnecessarily destructive to the soil base by reason of the dense road network. This road network produces large areas with unsuitable growing conditions (the road beds themselves) and large areas covered with sidecast material (often rock) which is both unstable and of low productivity.

d) Clearcut logging followed by broadcast slash burning on steep, rock outcrop slopes results in removal of protective vegetative cover which, in high rainfall areas, allows erosion of significant portions of the soil (Plate 7). The significance of this interaction is not unanimously agreed upon and probably requires some systematic "before and after" investigations to determine actual losses.

e) Skidding of logs and scarification on wet sites using wheeled skidders or crawler tractors frequently cause excessive rutting of terrain and impoundment of seepage water thus reducing future productivity.

2. Timber management practices which are considered to have an adverse impact under certain conditions but require further definition, quantifying and development of ameliorating practices

a) Windthrow increases from practices such as strip, patch and partial cutting systems and the preservation of streamside strips and wildlife corridors. However, knowledge and understanding of the basic causes is far from complete.

b) Roads, landings and associated cuts and fills can remove productive area from forest production.

c) Clearcutting and seed-tree harvesting systems can cause extremes in microclimate which are critical for tree establishment and growth. Documentation of the adverse effects of a harsh microclimate on regeneration in high-elevation zones and in dry zones is growing (55). Because of the greater edge effect, patch and strip cutting have less adverse impacts than continuous clearcutting or clearcutting in large blocks. Partial cutting or a shelterwood system would decrease the impact and might have to be considered on particularly sensitive sites.

d) Clearcut and seed-tree harvesting systems and to a lesser extent the shelterwood system, reduce evapotranspiration which results in a higher soil moisture content and a rise in existing water tables. Where water tables are normally high, this can cause flooding and adversely affect tree establishment and growth.

e) Clearcut and seed-tree harvesting systems drastically alter the density and composition of minor vegetation. This results on some sites, particularly the more productive ones, in a serious brush competition problem and a consequent reduction in tree productivity if adequate control measures are not taken.

f) Clearcutting and seed-tree harvesting increase soil erodibility by removing protective vegetation, reducing surface organic horizons, and changing runoff patterns by the creation of yarding furrows, skidder and mechanical harvester tracks.

g) Slash burning can reduce infiltration capacity and allow a rapid release of nutrients from organic matter thus affecting biological soil properties. The reduced infiltration capacity and removal of protective vegetation and organic horizons can increase soil erodibility. The degree of adverse effects depends much on the biogeoclimatic zone, ecosystem type, and on the intensity, duration and season of the burn.

h) Scarification by excessive scalping can result in the creation of an unsuitable medium for establishment and early growth of trees. Such scalping will be particularly critical in areas of low rainfall and high $CaCO_3$ concentrations in the subsoil, or on strong iron podzols in which many of the nutrients are concentrated in the upper organic horizons.

i) Herbicides reduce vegetation density and can increase the chances of nutrient leaching.

j) Road construction disrupts the normal pattern of runoff. In terms of site deterioration, this can result in gullying and high surface erosion. Effects are likely to be greatest on steep slopes with easily erodible soil.

k) Road construction results in the deposition of sidecast material often of low quality for tree establishment and growth (Plate 6). The extent of sidecast material can be considerable on steep slopes.

3. <u>Interactions which are known to occur but without further survey and research it is uncertain whether the impacts are adverse and whether they are important</u>

a) Clearcutting affects soil physical properties through compaction by machinery and the yarding and skidding of logs; chemical soil properties through a greater decomposition rate of organic matter, higher temperatures and greater soil moisture in the summer, all caused by opening up the stand; and soil biological properties through changes in the physical and chemical properties. There is considerable question whether the soil biological and chemical changes are detrimental. Much depends on how quickly new growth can be established to utilize the newly released nutrients. All these environmental conditions are affected greatly by the logging method. Adverse impacts would tend to lessen from skidder to access to grapple to high lead to skyline to helicopter methods. Impacts would tend to be less when the logging is performed in snow. Clearcutting with full-tree yarding would have greater impact on the nutrient reserves than when limbing is at the stump.

b) Slash burning temporarily reduces the density and composition of minor vegetation. This can have an adverse effect in dry, exposed sites where the shade of vegetation is critical for establishment and early growth of seedlings.

c) Slash burning increases microclimatic extremes through the production of black surfaces, particularly near the ground-air interface.

d) Scarification can increase erodibility by removing the protective vegetative cover and disturbing organic horizons.

e) Scarification reduces vegetation density which may adversely affect the establishment and growth of seedlings, particularly on dry, exposed sites.

f) Scarification affects soil physical, chemical and biological properties by acting as a cultivator thus increasing the rate of decomposition of organic matter. Whether the impact would be an adverse one would depend on such factors as climatic regime, ecosystem type, topography and rate of revegetation.

g) Scarification can affect runoff pattern by diverting and concentrating natural runoff and thus accelerating erosion.

h) Herbicides and other chemical control agents may adversely affect the biological component of soil.

i) Road construction intercepts underground seepage which may be to the detriment of those below-road sites which depend on seepage water for their high productivity.

j) Selective logging will affect the composition of trees and minor vegetation by favoring shade-tolerant species. This may have deleterious effects on soil chemical and biological properties which, in turn, may affect future forest production.

k) Planting a single species (monoculture) may result in soil deterioration as a result of an incomplete demand for soil nutrients by a single species and resultant nutrient leaching.

GENERAL REGIONAL AND SITE CONSIDERATIONS

The factors operating to cause site deterioration act on all ecosystems under timber management. However, the magnitude of deterioration will differ greatly depending upon biogeoclimatic zone and ecosystem type. Severe site deterioration resulting from timber management practices are not likely to occur over the fairly broad range of middle sites (submesic to subhydric soil moisture conditions) with gentle topography and situated in productive (for timber) biogeoclimatic zones.

It is on the more extreme sites that significant site deterioration is most likely to occur. Extremes may be in terms of soil (particularly moisture, depth and texture), topography (steepness) and climate. Some examples of these extreme situations are:

1. Extreme sites within any biogeoclimatic zone

   a) Extremely dry, e.g., the Lichen, Salal-Lichen, or Dry Moss ecosystem types. Problems include severe erosion of already shallow rock outcrop soils even to the point of soil removal to bedrock particularly following clearcutting and broadcast slash burning (Plate 7). Depletion of nutrients through erosion and crop removal may be significant when related to the already low nutrient reserve of the sites. The result of such deterioration is difficulty in reforestation and poor tree growth.

   b) Extremely wet, e.g., the Skunk Cabbage and Sphagnum Bog ecosystem types. Effects of timber harvesting might include a raising of the water table and excessive ground disturbance including the creation of small impoundages with consequent tree regeneration, survival and growth problems.

   c) Extremely steep sites. Steep topography can occur everywhere including some very productive sites. Problems are mainly associated with erosion which is accelerated by road building and harvesting.

This can result in losses in soil productivity and in tree regeneration and survival difficulties.

2. Biogeoclimatic zones with severe climatic limitations on tree establishment and growth

   a) Subalpine zones, e.g., the Mountain Hemlock Zone of the Coast, particularly the upper Subalpine Parkland Subzone, and the Engelmann Spruce - Subalpine Fir Zone of the Interior, particularly its upper elevations and northern locations. These are major biogeoclimatic zones valued for watersheds and recreation as well as for wood production. Clear-cutting will affect the microclimate by increasing insolation and wind speed and thus such factors as amount and duration of snow accumulation which are critical to tree establishment and growth. The fact that meadows are often interspersed with forested areas in these zones indicates that a fairly delicate balance exists between the type of vegetation and environmental factors. Invasion of logged areas by grass in these zones reflects this same critical balance.

   b) Boreal White and Black Spruce Zone. Because of the short growing season at this northern latitude, tree growth is poor. Logging of the extensive black spruce and tamarack bogs or of immediately surrounding stands may cause an increase in water table levels with the possibility that unlogged trees are killed or that logged areas are difficult to regenerate. Even if regenerated, the already low productivity of these areas might decrease because of the higher water tables. On dry sites in this zone, nutrient reserves may be seriously depleted by complete removal of tree cover.

c) Ponderosa Pine Zone and the Drier Subzone of the Interior Douglas-fir Zone. Because of the lack of summer rainfall and the higher summer temperatures in these zones, regeneration after clearcutting is difficult. The microclimate becomes extremely harsh including high surface soil temperatures, low surface soil moisture and high air temperatures near the ground.

Any combination of the above extreme site conditions and severe climatic limitations will, of course, heighten the chance of site deterioration. For instance, a steep, dry (rock outcrop) slope in the Mountain Hemlock Zone would likely require a more drastic modification in current harvesting practices to prevent site deterioration than a similarly steep but mesic (medium moisture) slope in a more climatically moderate zone.

SECTION IV

IMPACT OF TIMBER PRODUCTION PRACTICES ON WATER AND FISH

WATER-TIMBER MANAGEMENT INTERACTIONS

Water is an integral component of the forest ecosystem. Only after threading its way via different pathways through the land environment does it emerge in stream channels. It follows that modification or disruption of the forest ecosystem by timber management practices will modify or change to some extent the movement, storage and characteristics of water within this system.

A matrix of potentially significant or adverse stream water-timber management interactions is presented in Fig. 4. Chemical water quality changes are taken to mean increased concentrations of dissolved organic and inorganic materials and chemicals, or variations in pH, while physical water quality characteristics include changes in water temperature, dissolved oxygen, colour, taste, odour and the presence of debris. The term 'sediment' includes both suspended and bed-load material and is included separately because of its importance as a major stream impairment factor. Water regime summarizes changes in total stream water yield and the variability in flow rates and timing produced by both spatial and temporal modification of natural drainage patterns,

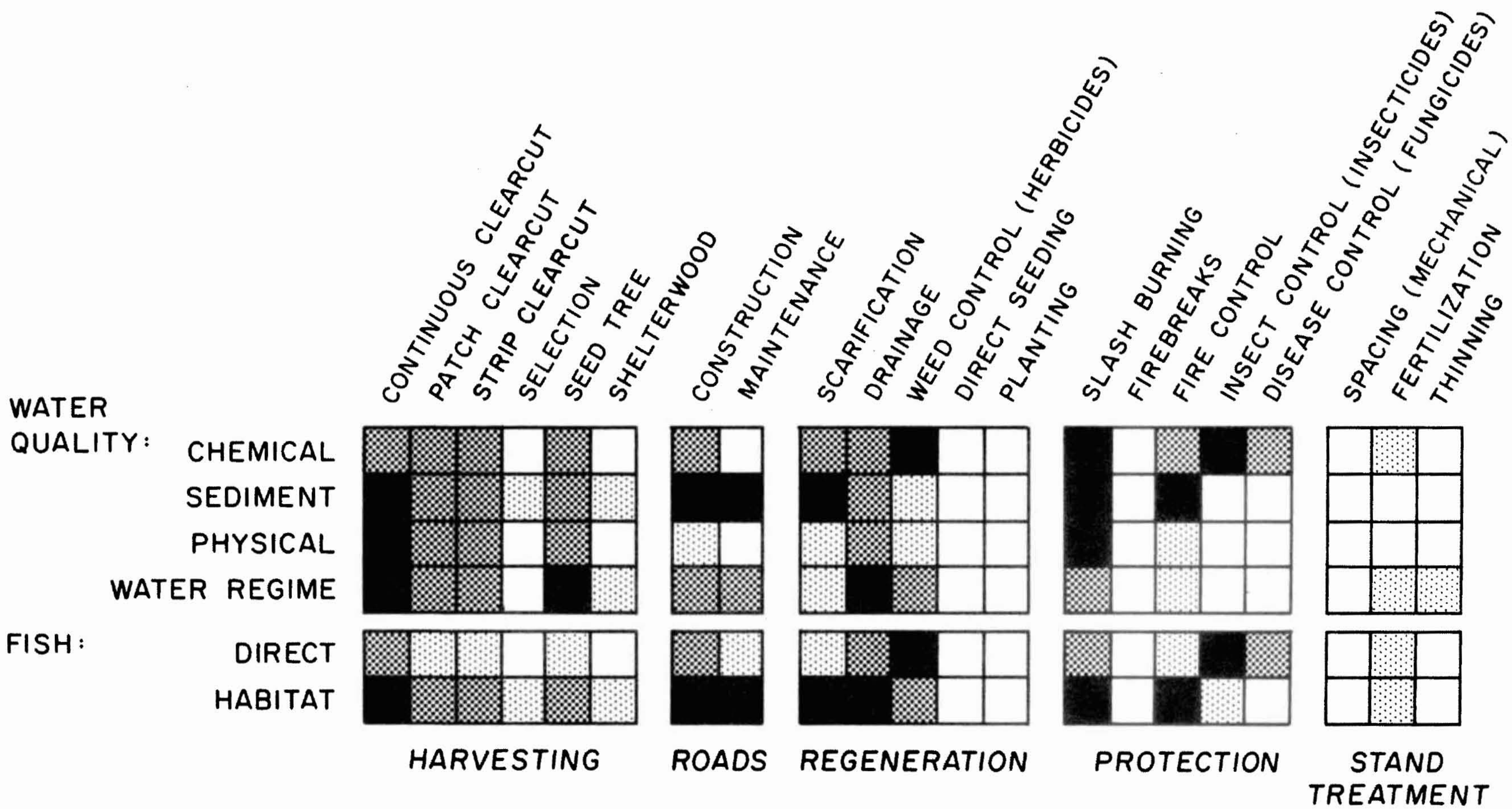

Fig. 4. Areas of potentially adverse interactions between timber management practices and water and fish.

Level: ☐ = none, ░ = low, ▒ = moderate, ■ = high

particularly increased peak flows and diversion of water. The matrix illustrates the possible maximum magnitudes and relative severity of potentially adverse interactions and does not assess their overall importance (e.g., extent of impact in Province).

The nature of some of the significant water-timber management practice interactions are discussed below in relation to vegetation, soil and stream environment to provide some perspective for the subsequent categorization of impacts.

MODIFICATION OF VEGETATION COVER

Reduction in forest stand density has a host of ramifications for water movement, storage and quality within the forest ecosystem. The degree of impact is directly related to the extent and pattern of tree removal. In addition, the magnitude of changes in stream water characteristics, particularly regime and yield, is usually proportional to the percentage of stream drainage area affected. Cutting practices in order of increasing impact are selection cut, thinning, strip cut, patch cut, and continuous or large clear cut.

The removal of trees results in a decrease of transpiration, an increase in soil water content, an increased yield of water to the stream from the area cut over and possibly higher streamflow levels during the summer low flow period. Exposed mineral soil will be subject to erosion initiated by high intensity rainfalls unimpeded by the forest canopy. In addition, organic matter exposed to solar radiation decomposes more rapidly. This action, in combination with a reduction in nutrient uptake by trees and an increase in soil water flow, results in increased leaching of nutrients from the soil and enrichment of stream and lake water, the duration of which is dependent on the rate of revegetation.

Clearcutting drastically alters snow accumulation patterns and melt rates. Snow melts faster in clearings than beneath the protective forest canopy, the result being an earlier melting of a greater volume of snow from openings during the spring snow melt period. The major impact of this change in snow behaviour is on peak rates of streamflow, and the effect may be two-fold depending on the distribution and size of openings and the percentage of the watershed cleared. First, snow in logged and undisturbed parts of a basin will melt at different rates resulting in a decrease in peak streamflow volume. On the other hand, peak flows may be increased particularly where larger clearcut areas are involved. Under special circumstances, the snow melt period could conceivably be extended but the potential duration of such an extension would tend to be small and of minor importance.

On steeper slopes, decay of root systems following harvesting results in gradual reduction of soil stability. Since the soil is bound or anchored less firmly to the slope and soil water contents also tend to be higher, the chances of mass wasting, soil slumping or sliding are increased. This form of erosion is damaging to the land base as well as to stream water quality or the stream environment. Soil erosion is also accelerated following slash burning which exposes the soil by denuding it of minor vegetation as well as slash and litter. However, the effect is usually temporary because of the re-establishment of an adequate ground cover.

The promptness and nature of reforestation can influence the duration of changes in water yield from a clearcut area. If trees are replaced with grass which has a shallower rooting depth, for example, at least a portion of the increased yield would be maintained indefinitely. In any case, the longer reforestation is delayed, the longer any change in water yield will endure.

IMPACT ON SOIL

Soil is subject to considerable direct impact from a number of logging and related timber management activities. Any operation which disturbs the soil changes its physical characteristics which in turn leads to changes in its hydrologic behaviour. These changes may initiate or promote overland flow, accelerated surface erosion, mass wasting, stream sedimentation or blockage and modification of peak stormflow characteristics.

There is almost universal agreement that roads present one of the greatest single problems in so far as their impact on soil and adverse interaction with water are concerned. The magnitude, or intensity of effect will bear a direct correlation with the density of the road network which is a function of logging method and cutting practice. Logging methods in order of increasing road density, and thus of generally increasing soil-water impact, are helicopter logging, skyline cable systems, high lead, tractor or skidder logging, and access logging. Cutting pattern will influence both the need for and timing of road construction. Selection cutting requires more roads than clear-cutting. A series of distributed patch cuts necessitates advance road development more than a continuous clearcut or smaller number of larger openings. The degree of impact depends on road type and tends to increase in the following order - permanent mainline haul road, secondary road, spur, skid trail.

The effects of roads can be summarized in relation to their impact on water flow and on erosion. Firstly, roads intercept sub-surface drainage water and flow from small ephemeral or intermittent channels and force precipitation to run over their impervious surfaces. They thus divert water more rapidly to stream channels and effectively increase the density of the natural drainage system. If located near streams or other storm flow source areas, roads further increase over-land flow and hasten timing of storm flow.

Erosion of road surfaces, ditches and cut and fill slopes often leads to significant stream sedimentation as well as damage to the road itself. Grass seeding of cut banks will reduce this impact. Mass wasting is likely to occur if the road undercuts or overloads a potentially unstable slope. Inadequate drainage facilities involving spacing and size of culverts, size of ditch, or non-use of water bars or other measures are major causes of road washouts or failures. Such failures are a serious source of sediment as well as impairing use of the road. Diverted drainage water may also initiate erosion downslope from the road.

The action of <u>yarding</u> or dragging logs over the ground surface will disturb the organic layer and can lead to soil erosion. The severity and extent of soil disturbance is a function of logging method and topography. Tractor or skidder yarding has the greatest impact because machines must traverse a large proportion of the watershed. This compacts the soil and thereby reduces its infiltration capacity. Both logs and machinery can create conditions which promote overland flow and channels which concentrate this flow, leading to erosion and speeding the delivery of water to stream channels. High lead yarding tends to be less damaging as machinery is restricted to roads and landings. Skyline or balloon cable systems which lift the logs above the ground during the transport to the landing create little soil disturbance, while helicopter logging is potentially the least damaging of all. Winter logging over frozen ground or snow pack produces virtually no direct soil disturbance. Skidding trees over storm flow source areas near streams will have a greater direct impact on streamflow than the same operation further upslope.

Scarification involves the use of heavy machinery and produces considerable soil disturbance. This practice could cause significant overland flow, erosion and stream sedimentation if it occurs near stream channels, storm flow source areas or roads which act as extensions of the channel network.

Slash burning breaks down forest debris and organic matter into finer material more easily transportable by water, and produces a hydrophobic coating of surface soil layers which can inhibit infiltration. Fire also exposes mineral soil where the organic layer is thin or the burn severe enough. This combination of factors promotes overland flow, erosion, removal of nutrients from the land and consequent changes in stream water chemistry. Burning also releases nutrients which are then subject to increased leaching from the soil mass by subsurface water movement.

IMPACT ON STREAM ENVIRONMENT

Stream environment is taken to include the stream channel and its contents, adjacent banks and streamside vegetation, adjoining tributaries and backwater areas within the stream flood plain. Stream water physical, chemical, biological and flow regime characteristics are also considered part of the stream environment. Timber management activities which cause adverse changes in any of these features, either directly or indirectly, impair the use of the water or stream. Impacts on the stream environment result both from activities removed or upslope from the stream and from disturbance of the ecosystem in and near the stream channel itself.

Land-based or upslope effects of harvesting, yarding, road building, fire and scarification on the water resource have already been discussed. The changes in stream parameters resulting from these effects involve modification of flow regime and water quality and stream blockage or diversion by land slides. To these effects may be added changes in water chemistry produced by the use of fertilizers, herbicides and insecticides.

The probability of major impacts on the stream environment is increased when timber management activities take place in or near the stream channel. Source areas for storm flow that are adjacent to the channel tend to be more sensitive to soil and vegetation disturbance than drier upslope sites and direct disturbance of the channel itself is therefore more likely to occur. The potentially adverse in-stream effects are outlined in the next section on fisheries interactions.

FISHERIES-TIMBER MANAGEMENT INTERACTIONS

Since most timber management operations have an effect on some phase of the water cycle, the probability of resulting impacts on the stream environment and hence on the fishery resource is high. Adverse impacts include damage to spawning and rearing habitat, outright destruction of fish or eggs, or sub-lethal effects which impair fish physiological functions and curtail production. Many changes in water quality fall into this latter category. The intensity or degree of impacts varies with fish species and stage of life cycle, being most critical during the embryo-fry stages.

The matrix of Fig. 4 illustrates the relative magnitudes of potentially adverse impacts of timber management practices directly on fish themselves and also on the aquatic habitat. In essence, habitat modifications are the integrated expression of the effects of changes in water characteristics indicated on the same diagram.

Changes in fish habitat result from both direct and indirect interference with the stream environment and its processes. Habitat is defined primarily in terms of spawning beds, which mean stream gravel of acceptable quality, and rearing areas, which include pools, space in and under stream banks, and accessible backwater and tributary areas. The availability of habitat, barring obstruction by debris or other natural barriers such as waterfalls, is a function of water depth and flow velocity, which determine whether or not fish can remain in a given location. Direct damage or destruction of both spawning and rearing habitats, including scouring, gouging or shifting of bed material, results from use of machinery in the channel, yarding logs through or across the stream or by increased bed load and debris movement promoted by increased rates and frequency of peak flows. One indirect impact which reduces habitat availability is diversion of flow from one drainage area to another which results in lower water levels.

Streamside vegetation protects streams in many ways. Its removal by harvesting, fire or herbicides will expose the stream to increased solar radiation, and result in increased water temperatures all the way from lethal through sub-optimum, to beneficial levels for fish. An important terrestrial food source, leaves and insects, will be sharply reduced. The combined effects of adverse impacts will be at least a decrease in fish productivity.

Sediment inputs to streams, including both organic and inorganic material, have several potential effects. A major impact is the blanketing of spawning beds by sediment and resulting destruction of eggs and fry by cutting off oxygen supply, filling gravel voids and preventing escape to the stream. Decomposition of incorporated organic matter further reduces available dissolved intra-gravel oxygen. Water turbidity reduces light penetration and thus interferes with food chains and feeding behaviour with a resultant decrease in fish productivity. Suspended sediment can directly impair fish physiological functions if concentrations are sufficiently high. Stream sediment is derived from both upslope (land environment) and in-stream sources. In-stream sources which include stream beds, stream banks, and point sources such as road crossings and adjoining slides, are particularly important since they are susceptible to continued erosion by the stream water itself, especially during peak flow events.

Jammed-up logging debris in streams may block fish migration or by diverting water around or beneath it, produce bank erosion or bed scour. When the jams release there may be damaging surges of water, debris and bed material. Debris decomposition reduces dissolved oxygen and releases chemicals to the stream.

Changes in water chemistry are produced by increased leaching of soil nutrients following fire or clearcutting, fertilizer application, additions of toxic insecticide or herbicide chemicals, by decomposition of organic matter in the stream and by increases in stream water temperature. Potential effects of adverse water quality changes include stream or lake eutrophication and associated habitat impairment, disruption of food chains, reduction of fish production or contamination of fish, rendering them unsuitable for consumption.

Other direct impacts include operation of machinery in the stream channel which can result in direct crushing of eggs and small fish, and improperly installed culverts which effectively block fish passage by presenting a physical barrier or a velocity barrier if the gradient is too steep.

In summary, fish or stream productivity is determined by the integrated effects of water volume and rates of flow, water temperature, radiation input, water nutrient and oxygen content, suspended and bed load movement and available protected and suitable living space. The potential adverse impacts of timber management practices on these features are numerous and of some consequence; however, not all impacts on the stream environment are detrimental. In some areas, increased stream temperatures and nutrient levels may actually improve habitat conditions and increase fish productivity. Increased summer low flows which extend available habitat during that season may ensure greater fish survival rates. Larger logs and debris in the stream channel which create needed pools and provide shade further improve fish habitat conditions. In short, the ramifications of fisheries-timber management practice interactions are positive as well as negative, implying that broad generalizations must be regarded with caution.

MANAGEMENT AND RESEARCH INITIATIVES

The diversity of topography, geology, soils, vegetation and climate in British Columbia, together with historic attitudes and economics have resulted in a variety of timber management practices. This combination of factors has produced a marked regional variation in impacts on the soil and water resources, and, by implication, a need for local or regional information concerning these impacts or interactions. In very general terms it can be stated that:

- Hydrological processes and events, and thus logging impacts, are magnified at high elevations in British Columbia due to high precipitation, the energy imparted to flowing water and soil by gravity and a harsh climate.

- The significance of impacts may increase from south to north as the climate becomes more rigorous.
- Accelerated erosion occurs to some extent wherever there is logging, with variations resulting from differences in intrinsic soil erosion hazard and standard of logging practice.
- The greater the areal extent of disturbance the greater the impact. The extent of disturbance is a function of harvesting method, logging technique, road density and slope.
- The degree of impact on the stream environment tends to be inversely related to the distance between the activity and the water course.
- The logging practices used in steep terrain in the Interior tend to be more destructive than on the Coast because of the type of equipment used.

In order to predict the occurrence and importance of impacts of specific management practices on the water and fisheries resources, it is necessary to have a detailed knowledge of the environment in which the practice is to be performed; the location, extent, type and way in which the activity is to be carried out; the interactions, direct and indirect, between the practice and both the terrestrial and stream ecosystems. It is the latter item for which there are important gaps in knowledge. Until very recently, there has been little investigative work on the environmental impacts of timber management practices in

British Columbia itself. A considerable body of relevant and helpful research information does exist for contiguous areas in the United States from which reasonable implications may be drawn. However, notable differences in soil conditions and the hydrological response of watersheds, resulting mainly from differences in climate and the effects of glaciation, dictate the cautious application of research results from these areas.

The important management activity related interactions are grouped into three categories on the basis of information known and required concerning full documentation of the interactions and possible procedures for amelioration.

1. Timber management practices which have a predictable adverse impact and for which corrective procedures exist

   a) Timber management practices that impinge directly on the stream environment are unnecessarily destructive. These include practices such as operation of machinery in streams (Plate 12), felling timber in and yarding it through streams, road construction along streambanks (Plate 6), improper installation and inadequate maintenance of culverts or stream crossings (Plates 3, 9-10, 11). Included also is the application of pesticides directly into streams.

b) Sub-standard road construction resulting from non-adherence to known principles or guidelines for minimizing or avoiding erosion and subsequent stream damage can have detrimental effects. Factors involved include road location (Plate 13), season of construction, quality of construction (Plate 12) adequacy of maintenance and de-activation of abandoned or temporary roads.

2. <u>Timber management practices which are considered to have an adverse impact under certain conditions but require further definition, quantifying and development of ameliorating practices</u>

a) Road construction can induce mass soil movement by direct disturbance of inherently unstable slopes or diversion of surface and subsurface drainage waters as illustrated in Plate 13. Road related mass wasting is a significant form of accelerated erosion in the following zones:

i) Coastal Western Hemlock and Mountain Hemlock, particularly on the very steep glacial valley slopes of the mainland mountains (48).

ii) Western Hemlock and Engelmann Spruce-Subalpine Fir of the Interior highland and mountain belts.

b) Roads also initiate erosion by failure or washout resulting from inadequate drainage facilities and by promoting overland flow as illustrated in Plate 9. Much basic knowledge is still needed on road interception of surface and subsurface drainage waters and culvert size and spacing requirements for adequate dispersion of these waters.

c) Skidding of logs by tracked or rubber-tired vehicles and yarding by cable methods may promote overland flow and subsequent erosion. High erosion hazard conditions are particularly a problem in the Interior where deposits of unconsolidated glacial gravels, sands and silts are widespread. For examples see Plates 8 and 13. Soil erodibility and slope sensitivity to disturbance are two important factors requiring understanding before adverse impacts can be reliably predicted.

d) Clearcut logging on steep slopes may lead to mass soil movement as a result of root deterioration and changes in soil water regime. This problem has received some attention in coastal British Columbia (48). The extent and significance of such mass wasting and the processes involved deserve further study, both for Coastal and Interior mountainous areas.

e) Clearcut logging produces changes in water yield and streamflow regime which can result in higher peak flows. This effect is of particular significance in the Interior where peak flows are generated mainly from snow melt and where regime changes may persist for years because of the relatively slow rate of forest regeneration. Very large openings which occupy a high percentage of a watershed, such as those created by salvage logging of spruce bark-beetle killed stands (Plate 1), have the highest potential for producing damaging peak flow changes. In the case of very high winter rainfall events in coastal watersheds, the presence or absence of forest cover may have little effect on producing extreme peak flow values. Relatively rapid re-establishment of the forest cover also tends to reduce and shorten the duration of flow regime changes. However, as there is little information yet available on these processes in British Columbia, investigation of streamflow modification by timber harvesting is an important need.

f) Various forestry practices result in sediment production or changes in streamflow regimes which increase bed scour and bank erosion. The extent, magnitude and duration of changes in in-stream sediment amounts and channel modification require separate investigation to determine the impact of such changes on fish spawning and rearing habitats and hence on fish production. This information is needed to establish a factual basis for evaluating the real significance of these forestry-fishery interactions.

3. <u>Interactions which are known to occur but without further survey and research it is uncertain whether the impacts are adverse and whether they are important</u>

   a) Slash burning may impair water quality. Information is needed on both the magnitude and duration of erosion, stream sedimentation and water chemistry changes following fire.

   b) Clearcutting alone, eliminates nutrient uptake by trees thereby promoting increased leaching of nutrients and changes in water quality. Research in Oregon and Washington indicates that nutrient losses from coastal watershed clearcuts tend to be both small and of short duration, probably because of coarse soils and rapid revegetation (9,19). While similar results might be anticipated for coastal British Columbia, verification is needed to establish the significance of this process both on the Coast and particularly in the Interior.

c) Forest fertilization may result in increased nitrogen levels in streams and lakes either by direct input or indirectly by soil water leaching. Research results from coastal Oregon and Washington, although meagre, indicate that total amounts of fertilizer nitrogen entering streams tends to be relatively small (33,44). More information on a wider range of field conditions and applications is needed to substantiate these findings. In addition, the importance of such nutrient additions to various aquatic ecosystems needs investigation.

d) The application of pesticides particularly by aerial methods, can result in stream contamination. Further study of this potential impact is warranted if the use of forest chemicals increases.

e) Scarification may lead to stream sedimentation. The extent of occurrence of this interaction requires definition.

f) The Interior winter logging practice of skidding trees over the snow surface can result in a considerable volume of fine debris input to streams when the snow melts. The significance of this process requires investigation.

g) The Interior winter logging practice of constructing ice bridges over small streams can result in considerable channel disruption, flow diversion and stream sedimentation as illustrated in Plate 3. Information is required on the extent and significance of this practice.

h) Roads increase and hasten stormflow runoff by promoting overland flow and acting as extensions of the stream network. The significance of this effect should be evaluated.

i) Rehabilitation of wetland sites by facilitating or encouraging more rapid drainage, through ditch construction or channel network modification, can substantially change streamflow characteristics and fish habitat. At present, this practice is very limited but merits study where it does occur.

j) Removal of streamside vegetation exposes streams to increased solar radiation and resulting increased stream temperatures, particularly in small, shallow streams during the summer low flow period, with potentially harmful impacts on fish. A method has been developed in the United States for estimating the magnitude of such temperature increases (8). This or similar procedures should be developed, tested and applied, along with concurrent field measurements, on a regional basis in British Columbia.

k) Removal of streamside vegetation disrupts aquatic food chains by reducing terrestrial supplies of leaves and insects. The significance of this effect requires elucidation.

In summary, the significant impacts on water resource characteristics fall into two main groups, those which may be avoided and those which are essentially unavoidable. Impacts which may be circumvented by adequate protective measures include accelerated erosion, mass wasting and stream sedimentation, debris in streams, water temperature changes, stream contamination by chemicals, harmful regime modification, and general damage to the stream environment. Inevitable changes resulting from forest harvesting include water yield increases, flow regime modification and some nutrient leaching, all of which can be controlled but not eliminated.

SECTION V

IMPACT OF TIMBER PRODUCTION PRACTICES ON DOMESTIC AND WILD ANIMALS

The type and degree of timber production impacts on domestic animals clearly differs from those on wild animals. Domestic animals are intensively managed and because they can be fed, housed, tended and are accustomed to man, are less subject to environmental modifications. Wild animals, on the other hand, are almost totally dependent on environmental conditions and are therefore more subject to environmental modification.

DOMESTIC ANIMALS

Cattle and sheep are the two principal domestic species grazed on forest ranges in British Columbia. Production is centered in the interior of the Province. The animals are generally dependent on open forest ranges for their summer food supplies and are fed, or receive supplementary food, during the winter. Consequently, their production is limited mainly by summer food and winter hay supplies.

Many timber production activities are beneficial. The removal of timber encourages a significant increase in understory production of palatable species, thereby increasing summer food production. Timber production activities rarely affect winter food supplies.

The adverse impacts, listed below, are mostly indirect in that they reduce the availability and amount of the increased understory production.

1. Forest management regulations and procedures protect natural regeneration which is encroaching on open grasslands of the dry Central Interior. Formerly, these lands were natural, fire-maintained communities and these practices have served to reduce total available rangeland.
2. Artificial regeneration reduces the regeneration timespan and thus increases the rate of succession. Consequently, maintenance of increased understory production following logging is shortened.
3. Large clearcuts, while increasing food production, reduce availability of shade.
4. Low utilization standards and inadequate cleanup create physical hazards and in addition, decrease the area available for grazing.
5. Dense road networks can remove significant areas from production, create physical barriers for movement of stock within established grazing units, and increase the opportunity for rustling.

6. Timber management practices, including slash burning, scarification and road construction may reduce productive capacity and can favour unpalatable plant species.

While not being an impact, the fact that at present the livestock industry is regarded as being secondary, regardless of timber or livestock production potential, favours sub-optimal utilization of the ecosystem resource in some areas.

WILD ANIMALS

British Columbia is endowed with a rich and highly diversified fauna providing an unequalled opportunity, in North America, for recreational activities associated with wildlife. For example, Cowan and Guiguet (12) lists 126 known mammal species, Guiguet (23) lists 38 species of shorebirds and Guiguet (24) lists 17 species of upland game birds. Added to these are many other birds, reptiles and amphibians. The well-being or in some cases, continued existence of these species, is dependent on meeting their individual habitat requirements. Timber management practices affect animal habitat as follows:

1. <u>Changes in the landscape mosaic</u> alter the distribution and amount of feeding, breeding, resting, sleeping, migrating and escape terrain. The extent and significance of these changes depend on cutting method, size, distribution and rate of cut. The main factors determining the ability of

an animal to utilize the landscape are its behavioural characteristics and the degree to which the landscape is altered.

2. <u>Changes in plant community structure</u> have their principle effect in terms of the type and amount of food available. These changes may be beneficial or detrimental depending on the particular animals' food requirements. For example, removal of mature forests may result in reduction of winter food supplies such as lichens but at the same time may greatly increase summer food. In addition to changes in species composition and productivity of understory vegetation, the vertical stratification of plants is changed and consequently results in loss of a habitat type.

3. <u>Changes in microclimate</u> result from modifications to the structure of plant communities and have their principle effect through changes in radiant energy cycling. A good example is the effect on snowpack which may, especially in the Interior or at higher elevations on the Coast, control the availability of winter food supplies and animal movement. Mature forests intercept snow and may thereby provide accessible areas suitable for overwintering. This, of course depends on the biogeoclimatic zone and local physiographic features. For example, in the dry Southern Interior, the southfacing slopes are generally snow free and hence maintenance of mature forests for overwintering serves little purpose and, in fact, results in decreased understory production.

4. Changes to soil and water relations have been discussed in detail in preceeding sections. Their effects usually occur over relatively small areas but nevertheless may have serious consequences. Typical effects would include reduction in available nesting sites and depletion of habitat due to innundation or drainage.

5. The construction of roads into hitherto inaccessible areas has the potential of endangering vulnerable species, for example, mountain goats, through disturbance of traditional breeding areas and general harassment. This is a growing problem especially in high elevation areas, because of a tremendous increase in access.

As seen from the preceeding discussion, timber management practices can have a variety of effects, some profound, on habitat and consequently on animal well-being or survival. If animals are to be produced and managed on forest land, it is essential that where necessary, these practices be modified in consideration of animal species requirements. However, the efficacy of such modifications will depend on adequate inventories of species, numbers and habitats; improved knowledge of animal requirements; an ability to forecast the impacts of timber management practices; and, joint planning between timber and wildlife managers.

MANAGEMENT AND RESEARCH INITIATIVES

1. Timber management practices which have a predictable adverse impact and for which corrective procedures exist

    a) Cutting on winter ranges. Winter ranges are usually the controlling factor for many wildlife species. They are generally of limited size, are easily delineated and should be excluded from cutting permits.

    b) Construction of major haul roads through winter ranges. The resultant increase in accessibility and the disturbance is deleterious to wildlife.

    c) Excessively large clearcuts. Large clearcuts magnify the effects on animal habitat that result from clearcuts of any size. Moreover, they reduce variability in the landscape mosaic thus creating imbalances in the resources available to animals. For some animals, large clearcuts also tend to discourage full utilization of central portions due to reduced escape potential.

    d) Cutting game corridors. These corridors are necessary for migrating animals. The removal of timber exposes the animals to additional hazards and may create barriers to winter travel due to increased snow depth.

e) Dumping of logs and debris in estuaries, and land-filling and drainage of wetlands. These areas, which are critical to the survival of many animal species, are extremely limited. Not unlike many other land use practices on such areas, timber production activities cause obvious damage to wildlife habitat, some of which is irreparable.

2. Practices which are considered to have an adverse impact under certain conditions but require further definition, quantifying and development of ameliorating practices

a) Cutting in the subalpine and alpine zones. Cutting at these elevations may interfere with the breeding of species such as elk. Further, the increased access and associated disturbance threaten such species as grizzly bears and mountain goats.

b) Herbicide and pesticide application. Application of herbicides changes species composition which directly affects food supplies. Pesticides can cause contamination of food supplies and affect breeding success of raptors.

c) Monoculture. Decreasing the diversity of tree species directly affects habitat which may affect the ability of animal species to occupy the area.

d) Full tree logging and slash burning. Removal of cover, either through full tree logging or slash burning, removes small animal habitat and makes such animals vulnerable to predators.

e) Construction of roads. The construction of roads is rapidly decreasing the area of inaccessible land and only can result in increased harassment of big game species including those which cannot tolerate the presence of man.

f) Fire prevention. Fire prevention practices can result in the encroachment of trees onto natural grasslands, which in turn, can reduce the amount of winter food.

3. Interactions which are known to occur but without further survey and research it is uncertain whether the impacts are adverse and whether they are important

a) Harvest planning. The timing and distribution of cuts may have positive or negative effects on the provision of balanced animal habitats. At this time, however, they require some definition.

b) Stand treatments (juvenile spacing, pre-commercial and commercial thinning and disease control). These practices are bound to have effects either beneficial or adverse on the health and habitat of animals, but details are unavailable.

SECTION VI

IMPACT OF TIMBER PRODUCTION PRACTICES ON OUTDOOR RECREATION, IRREPLACEABLE NATURAL ASSETS AND NATURAL AMENITIES

Militant recreation-conservation interest groups argue that many timber production activities are inimical to enjoyment of the outdoors, the maintenance of a high level of natural amenities and a high general environmental quality. Some state therefore, that the strict segregation of timberlands and recreation lands is the only solution and that the only real issue is the number of acres allocated to recreation.

A "black and white" argument of this nature is predictable when it is interpreted as a plea for reassurance in the face of a rudimentary approach to outdoor recreation (3) and environmental planning in British Columbia. With the supply of opportunities for many forms of outdoor recreation left to individual enterprise and preservation of beautiful scenery outside park boundaries without a legal or administrative parent, the activities of extraction industries are regarded by these groups with great alarm, whatever impacts are likely to occur. At the same time alarm is being expressed by the forest industry because it is feared that the political lobbying of public groups for more parks and the restriction of timber production activities will interfere with the efficiency and output of logging operations and timber processing plants.

The existence of conflicts between recreationists of different interests as well as between recreationists of particular interests and those conducting timber production activities suggests that it is most important to find out which people want what before evaluating impact. The powerboat enthusiast or the hunter may be overjoyed at the prospect of a new lake being opened up by logging roads (Plate 14). Others may protest vigorously. Which voice should be heeded? Many people in the forest industry would support the former group but the decision cannot be made on that basis alone.

The absence of planning and action programs therefore work to the disadvantage of general public welfare. Attitudes and opinions are polarized, and the middle ground of integrated timber production, recreation management, tends to be neglected.

The remainder of this section sets out to show that the quality of the current public debate would be much improved if the following points were generally agreed upon: first, timber production activities have a strong positive effect on the ability to enjoy outdoor recreation experiences; second, conflicts between diverse recreational interest groups confuse the timber-recreation conflict and should be given management attention; third, timber production activities can have a strong negative effect on outdoor recreation sites and experiences; and last, special attention must be given to the basic natural amenities of clean air, clean water and scenic beauty because they are important factors in the enjoyment of outdoor recreation opportunities. Their maintenance is also essential to the general quality of life in the Province.

POSITIVE EFFECTS OF TIMBER PRODUCTION PRACTICES

There is a close relationship in British Columbia between the ability of the citizen to indulge his desire for contact with the "natural" forest environment, and the wood products industry. This relationship is both direct and indirect. It is direct in the sense that the industry has provided the means of access to many areas of the Province which were formerly remote wildlands open only to a few with specialized outdoor skills and knowledge. The effect of clearcutting on the availability of summer forage for deer in the coastal regions of the Province, and the protection afforded to all wildlands by the fire control efforts made to protect the timber resource are other examples of direct and positive links.

The indirect relationship comes about because participation in outdoor recreation is a function of income and leisure time, among other factors, and the present high standard of living in British Columbia is in part attributable to the role of the wood products industry in regional economic growth. This point is a useful reminder that some balance must be sought between demands for exclusive recreational preserve and the community's economic interest in timber production. Perhaps the reminder would be more effective if studies were available to show the real economic effects of park programs involving large land withdrawals, for example, the Nitinat Triangle. Recent discussions of impact have been most simplistic in suggesting straight line relationships between reduction in the allowable cut of timber and processing employment. For example, little or no attention has been given to the duration of employment losses which is an important impact measure when the economy is growing and new jobs are being created. Similarly, the role that intensive forest management has to play in replacing mature timber lost in park reserves and other land withdrawals is usually passed over.

NEGATIVE EFFECTS OF TIMBER PRODUCTION PRACTICES

Most people will agree that timber production activities can impair outdoor recreation experiences and can eliminate the possibility of outdoor recreation on specific areas for varying periods of time. The most contentious activities are harvesting (except selection cutting), road building, slash burning, and insecticide application.

How do the impacts come about? The precise effect of each activity will depend on:

1. Existing and expected demands for the site of a recreational experience

    If the existing demand for a recreational site is high, the impact of any timber production activity will be high. This is true whether the demand is local, for example where harvesting is planned along the edge of a fishing hole favoured by local inhabitants, or is provincial or even national in scope. Calculation of expected demand for a site is also important when estimating impact. However, before impact can be adequately assessed knowledge is required about future outdoor recreation and the many ways in which recreation planning can meet future demands.

2. Nature of the site

The degree of impact on a given recreational site depends on that site's physical and biological attributes, the degree of development which has already taken place, and its uniqueness. Camping sites occupy discrete areas of ground and have specific requirements of shade, water, drainage, and comfort. Timber production activities can destroy the site by altering any of these requirements. Their effect on a hiking trail which winds through the diverse features of a forested landscape may be less serious because the path of the trail can be changed. The biological attributes of a site influence its rate of recovery from the impact of timber production activities. Highly developed sites such as resort areas, related perhaps to some locally significant feature of the landscape, usually tolerate only a low level of timber production activities. Visible harvesting activities and slash burning are frequently viewed with displeasure.

There are some assets of the natural environment which are unique and irreplaceable. Because the supply is limited and interest in them is increasing, their value is high and also is increasing. Among these assets are rare animal and plant species and those parts of the landscape touched only lightly by man, and called "Wilderness" as a formal identification. In the case of rare plant and animal species of the forest, timber harvesting may destroy some essential element or part of their habitat, and the species, already in a precarious state, may become extinct. No case of extinction caused by timber harvesting has been documented in the Province, but it has been argued that harvesting should be prevented where there is any chance at all that this might happen. Protection for the coastal forest habitat of the Roosevelt elk on Vancouver Island is now being sought on these grounds. In the case of wilderness, the impact of timber harvesting or any other practice is clear. Even protection from fire contradicts the essence of wilderness.

A second kind of natural asset is not irreplaceable in the very long term, but its unique value may be lost within a portion of a person's lifetime and of the lifetime of their children. The impact of timber production activities is more widespread here. Enormous trees of the Coast forests fall into this category, for it is often remarked that we shall never see their like again. Unique panorama which are scarred by logging on sensitive sites where regeneration and re-growth is exceptionally slow, may also be irreplaceable for current generations. Fortunately, experience with widespread wildfire damage suggests that the scars are not longlived or at least the eye adjusts and may even note them as a feature of interest. The value of other unique phenomena is also impaired. Thus, the experience of visits to geological features, like the Bednesti eskers, for example, is reduced in value by the harvesting that has taken place there. Similarly, part of the experience of watching a salmon run is the beauty of the surrounding forest.

3. Nature of recreational activities

Recreation activities can be separated into those which are action oriented like mountain climbing, and those which are perception oriented, like driving through mountain scenery. Naturally, there are many activities which combine both, fishing being a good example. Nonetheless, the distinction is a useful one for examining impact. Recreational activities which are heavily action oriented may be able to tolerate higher levels of timber production activities. Rock climbers, for example, are notorious for their dislike of the initial walk to the rock face and therefore harvesting with its associated roads is often welcomed. On the other hand, removal of forest cover has a serious effect on perception-oriented recreation. Wilderness recreation, which demands a minimum of human interference with nature, is the extreme example.

4. Stage of the recreational experience

Areas of low demand which have no special features and attract only action-oriented recreation activities are capable of tolerating high levels of timber production activities without impairment of the recreational experience. However, when this experience involves a journey to one or more specific sites, what people see on the journey also impinges on the experience. The concept of recreational experience must therefore be expanded to include all phases from anticipation and planning through to recollection (10). This means, that the concept of site must be expanded to include the regional landscape. One this is done however, it becomes difficult to distinguish between outdoor recreation and the natural amenity values of landscape which businessmen driving from city to city or a farmer working in the region might enjoy. As might be expected, highly visible timber production activities have a high impact on the total recreational experience.

5. Natural amenities

Natural amenities such as clean air, clean water and scenic beauty are not site specific (Plate 15). The demand for their protection is ubiquitous. The effect of timber production activities on these amenities must therefore be given special attention. Priorities include major urban areas for all three amenities, and principal highways for scenic beauty.

Slash burning, which injects smoke into the air of the lower mainland regions of the Province for short periods has a very high aesthetic impact. Most harvesting systems and associated road building and slashburning in municipal watersheds have the potential of serious impacts on water. And the current public attitude toward chemical applications have raised their opinion of the expected impact of fertilizers and pesticides to a high level. Harvesting beside major highways by all but selection methods can have a large total aesthetic impact (Plate 15). Even though the area may be viewed for a short length of time at high speed, the number of viewers is high and the effect on their attitude toward timber production activities everywhere may be negatively influenced.

MANAGEMENT AND RESEARCH INITIATIVES

1. Conditions under which timber management practices have predictable adverse impacts and for which corrective procedures exist.

    a) Recreation areas of high current demand which have specific forest environment requirements (e.g.

(campsites) especially when well developed facilities are present or which are a location for perception-oriented activities with low tolerance to timber production activities, (e.g. fishing streams).

b) Areas with known unique or irreplaceable assets directly or indirectly associated with forest cover.

2. Conditions under which timber management practices have uncertain adverse impacts but require further definition, quantifying and development of ameliorating practices.

   a) On areas of heavy expected demand.

   b) On areas with suspected unique or irreplaceable assets (especially large wilderness area proposals by recreation groups).

   c) On areas with low but steady current and expected demand.

   d) On areas adjoining well travelled highways and significant urban areas.

   e) Where practices affect quality of air, water or scenery experienced by recreationists and residents alike.

   f) Where practices affect the natural diversity of plant and animal communities relative to recreational values.

To conclude, and in more general terms, recreation on forest land outside of parks deserves considerably more administrative and research attention than it has thus far received. Beyond general effects, little is known of specific timber production-recreation conflicts other than that they exist. There is a deficiency in what is known concerning the recreational opportunities that do exist in the Province, although the Canada Land Inventory has pioneered in amassing this type of data. Little is known of the demand for recreation - what people want from recreation, how much and what they are willing to pay. There are many questions concerning who should be responsible for providing facilities including safe access, and the types of facilities required. The role of timber management practices in enhancing recreation, including aspects of scenery and aesthetics, is not well understood.

Important phases of recreation are wildlife (plant and animal) viewing and photography. Investigations are required to determine whether timber harvesting would be beneficial in providing a diversity of habitats for wildlife in parks, wilderness and other areas presently protected from fire and logging.

SECTION VII

SUMMARY AND CONCLUSIONS

A central goal of this report has been the identification and assessment of problems associated with environmental forest management, particularly those requiring research attention. However, as can be seen from earlier discussions, environmental problems can not all be resolved by research alone, simple elimination of specific ecological impacts or other piecemeal approaches. An integrated multi-resource management strategy is considered essential for satisfactory problem solution and to place research needs in perspective.

Specific adverse timber management practice - environmental interactions, which are discussed in some detail and summarized in previous sections, are presented now in abbreviated form and in terms of short- or long-term actions. While the following lists are not complete, the problems identified are considered to be of major significance.

SHORT-TERM ACTIONS

In this context "short-term" refers to a period of about three years within which timber production practices, where necessary, can and should be modified to reduce their impacts on other resources. To facilitate the implementation of effective short-term actions, some background and guiding principles are offered.

PRODUCTION THEORY

The trade-off curves, AB and CD, in Fig. 5, are useful in showing those situations on which immediate actions should be concentrated (51). The curves show the physical capacity of a parcel of land to produce combinations of timber and some other forest resource. Further, their curvature indicates the degree of competitiveness between the two resource uses. In the case of curve AB, timber production and the other resource are relatively compatible because substantial quantities of each can be produced without great cost to the other. Curve CD, on the other hand, illustrates a very competitive situation. In this case, a higher proportion of the output of either resource must be given up to obtain any substantial output of the other. It follows that short-run actions should concentrate on:

- situations in which small decreases in maximum timber production will allow large increases of other resource outputs (curve AB),
- situations in which even a low level of timber production leads to a relatively high impact on another resource (curve CD), particularly if the impact of timber production is irreversible for a generation (25 years) or more.

GUIDING PRINCIPLES

Three principles can be applied to contemplated actions.

- The inability to place a firm value on a non-timber forest resource should not deter attempts to apply corrective action.
- Uncertainty about the exact shape of a trade-off curve should not deter ameliorative action.
- Flexibility should be the rule. In this regard, the "guideline concept" can be a useful tool for prescribing necessary administrative constraints on timber operations.

SPECIFIC SHORT-TERM ACTIONS

The following is a repetition (and in some cases, rephrasing) of possible short-run actions noted in "Impact" Sections III to VI.

1. To obtain adequate, prompt natural regeneration, plan harvesting operations with regard to such factors as species, size, arrangement and timing of clearcuts and site preparation practices.

2. Take all practical precautions to protect residual trees from mechanical damage and accelerated insect and disease development resulting from harvesting, site preparation practices and road construction.

3. To prevent fringe burns, escapes and their side effects, burn slash in weather and under conditions which maximize control.

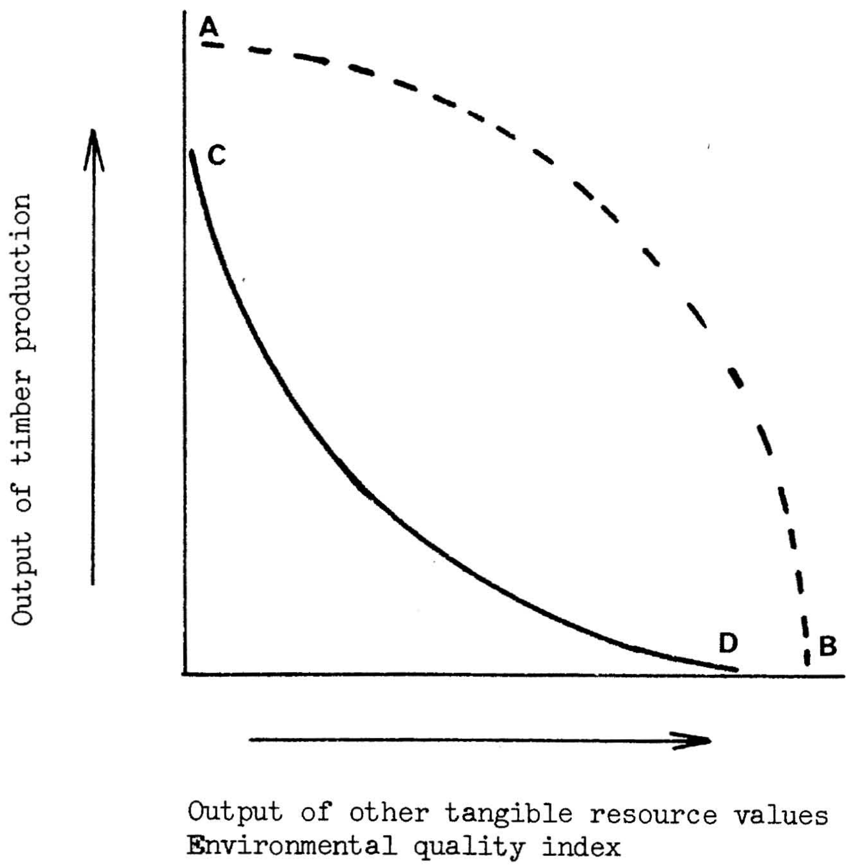

Fig. 5. Trade-off curves for relatively compatible (AB) and incompatible (CD) forest resource uses.

4. Stop clearcutting by access logging methods on moderate and steep slopes.

5. Adhere to slash burning guidelines to prevent accelerated erosion and reduced productivity on steep, rock outcrop slopes.

6. Avoid the use of wheeled or tracked skidders and other heavy equipment on wet sites.

7. Protect streams from direct damage by;

    a) prohibiting the operation of logging and road building equipment in streams,

    b) prohibiting the felling of trees into streams or the yarding of logs through them,

    c) ensuring adequate stream crossing procedures, including proper installation and maintenance of culverts and timely removal of temporary bridges,

    d) avoiding road construction near streams particularly during wet weather,

    e) eliminating the direct entrance of pesticides into streams.

8. Protect streams from indirect damage by;

    a) upgrading construction of all types of roads in accordance with known principles and guidelines,

    b) enforcing adequate road maintenance procedures, including provision of protective drainage measures for abandoned or temporary roads.

9. Prohibit logging on and construction of major haul roads through wild ungulate winter ranges.

10. Keep clearcuts as small as practical to minimize adverse effects of harvesting on wild animals and to enable full utilization of the cutovers.

11. Reserve and protect important game corridors.

12. Prohibit dumping of logs and debris in estuaries, and prevent landfilling and drainage of wetlands where important wildlife habitat is present.

13. Reserve and protect recreational areas;
    a) of high current demand,
    b) with specific forest environment requirements, e.g. campsites or areas supporting perception-orientated activities with a low tolerance to timber production practices.

14. Protect rare and endangered plant and animal species and other irreplaceable natural, physical and biological phenomena.

LONG-TERM ACTIONS

Short-term actions are important; however, to gain full value from the forest land base, longer-term and more fundamental measures are required. This work should begin without delay but because the required measures necessitate a new and wider knowledge base gained from surveys, research and testing supported by many disciplines (rather than the forestry profession exclusively) their successful application will require some time.

In addition, it is highly probable that planning for environmental forestry in the long term will require a critical appraisal of the existing institutional framework within which present resource decisions are made. The Province has already responded to this need first by establishing the Environment and Land Use Committee and now a Secretariat for that Committee. In this regard, and to put this situation appraisal of forest resource management and research needs into perspective, a brief review of some of the institutional questions is offered, concluding with a list of possible research initiatives.

ECONOMIC ASPECTS

The market place, while much affected by various government regulations and policies, is still the place to which timber management decisions must refer. The solution to negative impacts of timber production may be in making use of the market including the application of financial incentives not unlike those proposed to alleviate industrial water pollution problems. Incentives might be used in the following ways:

1. Increased allowable forestry costs for logging methods designed to reduce environmental damage.
2. Decreased stumpage charges for higher degrees of utilization.

In any event, it is essential to acquire an ability to forecast the effects of changes in resource management on regional economies and regions. A comprehensive, holistic approach is necessary; first, to identify the problems of environmental management; second, to identify possible alternative solutions; and third to evaluate the consequences of alternative actions. To accomplish these planning tasks, a regional approach is required and sophisticated computer modelling probably is necessary to handle the high degree of complexity likely to be encountered. For timber management problems this approach is being developed by Davis et al (14) among others.

ADMINISTRATIVE ASPECTS

The successful development of integrated resource management clearly requires an adequate administrative framework capable of handling the following problems:

1. Fragmentation of resource management jurisdictions at federal, provincial and regional levels.
2. Efficient and effective allocation of limited trained personnel and back-up services.
3. Development of management and planning procedures including provision for:
   a) critical examination of timber management practices and protective measures to determine if they are fulfilling stated objectives and to make corrections or modifications where necessary,
   b) supervision of field activities to ensure compliance with environmental guidelines, and
   c) continuing revision and updating of logging and other guidelines to incorporate new information.
4. Development of research planning, strategy and management in consideration of:
   a) establishment of lead agencies to define research

objectives and to coordinate research,

b) rigorous planning and evaluation of research projects to ensure that they conform with the defined objectives,

c) ensuring that adequate techniques are available for handling and integrating data, and

d) provision for evaluation of alternative management and timber production strategies.

SOCIAL ASPECTS

Environmental impacts or disturbances really only become problems when related to people using or affected by forests and forest land products. Further, because many of the values of the forest cannot easily be measured, people do not have a ready means of expressing their preferences. Some have chosen to take matters into their own hands and have formed special interest groups. Most sit on the sidelines despite the fact that they too might be affected. As a consequence, serious problems can be promoted by the assumption that the majority prefers one situation over another without their opinion actually being asked.

Means of assessing public preferences, are coming under scrutiny and experimental efforts to consult wide ranges of people who would be affected by major resource development policies are underway (58). Somehow, the need for public participation in resource-use decisions must be satisfied and the applicability of the foregoing efforts should be examined.

RESEARCH

The following is a repetition (and in some cases, rephrasing) of possible research initiatives in the long term noted in "Impact" sections III to VI. Presentation is in two parts; first, problems requiring an assessment of adverse effects and development or refinement of necessary corrective procedures, and second, conditions requiring an assessment of adverse effects and if any, whether corrective procedures should be sought.

1. PROBLEMS REQUIRING AN ASSESSMENT OF ADVERSE EFFECTS AND DEVELOPMENT OR REFINEMENT OF NECESSARY CORRECTIVE PROCEDURES

a) Future Wood Production

i) Increases in windthrow resulting from use of various harvesting systems, and actions such as preservation of streamside strips and wildlife corridors.

ii) Reduction of productive area through

- construction of roads, landings and associated cuts and fills
- sidecasting
- serious brush competition on high sites following use of clearcut and seed-tree harvesting systems.

iii) Reduced survival and tree growth following use of clearcutting or seed-tree harvesting systems resulting from

- creation of harsh microclimates, particularly in dry zones or at high elevations
- raising of water tables in already wet sites
- excessive scalping during scarification.

iv) Loss of soil through gullying and high surface erosion following such practices as road construction, felling, extraction, burning and scarification which result in

- removal of protective vegetation
- reduction of surface organic horizons and infiltration capacity
- change in runoff patterns.

v) Decrease in soil stability and productivity resulting from sidecast material produced from road construction, particularly on steep slopes.

vi) Loss of soil nutrients following slash burning or application of herbicides.

b) <u>Water and Fish Production</u>

i) Mass soil movement on inherently unstable or steep slopes resulting from clearcutting and road construction particularly in Coastal Western Hemlock and Mountain Hemlock Zones and in the Interior Western Hemlock and Englemann Spruce - Subalpine Fir Zones.

ii) Modified drainage patterns and subsequent accelerated erosion and washouts promoted by roads and inadequate drainage facilities, tree skidders and cable yarding.

iii) Changes in water yield and streamflow regime resulting in higher peak flows following clear-cutting, particularly in the Interior and on very large openings.

iv) Increased sedimentation and in-channel erosion promoted by forest land disturbance.

c) Wildlife Production

i) Reduction of breeding areas particularly in the subalpine zone.

ii) Alteration of plant species composition and diversity through harvesting practices, slash burning, scarification, pesticide applications, monoculture.

iii) Removal of cover through full tree logging or slash burning resulting in loss of small animal habitat.

iv) Increased accessibility and resultant animal harassment.

v) Loss of natural grasslands.

d) Recreation

i) Effect of proposed timber management operations on
- areas of heavy expected demand
- areas with suspected unique or irreplaceable assets
- areas with low but steady current and expected demand
- areas adjoining major highways and significant urban areas.

ii) Deterioration of the quality of air, water or scenery experienced by recreationists and residents alike.

iii) Reduction of natural diversity of plant and animal communities.

2. CONDITIONS REQUIRING AN ASSESSMENT OF ADVERSE EFFECTS, AND IF ANY, WHETHER CORRECTIVE PROCEDURES SHOULD BE SOUGHT

a) Future Wood Production

i) Changes in physical, chemical soil properties through soil compaction, removal of protective cover, increased decomposition of organic matter, alteration of drainage patterns and higher soil temperatures resulting from harvesting practices.

ii) Changes in microclimate through increased light, surface temperatures and wind, and moisture conditions resulting from harvesting and site preparation practices.

iii) Changes in biological component of soils by such site treatments as fertilization, application of herbicides and insecticides.

b) <u>Water and Fish Production</u>

i) Changes in water quality resulting from
- stream sedimentation caused by scarification
- fine debris input caused by winter skidding on or near streams
- nutrient leaching following clearcutting, slash burning and fertilization
- movement of pesticides into streams.

ii) Changes in streamflow regime resulting from
- effect of roads on stormflow runoff
- channel disruption and flow diversion following use of ice-bridges
- drainage of wetlands.

iii) Changes in stream environment resulting from removal of streamside vegetation with its effects on water temperature and terrestrial food sources for fish.

c) <u>Wildlife Production</u>

i) Timing and distribution of harvest and its effects on the provision of balanced animal habitats.

ii) Juvenile spacing, thinning and disease control and their effects on the health and habitat of animals.

d) <u>Recreation</u>

i) Road development and its effects on producing conflicts between competing user groups.

CONCLUSIONS

Forest resource management in British Columbia is currently undergoing a shift in emphasis from management for a single resource, timber, to management encompassing a multitude of resource values. Even so, in many areas, timber production is and will remain the dominant land use. In this situation, the immediate concern is one of managing for timber, while at the same time minimizing or avoiding environmental degradation or adverse effects on other resources. There are a number of short- and long-term actions listed in this report which, if taken, will aid in achieving these objectives. One of the most important short-term actions is increased provision for restocking deforested land. In the longer term, surveys and research undertaken within an ecological framework will be increasingly important tasks. As the timber production practices of clearcutting, road construction and slash burning produce the greatest potential impacts they will require the most attention.

Many of the present environmental problems result from the lack of cohesive approaches to the management of forest lands to satisfy a great number of social and economic demands. In this context, a fundamental need is an administrative framework responsive to public preferences and capable of minimizing or avoiding present resource-use conflicts. Improved supervision of operational activities is required to ensure proper application of guidelines. In addition, procedures should be established for critical, follow-up examination of management actions to determine whether or not they fulfill the stated objectives. Priority should be given to coordinating and completing comprehensive Province-wide inventories of resource and ecological data. Such data will aid in forest land zoning and delineation of sensitive or critical sites which are basic to the solution of many of the problems outlined in this report.

A fundamental need of integrated resource management which overlies biological and physical knowledge requirements is sufficient, accurate, economic information. Studies should be initiated to determine costs of timber production practices which have to be modified to reduce environmental impacts. In addition, a better appreciation is required of tangible and intangible values of the different resources and resource uses for rational development of management strategies.

Development, testing and implementation of computerized information systems are essential steps toward proper storage, organization, interpretation and easy retrieval of collected information. Simulation models and linear programming are recognized as important planning and decision-making aids for the complex problems posed by integrated resource management. Development and testing of regional socio-economic and physical-based models capable of successful prediction of the outcome or consequences of management actions are recommended.

It is recognized that activities or processes have already been initiated or modified to help answer some of the questions posed in this report. However, a great deal more effort ranging from administrative change to basic research is required if the goal of integrated resource management is to be attained. For research in particular, there is an urgent need to organize and co-ordinate activities on a multi-disciplinary and multi-agency basis. It is hoped that this appraisal will aid in this endeavour by stimulating discussion which will lead to further refinement and definition of specific research tasks and priorities.

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Appendix A ECOLOGICAL ZONATION

Krajina (35,37,38) has proposed a division of British Columbia into 11 biological zones based on climatic, biologic (primarily vegetation) and physical (soil, substratum, topography, etc.) characteristics[1]. Several of these zones are subdivided into two or more subzones with more uniform composition. The zones are named by one or more of the main climax tree species, by altitudinal or geographical position (e.g. Alpine Zone) or by some combination (e.g. Coastal Western Hemlock Zone, Interior Douglas fir Zone). The terms "Coastal" and "Interior" denote in general those areas west and east of the summit of the Coast Mountain Range, respectively. Besides stratifying the province into reasonably uniform climatic and vegetative areas, the Zones provide a basis for discussion of soils and vegetation succession and stability, and thus a basis for understanding effects of various forest management (silvicultural) practices on the site and on the surrounding environment.

Because of the wide variability in site within Zones, the discussions of silvicultural prescriptions usually must refer to smaller units. In this respect, most of the Zones have been studied to define forest associations representing a wide range of site conditions and forest productivity, e.g. low to high soil moisture, low to high nutrient levels. Using Krajina's (38) description, one can determine, for instance, that Douglas fir occurs in the drier subzones of the Coastal Western Hemlock

[1] A map, "Biogeoclimatic zones of British Columbia", is obtainable from the B.C. Department of Lands, Forests and Water Resources.

Zone but except for xeric (dry) sites, only as a pioneer (shade intolerant) species. It varies in productivity from SI_{100}=50 on shallow rock outcrop (lichen) sites to SI_{100}=200 on sword fern sites supplied with seepage. The effects of the same forestry practices on these two sites will differ greatly. As these effects are quantified for various sites, the value of the site classification will increase.

Appendix B

Plates 1-15

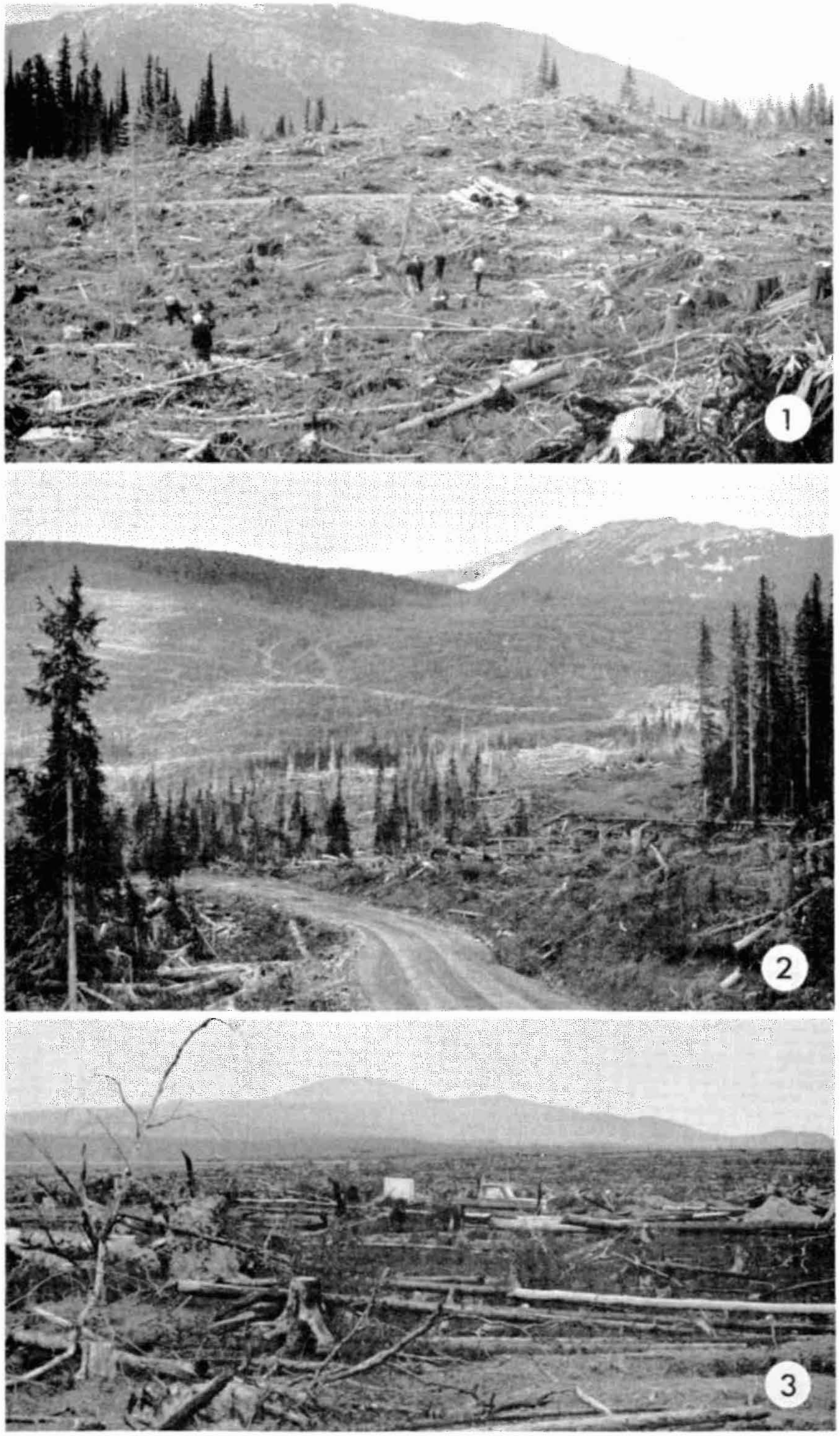

Plate 1. Large Clearcuts

Clearcuts larger than 100 acres are common throughout British Columbia (Figs. 1-3). Because of the limited dispersal distance of most seed and the periodicity of seed crops, many of these clearcuts will not restock sufficiently unless artificially reforested. Some exceptionally large clearcuts have been occasioned by salvaging bark-beetle attacked spruce stands in the Interior (Fig. 2).

Plate 2. Logging Damage to Individual Trees

Selective logging, such as practiced in portions of the Interior Douglas-fir Zone, may result in injury of leave trees by falling trees (Fig. 1) and by logging equipment (Fig. 2). The injuries predispose trees to attack by insects and decay-causing organisms and reduce the quality of the lower bole.

Plate 3. Winter Logging

Winter logging is less damaging to advanced regeneration and soil than is summer logging. It has, however, the disadvantage of increased waste through high stumps (Fig. 1). Also, stream damage may result from improper use of ice bridges which disintegrate during spring break-up (Fig. 2).

Plate 4. Slash-fire Escapes

Slash burns are occasionally accompanied by escapes into unlogged timber with resultant direct damage to trees, and, unless the trees are quickly salvaged, eventual deterioration by insects and fungi. Figs. 1 and 2 show how escaped slash fires have destroyed timber adjacent to the cutovers. The result in Fig. 2 was particularly destructive because the unlogged timber protected an extremely shallow-soiled site. Since the fire, the soil on the rock-outcrop site has been badly eroded leaving considerable exposed bedrock and a poor chance for natural regeneration or planting.

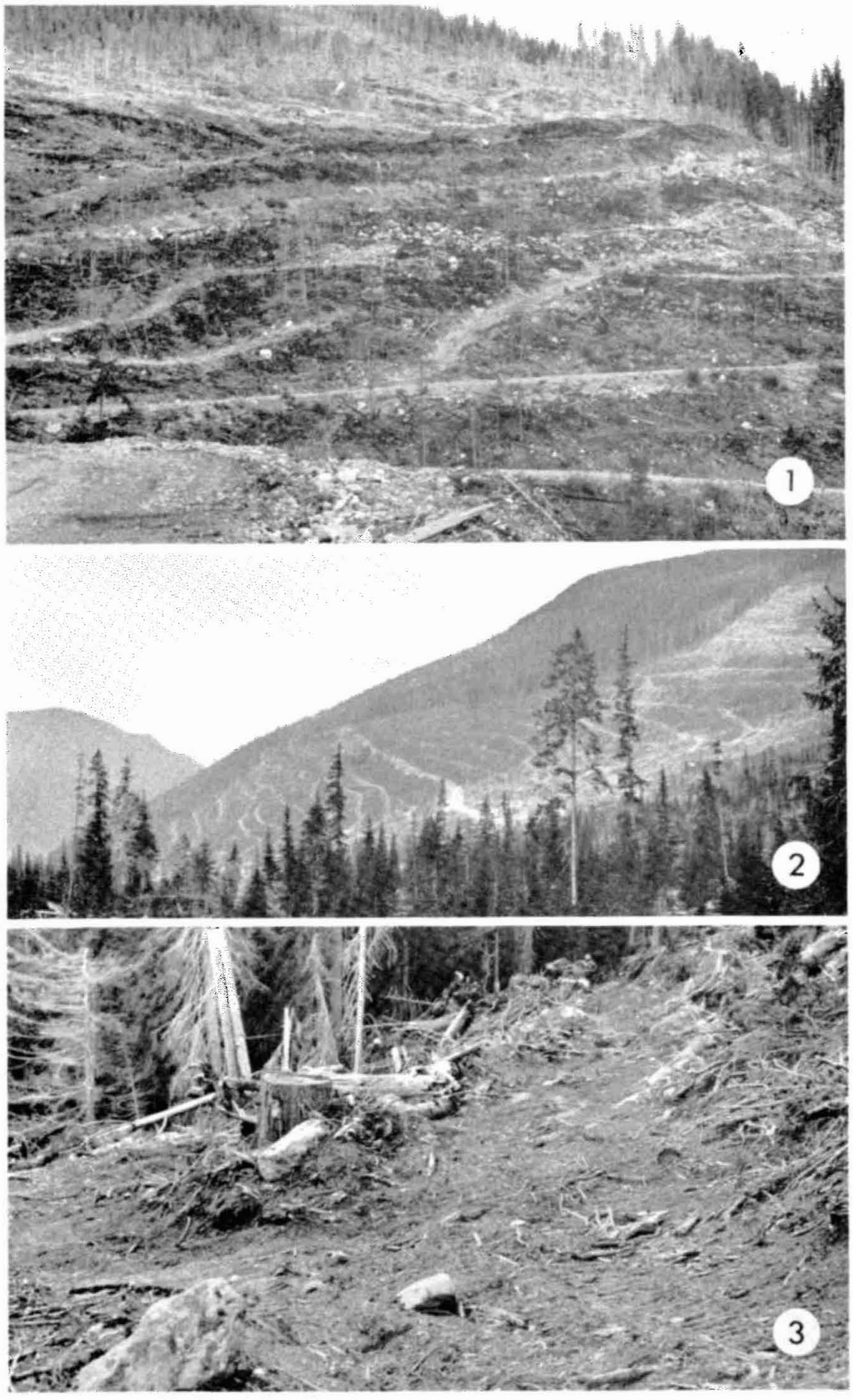

Plate 5. Area Disturbed by Skidroads

Tractor logging is the most common logging method employed in the Interior Western Hemlock, Interior Douglas-fir and Engelmann Spruce-Subalpine Fir Zones even on fairly steep slopes (Figs. 1 and 2). It results in a large percentage of the cutover area in skidroads and predisposes steep slopes to erosion (Fig. 3, Plate 9). High-lead logging has been used to a small extent in the Interior and where observed, soil damage on steep slopes was generally less than where tractor logging was used.

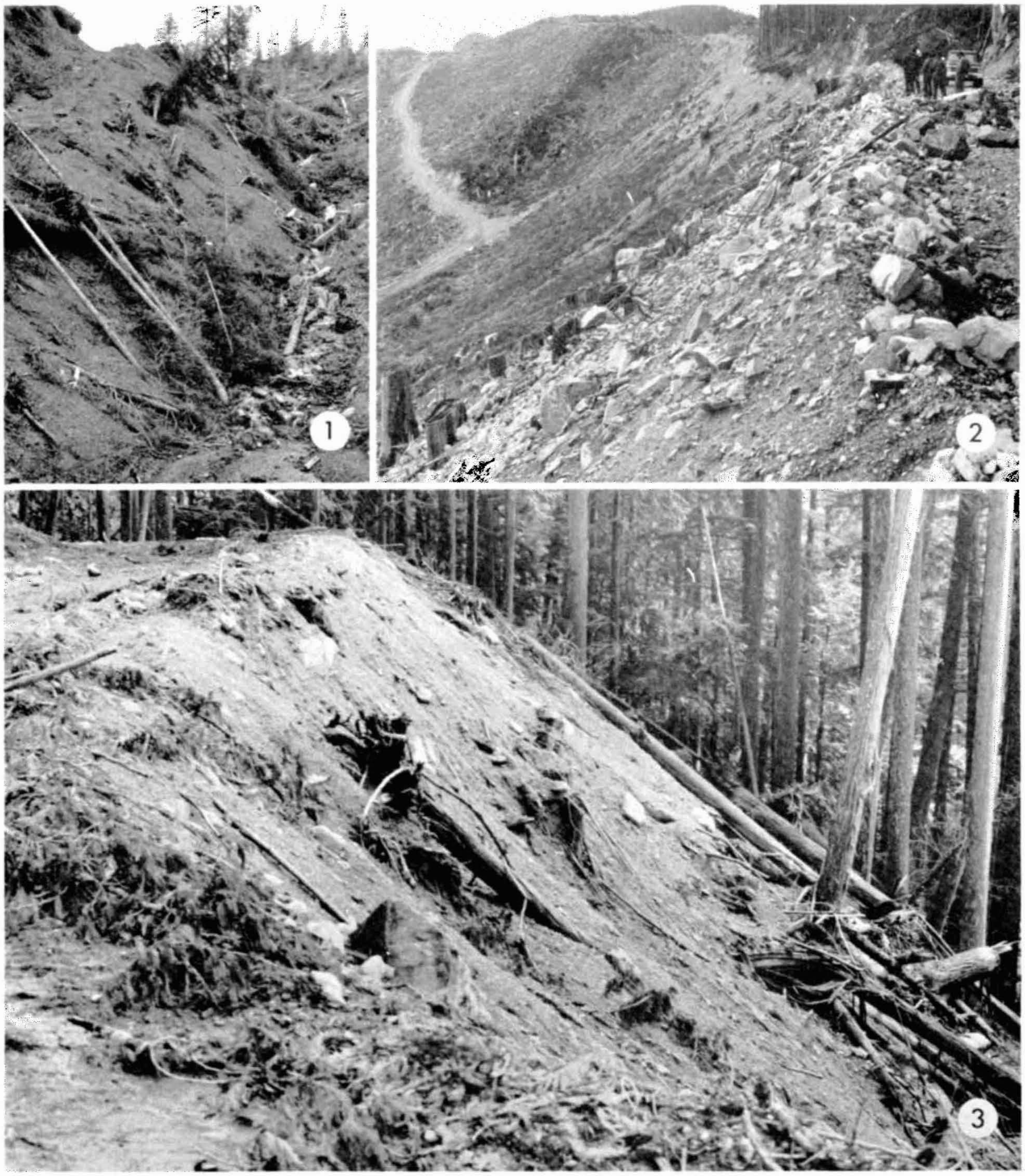

Plate 6. Sidecast Material from Road Construction

Sidecast material results from road building when cut and fill material is pushed over the lower edge of roads constructed on slopes. In addition to its effect on adjacent streams (Fig. 1), it also reduces productivity by covering considerable down-slope area with coarse and relatively infertile subsoil and blasted rock (Figs. 2 and 3). End hauling will reduce this effect and has been utilized to protect streams in some cases.

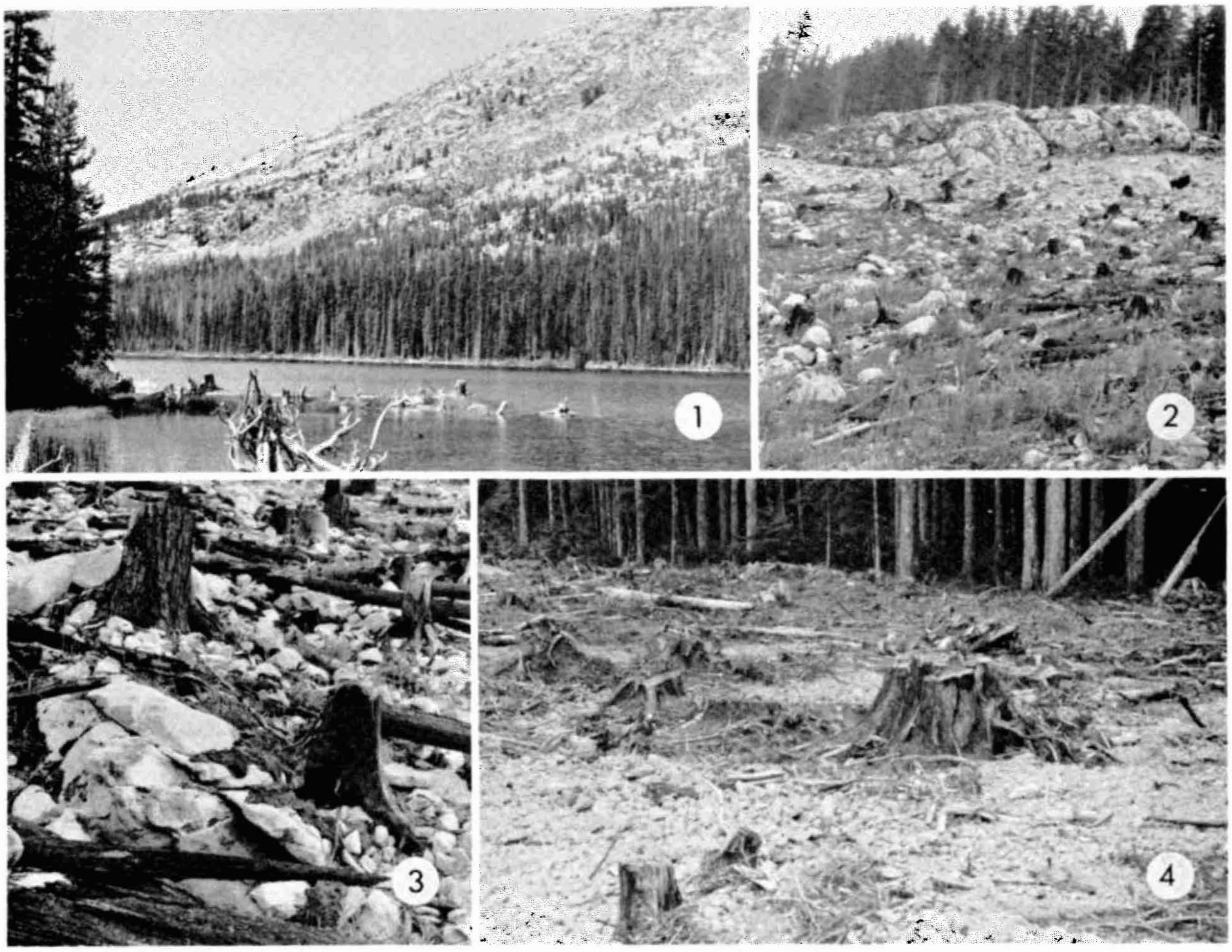

Plate 7. Fragile Sites

For reasons of extreme soil, topography or climate, some sites may be seriously damaged by logging and burning. The high-elevation site in Fig. 1 has been reduced to mainly bare rock after a wildfire. Even at low elevations, rock-outcrop sites will often present serious barriers to reforestation after logging and slash burning (Figs. 2 and 3). Some soils consist of only a thin organic-mineral layer over coarse colluvial rock. Erosion of the surface layer after logging leaves a poor site for tree establishment and growth (Fig. 4).

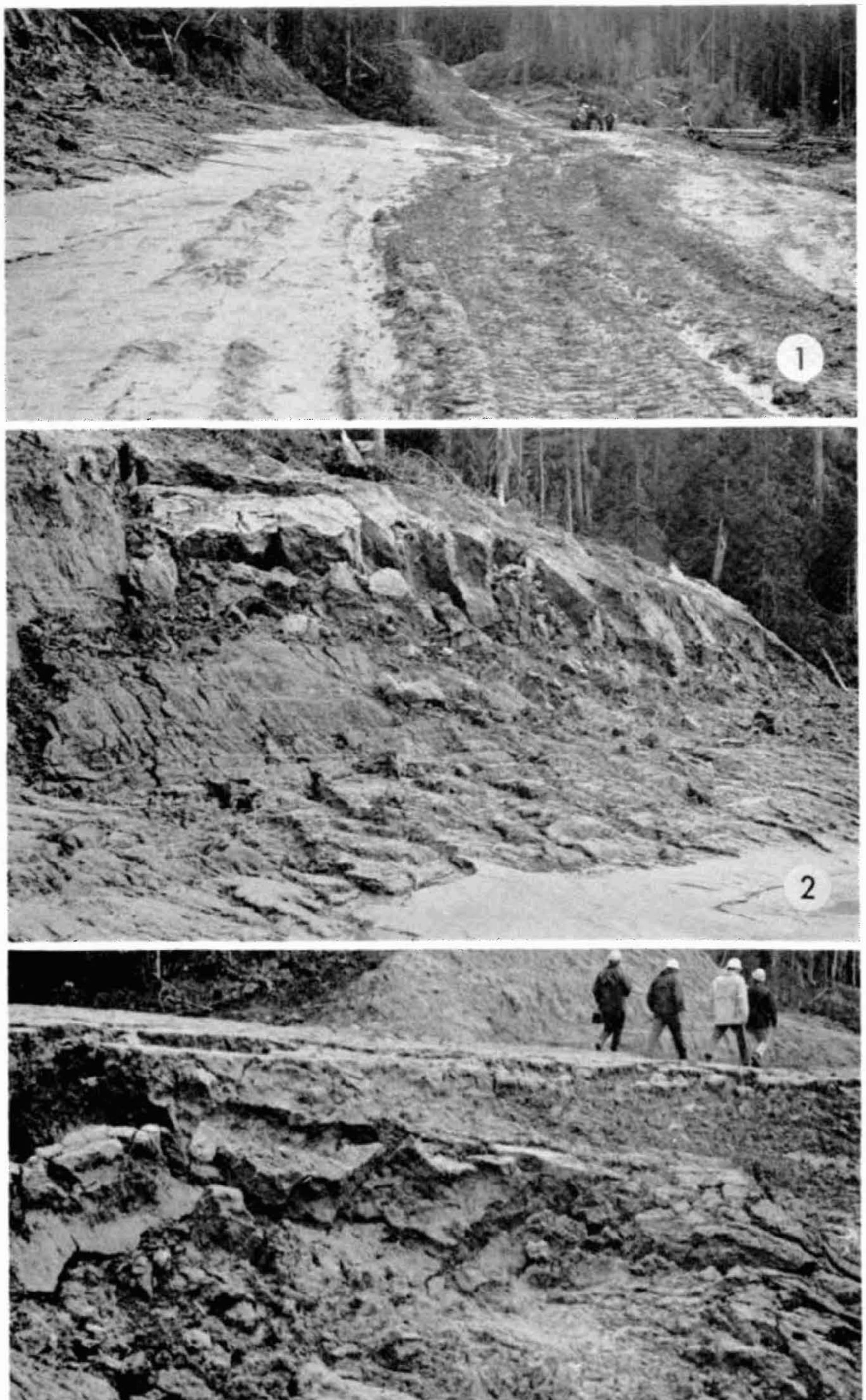

Plate 8. Logging Road Construction in Silty Soils

Winter road construction across a thick silt deposit resulted in the disturbance shown in Figs. 1-3. During the spring snow-melt period, this road was virtually impassible and served as a tremendous sediment source for nearby streams. Further along, the road was partially washed out where it crossed over a water-bearing ravine.

Plate 9. Improper Skid Trail and Culvert Construction

Fig. 1 illustrates a skid trail, which extended directly up slope from the main road for a considerable distance and channelled surface runoff which deeply eroded the skid trail itself. The culvert on the main road was unable to handle the excessive runoff which was then diverted across the road causing extensive erosion of the road surface and fill slope (Fig. 2). At the same site, water diverted by up-slope skid trails caused considerable erosion of the ditch and road edge (Fig. 3). In Fig. 4, the 30-inch culvert is clearly too small to handle flow from the 10- to 15-foot wide stream channel.

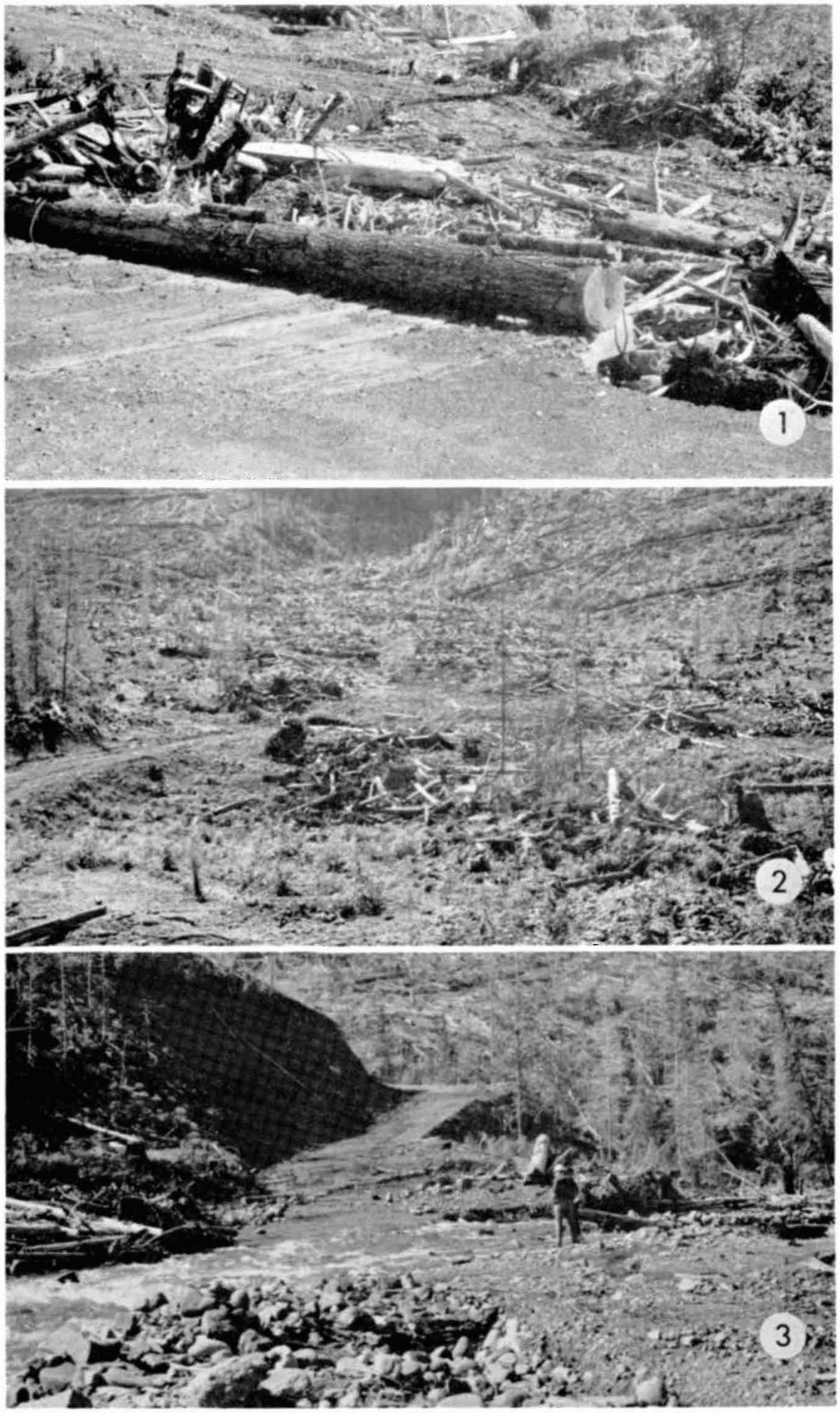

Plate 10. Debris-plugged Stream Crossings

In addition to direct channel damage, debris can plug culvert and bridge crossings causing road washouts and stream diversion. Fig. 1 shows a considerable amount of debris piled up behind a bridge located in a small valley bottom which was entirely logged over (Fig. 2). The stream was diverted by this debris jam necessitating creation of a new channel to concentrate the flow and avoid further extensive damage. Even then, road access was still impaired (Fig. 3).

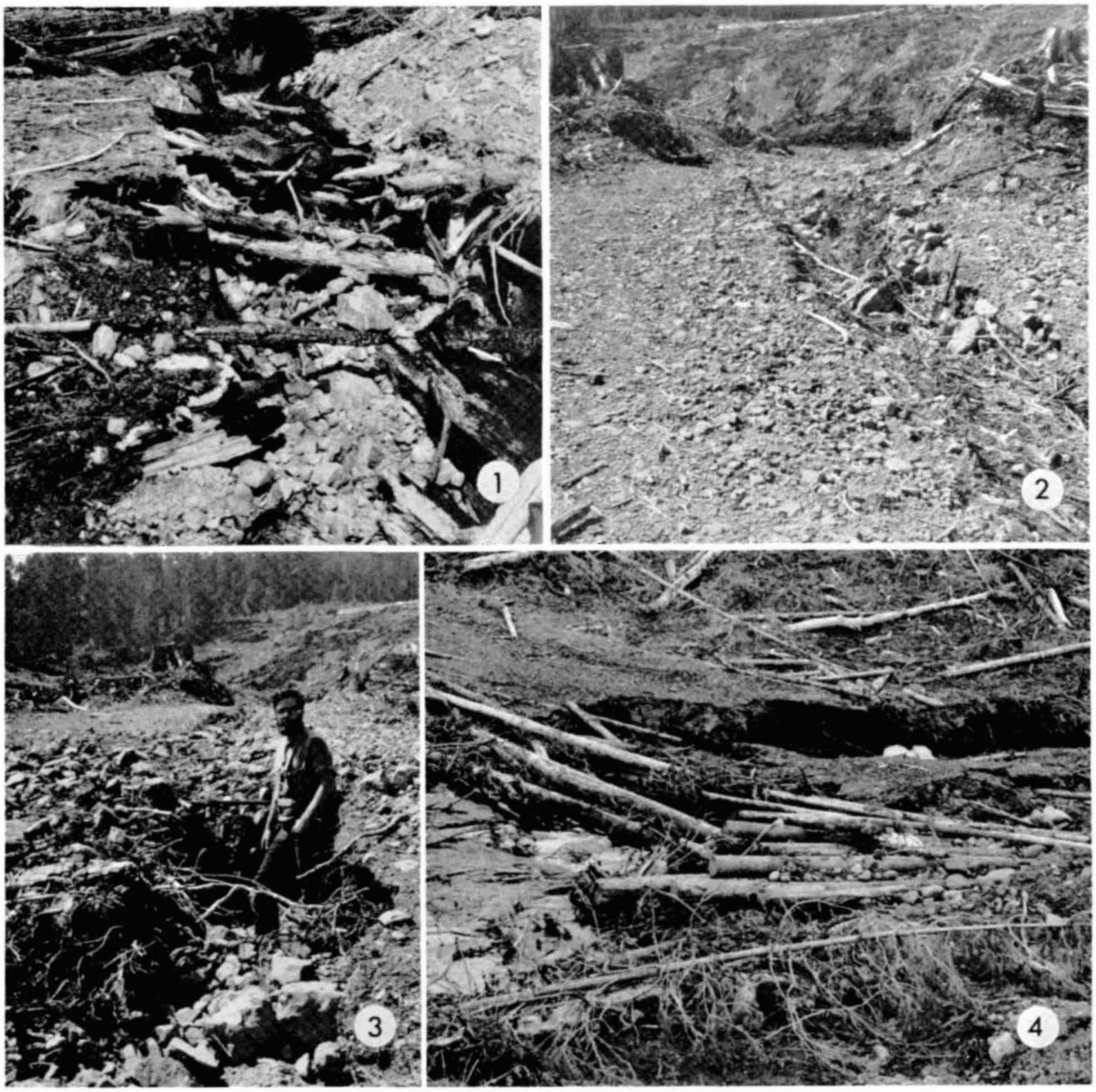

Plate 11. Road Erosion at Temporary Stream Crossings

Failure to remove temporary stream crossings can result in erosion and blockage of roads and scour and damage to stream channels and banks. Figs. 1-3 illustrate the results of filling a small drainage channel with earth in the dry season to facilitate logging activity. The temporary log bridge in Fig. 4 was washed out and eroded by spring snow-melt runoff.

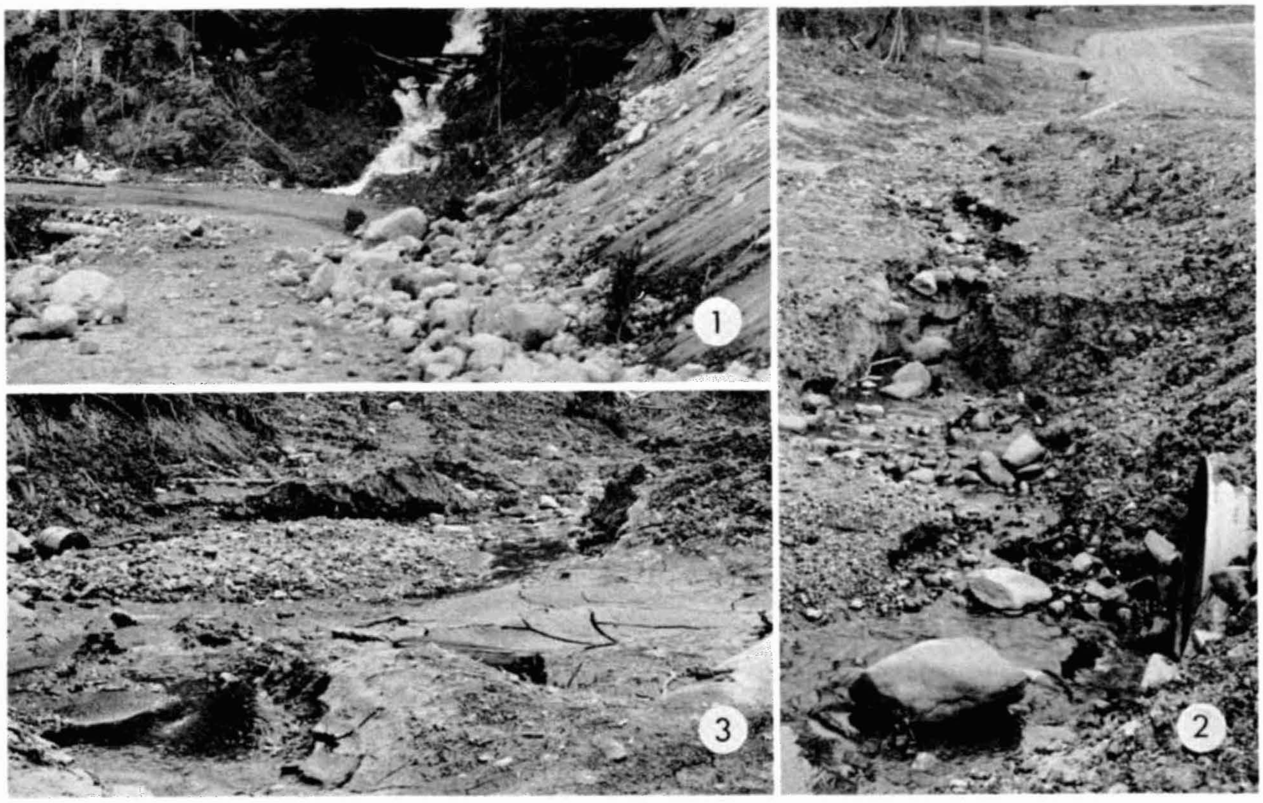

Plate 12. Road-caused Stream Sedimentation

Stream sedimentation results from a number of sources related to roads, of which three are illustrated above. Blockage of roadside ditches by cut-bank material can divert water which subsequently erodes the road surface and fill slopes on its way to the stream channel (Fig. 1). Direct water flow from ditches across exposed mineral soil can add considerable amounts of sediment to streams (Fig. 2). Operation of machinery in and near streams during road construction can produce continuing sources of sediment (Fig. 3).

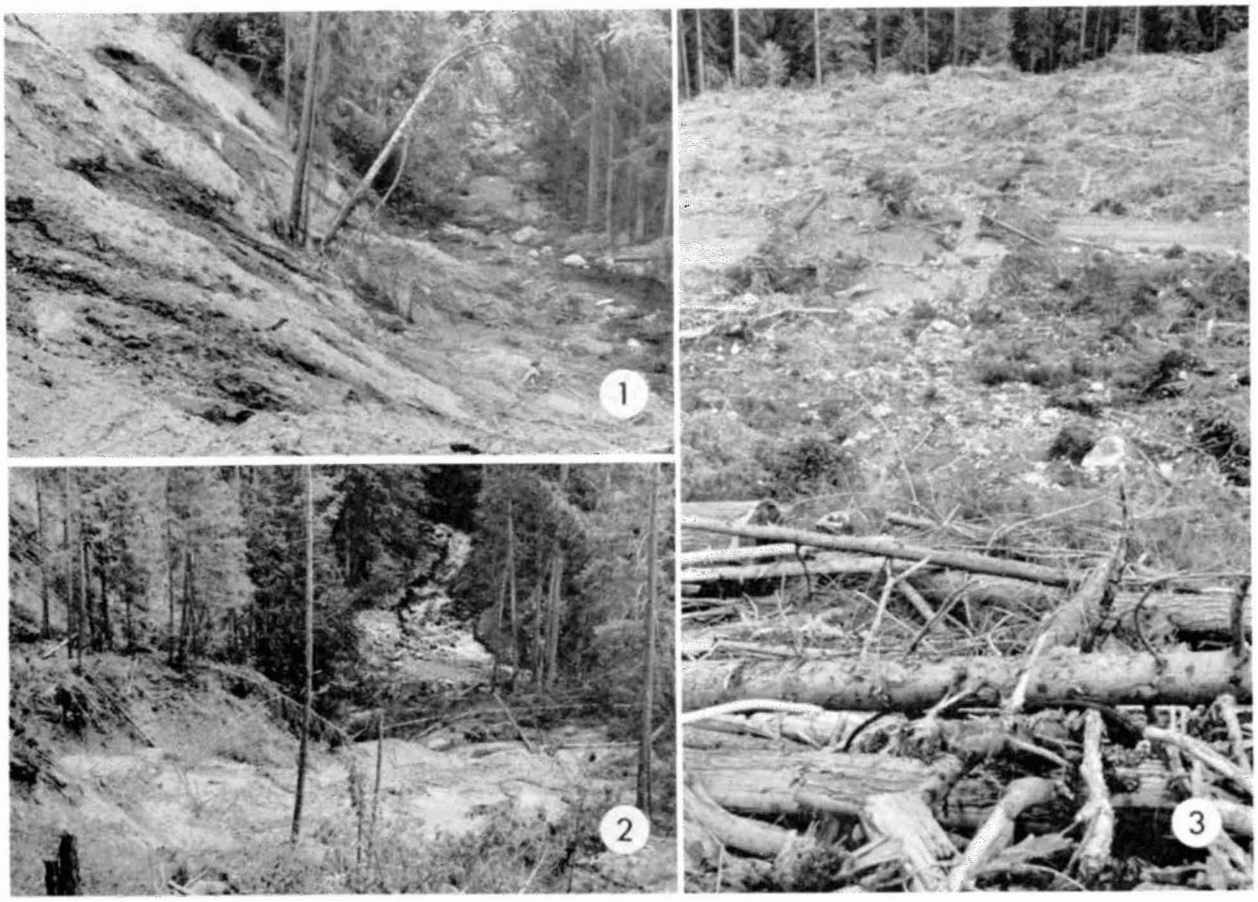

Plate 13. Roads and Mass Soil Movement

Logging roads and their interaction with water flow can be a major cause or initiator of mass soil movement. A road-bed failure caused by high spring sub-surface water levels in coarse gravelly outwash material and which resulted in stream sedimentation came unexpectedly after over 25 years of stable operational use (Fig. 1). A combination of mid-slope road construction and high spring snow melt resulted in the slide of Fig. 2 which cascaded down into the stream below. Water intercepted and concentrated by skid roads and then diverted onto the slope produced the slide in Fig. 3. In this case, the soil and debris did not reach a stream but road access was impaired and site productivity reduced.

Plate 14. Fringe Strips and Green Belts

Stream and lake protection through the use of unharvested fringe strips has had various degrees of application in British Columbia. The large creek in Fig. 1 is adequately protected by unharvested stands on the adjacent steep slopes. The smaller creek in Fig. 2 has been left entirely unprotected and even the hardwoods and understory conifers have been felled. The lake in Fig. 3 has been spared from harvesting to its shores and an attractive campsite has been provided by the forest company. The lake in Fig. 4 provides a contrast. The decision to log to the shore in this case was probably based in part on the lake's relatively remote location.

Plate 15. Aesthetics

In many cases, harvesting practices result in an overall reduction in aesthetic appeal rather than any specific effects on future productivity or damage to other resources. The creek in Fig. 1 may not be damaged in terms of fish habitat but its potential worth for casual recreation where scenic values are important has been reduced greatly. Operations such as the one illustrated in Fig. 2 are simply displeasing to the eye and disturbing to the mind. The logging operation shown had been halted temporarily leaving the felled and limbed logs. These will eventually be removed, but in the meantime, the average observer could not be blamed for feeling and expressing a concern. No attempt has been made to plan the logging shown in Fig. 3 to create a pleasing vista from the major, adjacent highway.