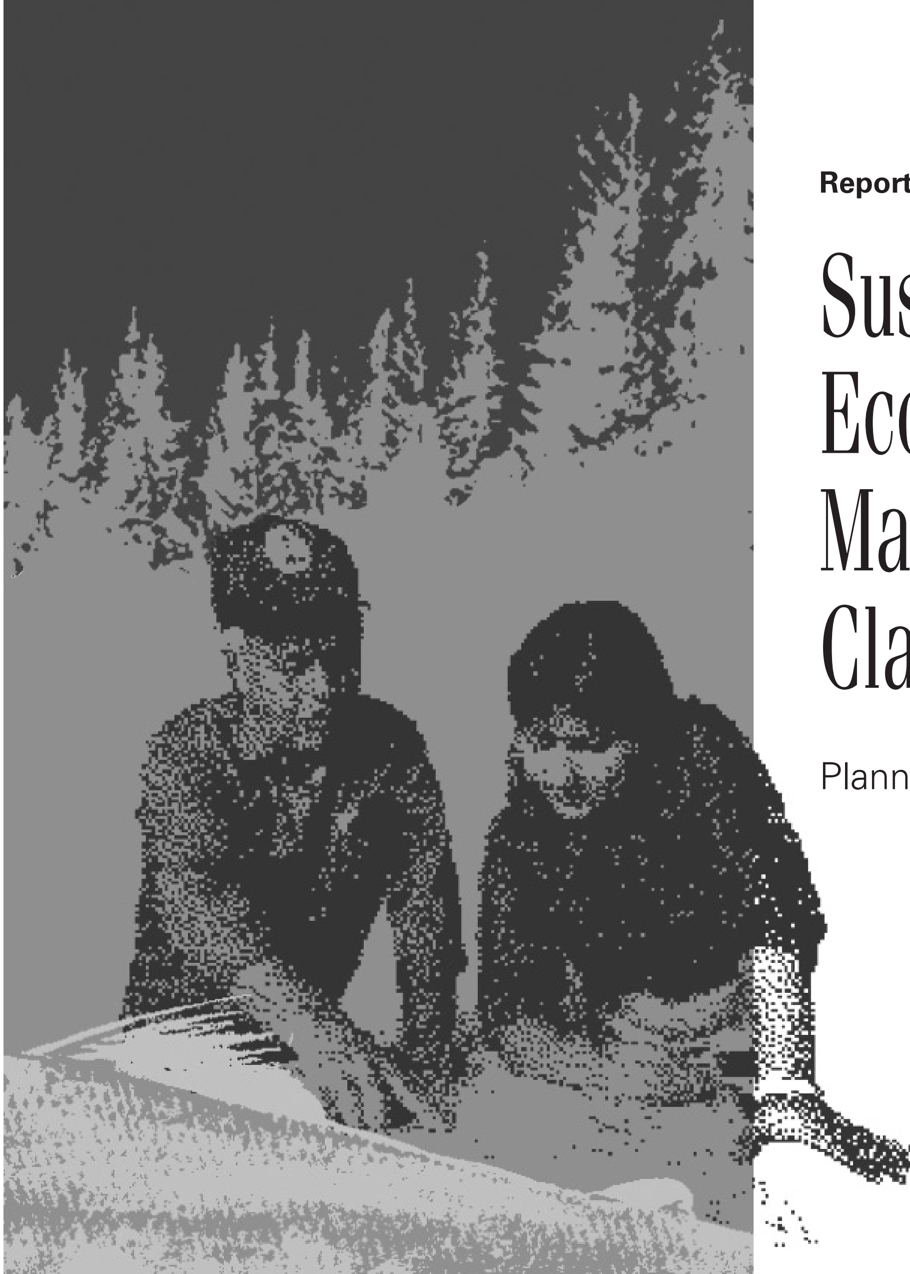
The Scientific Panel for Sustainable Forest Practices in Clayoquot Sound



Report 5

Sustainable Ecosystem Management in Clayoquot Sound

Planning and Practices

April 1995

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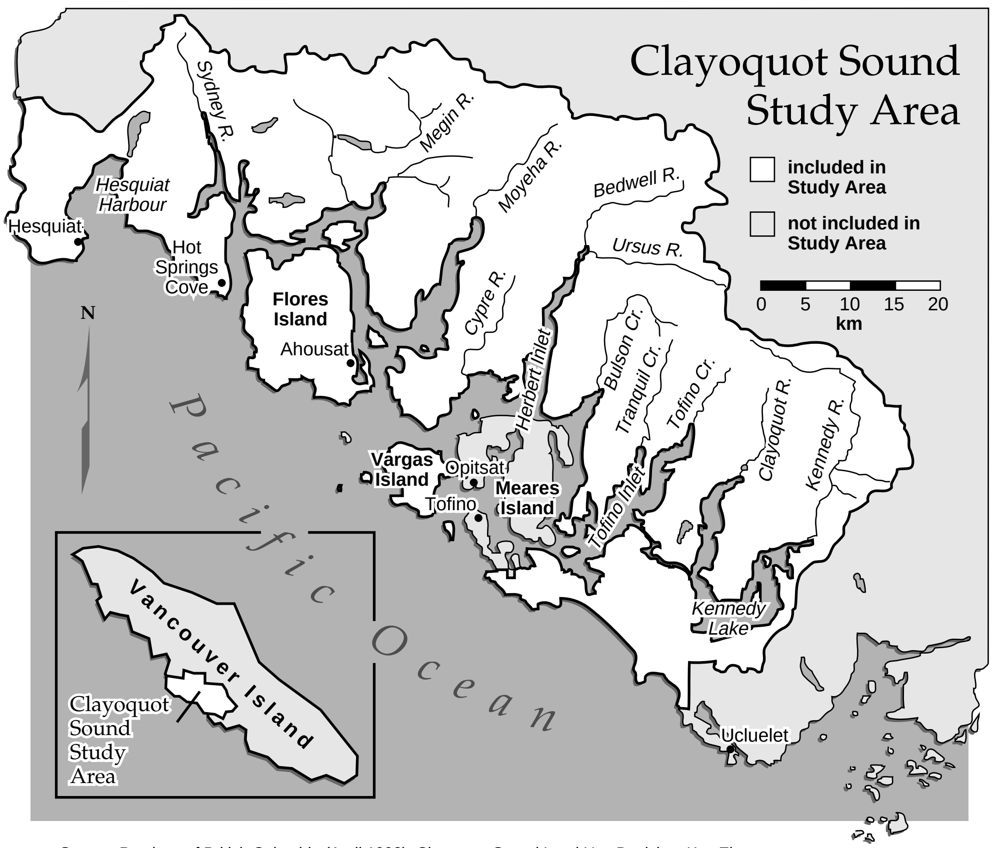

Source: Province of British Columbia (April 1993). Clayoquot Sound Land Use Decision: Key Elements.

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Executive Summary

This document presents findings and recommendations of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound based on its review of forest practices standards in effect in Clayoquot Sound as of September 30, 1994.

Panel findings note the extent to which current standards for forest planning and information collection, physical processes of timber extraction, and provisions for incorporating scenic, recreational, and tourism values meet precepts for sustainable ecosystem management.

Ecosystem management must acknowledge the physical structures, processes, and biological constituents of the ecosystem. This document describes those features for the Clayoquot Sound region and makes recommendations appropriate to their nature. Panel recommendations seek to create forest practices standards for Clayoquot Sound that are the best in the world.

Philosophy

Ecosystems, resources, and resource values are interconnected. The Panel asserts that sustainable forest practices in Clayoquot Sound must be judged by the extent to which all resources are respected and sustained. Sustainability depends on maintaining ecosystem productivity and connections.

Two key features have shaped the Panel's recommendations:

- recognition that ecosystems and the values with which they are imbued are dynamic, and that forest practices and policies must both anticipate and accommodate changing conditions; and

- recognition that forest practices and policies reflect the knowledge, understanding, and values in existence at a point in time.

For such reasons, Panel recommendations invoke the precautionary principle: act cautiously and make subsequent adjustments based on the application of methods tested and found successful in similar environments; support change by diligent monitoring of responses in the Clayoquot environment.

We do not know everything about the ecosystems of Clayoquot Sound, the technology of extraction, or the implications of new management options. The Panel's mandate is to provide informed advice, supported by science and the experience and knowledge of the Nuu-Chah-Nulth who made this area their home. Policy development and management must proceed adaptively.

Panel recommendations seek to define forest practices that are scientifically sound, operationally achievable, publicly acceptable, and safe. In its deliberations about appropriate forestry practices, the Panel respected the following priorities: safety, ecosystem integrity, operational effectiveness, and visual appearance.

Panel recommendations are intended to provide direction for developing standards that are measurable and enforceable.

Physical Environment

Standards for silvicultural systems, harvesting, and log transport were assessed in light of the physical characteristics and land-shaping processes of the Clayoquot Sound region. Major characteristics of the Clayoquot Sound environment and their implications for management are summarized in the following table.

Characteristic	Management Implication
Heavy precipitation delivers large volumes of water onto steep slopes of mountains; strong winds accompany winter storms.	Rates and patterns of forest removal must be prescribed to minimize disturbance to natural runoff mechanisms and to maintain hydrological regimes within the range of natural variation.
Shallow surficial materials are prone to surface erosion and landslides in the prevailing wet climate when protective vegetation is removed. At many sites, the forest floor layer constitutes the entire soil over bedrock.	Forest practices should strive to maintain the organic layer of forest soils because it contains virtually all of the available nutrients, has high water-absorbing and water-retaining capability, improves soil porosity and permeability, and protects the mineral soil from surface erosion.
Steep slopes, climate, and hydrology create conditions of potential instability in surficial materials. Debris slides and debris flows are triggered by heavy rainfall on ground already saturated by rain.	Clearcutting and roadbuilding increase the frequency of these kinds of landslides. Terrain stability assessment should be undertaken to identify sensitive sites.
Debris slides, debris flows, rockfalls, and shifting stream channels contribute to the natural pattern of forest disturbance. Windstorms are the most common natural agent of forest renewal in Clayoquot Sound.	A dramatic change in the rate of disturbance or rates of erosion may change the balance of available habitats and the viability of species. The rate and distribution of harvest must be planned carefully to minimize negative effects.
Vegetation development is affected by the natural disturbance regime.	Forest practices that approximate natural disturbance regimes help to retain ecosystem processes and maintain ecosystem productivity and connections.
Clayoquot Sound's almost continuous old-growth forests are characterized by uneven canopies with gaps where old trees have died and young ones are regenerating.	Retaining some near-continuous, older forest cover, including large live trees, snags, and downed wood, is particularly important to the region's biological diversity.
Much of the richness of resident terrestrial vertebrates is attributable to varied, complex forest cover.	Forest management regimes should maintain variety in forest structure and species in keeping with that found in unmanaged stands.
The forest canopy affects wind, light, diurnal variation in temperature and moisture, and seasonal patterns of snow accumulation and melt both within the stand and in adjacent open areas.	Forests buffer environmental effects; the pattern and timing of their removal or retention should consider effects on other resources.
The native vertebrate fauna of Clayoquot Sound is shaped by and adapted to an environment strongly influenced by water and dominated by near-continuous, long-lived forests.	Forest practices that significantly modify riparian or aquatic ecosystems can adversely affect many species. Reserves help to maintain and protect old-growth, aquatic, and riparian ecosystems.

The hydroriparian ecosystem—comprised of waterbodies and the immediately adjacent terrestrial environment—deserves special consideration in forest planning and management in Clayoquot Sound. It links estuary to alpine environments, is the focus of activity for a large portion of all fauna, and contains the most diverse flora in a watershed. Populations of some species rarely move between watersheds.

Forests in riparian areas play critical roles in shading, food production, and food-gathering processes within streams. These forests affect the rate of water movement through the soil, are the source of whole trees and smaller wood fragments that help to store gravel in the stream channel and provide habitat for a variety of aquatic organisms, regulate stream velocity, and influence stream channel morphology.

The hydroriparian ecosystem is the major travel corridor for many terrestrial and all aquatic organisms—essentially the skeleton and circulation system of the ecological landscape. About 72% of forest-dwelling vertebrates in Clayoquot Sound use riparian areas. Streams, lakes, and estuaries all provide incubation and rearing environments for trout and salmon. Linkages from terrestrial riparian systems to streams continue to the sea.

These land-water systems are strongly affected by logging and roadbuilding activities which can alter channel morphology, hydrology, water quality, and shading or thermal regimes. Events far upstream, well removed from spawning areas, can influence downstream characteristics and organisms. Changes in the riparian environment that modify physical processes or alter food availability influence the invertebrate faunas and thus may alter fish species composition or abundance. These points emphasize the importance of maintaining vegetation in riparian areas, restricting rates of forest removal (rate-of-cut) within watersheds, carefully locating and constructing roads, and treating watersheds as discrete units.

Key recommendations related to the hydroriparian zone include:

- adopting a new classification system based on characteristics of waterbodies and surrounding land;
- designating the entire hydroriparian zone as a special management zone; and
- defining areas entirely reserved from harvest, or where harvest and road construction are constrained, based on the classification system.

Planning

The Scientific Panel recommends an ecosystem-based approach to planning in which the primary planning objective is to sustain the productivity and natural diversity of the Clayoquot Sound region. Planning at a variety of spatial and temporal scales is critical at all stages of forest ecosystem management.

The Panel recommends three levels of planning—subregional, watershed, and site—and a planning process that is informed, iterative, and adaptive. Each level of planning defines the level beneath it, and lower levels provide details for interpretation and analysis at higher levels. The size, planning focus, and time frame of each recommended planning level is summarized in the following table.

Planning area	Map scale	Planning objectives	Time frame	Other comments
Subregional planning level				
Large areas consisting of aggregations of watersheds; generally greater than 50 000 ha.	1:50 000 to 1:250 000	To identify watershed-level planning units and plan linkages among them. To assess and plan for resources (e.g., scenery, recreation, habitats for wide-ranging wildlife populations) that span large areas. To coordinate and plan monitoring activities for subregional, watershed, and site levels.	100 years with major revisions every 10 years or as required.	Maps should be compiled that integrate all resource information, land-use zones, and locate corridors for recreation or animal migration. Extraction activities that cross watershed boundaries, and locations of cultural, scenic, and recreational resource areas should be identified.
Watershed planning level				
A single watershed or a group of contiguous watersheds; 5 000–35 000 ha.	1:10 000 to 1:20 000	To identify and map reserves and harvestable areas within the watershed planning unit.	100 years, showing projected activities in 10-year increments; revisions every five years or as required.	Reserves are intended to maintain long-term ecosystem integrity, protect First Nations' culturally important areas, and protect recreational and scenic values. Each working unit within the harvestable area must be planned in relation to other existing and potential units.
Site planning level				
One or more discrete units ("working units") proposed for a specific management activity; one hectare to several tens of hectares.	1:2000 to 1:5000	To develop management plans within harvestable areas. In areas identified for resource extraction or development, to determine appropriate levels of retention and appropriate harvesting methods.	10 years, starting five or more years ahead of the work, with revisions every year during active operations.	Site-level planning covers many types of sites and working units; e.g., areas proposed for logging (cutting units), recreation (recreation units), or specifically managed habitat for species at risk (wildlife units).

The planning approach recommended by the Panel differs from current planning methods in three major ways:

- planning is area-based, rather than volume-based;

  The planning process identifies the *area* in the watershed available for timber production, specifies a rate (percentage of area per year) at which the watershed can be harvested, and identifies the locations where harvesting may occur.

- forest reserves, based on credible biological and physical criteria, are designated at the watershed level *before* the delineation of harvestable areas and subsequent planning of specific forestry activities; and

- the timber volume available for harvesting each year from a watershed planning unit is determined by the planning process and depends on the characteristics of the area available for harvesting.

  These harvest levels functionally replace the allowable annual cut in defining expectations for harvestable wood volume from planning areas.

The recommended shift to area-based planning is critical to successfully implement other Panel recommendations and to achieve sustainable ecosystem management. Watershed-level planning is key because the cumulative effects of all land-use activities create stress on ecosystems within individual watersheds.

Managing for Timber Production

Most standards regulating forest practices in coastal British Columbia assume that clearcutting is the silvicultural system of choice. In Clayoquot Sound, clearcutting has been the predominant silvicultural system.

While size of cutblocks and means of forest removal have changed over the past few decades, major impacts of clearcutting and associated road construction remain:

- the essentially even-aged stand structures differ significantly from those created by the natural disturbance regime;

- the morphology of stream channels has been substantially disturbed; and

- other forest values, including cultural, scenic, and recreational, have been negatively affected.

In keeping with the goal of sustainable ecosystem management, the Panel recommends a shift in both planning and implementing timber harvesting—from a focus on the trees removed during harvesting to the trees retained. This shift is embodied at the watershed level by delineating reserves to protect ecosystem integrity and forest values, and carried through at the site level by specifying trees to be retained in individual cutting units.

The *variable-retention silvicultural system* recommended by the Panel provides for:

- the permanent retention of forest "structures" or habitat elements (e.g., large decadent trees, or groups of trees, snags, and downed wood) from the original stand that provide habitat for forest biota; and

- a range of retention levels.

The type, amount, and spatial distribution (e.g., aggregated in small intact patches or dispersed as individual trees or snags) of the retained material depend on site characteristics and management objectives.

Specific recommendations under the variable-retention silvicultural system include:

- on cutting units with significant values for resources other than timber or with sensitive areas, implement high levels of retention—at least 70%;
- on cutting units without significant values for resources other than timber or without sensitive areas, implement lower levels of retention;
- retain a minimum of 15% of the original stand on all cutting units with the exception of very small cutting units (less than four tree heights across); and
- retain a representative cross-section of species and structures of the original stand.

Maintaining the natural size- and age-class distributions of trees helps to retain the natural functioning of the forest-dwelling biota and sustain environmental integrity. Retention silvicultural systems meet many ecological objectives, and facilitate protection of culturally important sites, and scenic and recreational values.

Yarding methods, the means of moving logs from where trees are felled to where they are loaded for further transport, are critical to attaining variable-retention silvicultural objectives. The variable-retention silvicultural system requires yarding methods that:

- are efficient and safe;
- can accommodate different levels and distributions of retention;
- are appropriate to steep slopes;
- minimize soil disturbance and damage to retained trees; and
- require low road densities.

Maintaining log control during yarding is critical to minimize site disturbance, and to maximize yarding productivity in variable-retention silvicultural systems. Lateral reach and partial to full suspension capabilities are often required. For these reasons, skyline yarding is the cable-yarding method best suited for retention silvicultural systems. Ground-based systems can also be used where their impact on the soil and damage to the residual stand is not excessive. Most yarding equipment currently used in Clayoquot Sound can be adapted to a variable-retention silvicultural system.

Logs and other partly manufactured forest products are transported by both roads and water in Clayoquot Sound. The road network is used for hauling logs, access by workers, moving equipment (including heavy equipment), and access by recreational users and residents. Water transport is used to move most logs in Clayoquot Sound to processing facilities.

Roads alter slope hydrology and represent a potentially significant source of negative impacts on slope stability, stream morphology, and water quality. Existing road standards are insufficient to ensure that terrestrial and aquatic ecosystems are adequately protected. With respect to roads, Panel recommendations include requirements for:

- road location decisions to reflect the following priorities:
  - protect sensitive terrain (e.g., stability class V), rare habitats, active floodplain areas, and heritage and cultural features;
  - maintain watershed integrity and ecosystem function; and
  - mitigate potential damage to scenic or recreational values;
- the maximum percentage of the *harvestable area* designated for permanent access (roads and landings) to be determined on a watershed-specific basis, and, in general, to represent less than 5% of the harvestable area in a watershed (7% is allowed under current standards);
- full bench cuts and endhaul construction on main or branch roads consistently greater than 55% slopes; and
- revegetating (preferably with indigenous, non-invasive species) all disturbed areas associated with roads.

During the last two decades, major log handling improvements have reduced the impacts of log dumping. Most logs are now sorted and bundled on land, and dumped into the water for storage before transporting to manufacturing centres on log barges. Sheltered waters, however, are still used for dumping, limited sorting, and booming of logs. To protect the important biological and cultural values of estuarine and marine environments, the Panel recommends:

- developing comprehensive standards for log dump development, operation, and maintenance;
- undertaking ecological, physical, and impact assessments on all proposed log dump sites;
- minimizing the time that logs are in water, especially shallow water;
- locating log dumps at sufficient distances from sensitive areas and at sufficient depths to avoid problems; and

- restoring sites damaged by excessive accumulations of bark, woody debris, or fine organic material.

Education and training programs will be required to provide forest engineers, technicians, and forest workers with the knowledge and skills to plan and implement a variable-retention silvicultural system, appropriate harvesting methods, and environmentally sensitive transportation systems. Training must address both silvicultural objectives, such as habitat and biological diversity, and operational constraints, such as harvesting system requirements, road location and construction requirements, windfirmness, and yarding patterns.

Human Values

Clayoquot Sound is important to people for cultural, spiritual, and scenic values, and for recreational and tourism use. Most residents are economically dependent on local forest and marine resources. Landscape appearance is important to residents and visitors alike for aesthetic reasons and as an indicator of forest health. By recommending forest practices that sustain ecosystem integrity the Panel has sought to secure economic benefits and human values for current and future generations. First Nations' values have been addressed specifically in the Panel report *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound.*

New approaches to scenic resource management have been occurring in Clayoquot Sound as part of the Scenic Corridors Planning Process. Many of the Panel's suggestions for improving integration of scenic values into forest planning have already been implemented in this process.

Other Panel recommendations for incorporating non-timber values in forest practices standards include:

- involving provincial, regional, and local governments, First Nations, recreation and tourism groups, industry and other public groups in inventory, analysis, and planning of scenic, recreational, and tourism resources;

- developing an inventory and analysis system for scenic resources and preparing a long-term plan for managing and protecting these resources;

- developing a new scale to describe visual quality objectives that is easier for the public to understand, is unrelated to silvicultural system terminology, and accounts for uses other than forestry;

- developing plans for recreation and tourism at subregional, watershed, and site levels; and

- integrating the planning of visual landscape management, recreation, and tourism with forest planning and management.

Monitoring

Monitoring is an essential part of active adaptive management and improving management practices. Monitoring in the forest ecosystems of Clayoquot Sound will have three goals:

- to ensure that forest activities and practices comply with prescribed standards for ecosystem integrity and cultural integrity;
- to determine whether the forest practices standards adopted for Clayoquot Sound are appropriate for the intended management objectives; and
- to improve the basis for understanding mechanisms, both natural and those induced by human activity, that cause events and create changes in the ecosystem.

Panel recommendations emphasize the second goal—monitoring to evaluate success in attaining objectives. This requires a long-term monitoring program covering areas that are reserved from land-use practices and areas that will experience land-use practices. To this end, the Panel recommends objectives for monitoring:

- watershed and coastal integrity – including hillslopes and forest soils, stream channels, regional streamflow and water quality, and the coastal zone;
- biological diversity – including genetic variation, vulnerable and rare indigenous species, terrestrial environments, old-growth characteristics, and aquatic environments;
- human activities and values – including areas important to First Nations; scenic, recreational, and tourist values; and regional commodity production; and
- implementation of forest management plans.

For each of these areas, the Panel discusses key indicators for evaluating the success of sustainable ecosystem management, as well as specific monitoring activities. In some cases, alternative monitoring procedures are presented.

Local interest and involvement in monitoring are essential to the success of a monitoring program. To assure program efficacy and technical excellence, a professional land manager is also required. Because of labour requirements, the value of cumulated experience in many aspects of monitoring, and the need to secure local commitment to ensure the continuation of the program, many aspects of monitoring should be the responsibility of participants from local communities.

Clayoquot Sound is an excellent place to test the concept of local responsibility for sustainable ecosystem management.

1.0 Introduction

1.1 Panel Mandate

The Panel's goal is to make forest practices in Clayoquot Sound the best in the world.

This is the fifth, and final, report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound.[1,2] The Scientific Panel was established in response to a recommendation from the Commission on Resources and Environment following the provincial government's April 13, 1993 decision on land use in Clayoquot Sound. The Panel is charged with scientifically reviewing current forest practices standards in Clayoquot Sound and recommending changes to existing standards to ensure that these practices are sustainable. The Panel's goal, as defined by Premier Harcourt, is "to make forest practices in Clayoquot not only the best in the province, but the best in the world."[3]

The Panel's terms of reference focus on defining sustainable forest practices for the General Integrated Management Area as designated in the *Clayoquot Sound Land Use Decision* April 13, 1993. This report, however, considers the Clayoquot Sound region as a whole, particularly when discussing the physical setting and ecological systems (Chapter 2). Some recommendations (e.g., those involving planning) cannot be limited to the General Integrated Management Area.

The Panel's recommendations seek to define forest practices that are scientifically sound, operationally achievable, publicly acceptable, and safe.

Panel recommendations seek to define forest practices that are scientifically sound, operationally achievable, publicly acceptable and safe. In its deliberations about appropriate forestry practices in the General Integrated Management Area in Clayoquot Sound, the Panel invoked constraints in the order: safety, ecosystem integrity, operational effectiveness, and visual appearance. These recommendations are intended to provide direction for the development of subsequent standards that are measurable and enforceable.

The Panel recognizes the important influence of human values and interests (of both indigenous and non-indigenous people) on the management of resources in Clayoquot Sound. The composition and assignment of the Panel, however, allowed it to address only four broad topics:

1 the underlying physical and biological processes sustaining forest growth;

2 the practices of growing and harvesting trees;

3 scenic values, and recreational and tourism opportunities; and

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[1]The Scientific Panel for Sustainable Forest Practices in Clayoquot Sound will be referred to as the Clayoquot Scientific Panel, Scientific Panel, or Panel throughout this document. A list of Panel members is presented in Appendix V. Clayoquot Sound refers to the 350 000 ha area considered by the *Clayoquot Sound Land Use Decision* (British Columbia 1993a) and not the waterbody itself.

[2]The Panel's previous reports include: *Report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound, Progress Report 2: Review of Current Forest Practice Standards in Clayoquot Sound*, *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound*, and *A Vision and Its Context: Global Context for Forest Practices in Clayoquot Sound*.

[3]Premier Harcourt's announcement of the Clayoquot Scientific Panel, October 22, 1993.

4 Nuu-Chah-Nulth perspectives on forest values and forest practices.

The Panel has not addressed issues beyond these four broad topics of its mandate and its collective expertise.

1.2 Report Context

1.2.1 Previous Panel Reports

The Panel recommends forest practices that maintain the integrity of watersheds and the diversity of natural ecosystems, while providing for the needs of current and future generations.

In its first report, the Panel outlined guiding principles for forest management in Clayoquot Sound (Scientific Panel 1994b). These principles were used to evaluate current forest practices standards in the region. Findings and recommendations arising from this review are documented in the Panel's second and third reports (Scientific Panel 1994a, 1995b), and in this document.[4]

In its second report, the Panel recommended adoption of forest practices that maintain the integrity of watersheds and the diversity of natural ecosystems in Clayoquot Sound, while providing for the long-term spiritual, cultural, social, and economic needs of current and future generations of humans.

This report presents Panel findings and recommendations related to forest planning and information collection; the physical processes of timber extraction; scenic, recreational, and tourism values; and monitoring.

This report presents the Panel's findings and recommendations related to forest planning and information collection; the physical processes of timber extraction—silvicultural systems, harvesting systems, and transportation systems; scenic, recreational, and tourism values; and monitoring. Findings arise from a review of documents, field reconnaissance, and consideration of Nuu-Chah-Nulth and other local ecological knowledge. Panel recommendations are based on the following principles:

- Responsible land stewardship, including forest management, must respect the land and all living things.
- Ecosystems must be recognized as the functional base from which all goods and services are derived, and provisions must exist for determining and setting levels of resource extraction within the limits and capabilities of ecosystems.
- Planning must be long term and inclusive, linking provincial, regional, and local levels. At each of these levels, sustaining ecosystem productivity must take precedence over specific product outputs.
- Social, environmental, and economic dimensions of resource management must be incorporated into the planning process.

[4]Forest practice standards in documents dated up to September 30, 1994 have been reviewed. Standards under development or in unreleased draft documents on or after this date were not considered.

- Inventories must be expanded to include the status, abundance, and distribution of resources and values in Clayoquot Sound and the critical factors (e.g., slope stability) that affect timber harvesting or other resource-extracting operations. Some undeveloped areas must remain as baseline reference areas against which managed areas can be compared.

- An effective monitoring program must be implemented and adaptive management practised to improve forest practices and procedures as experience and knowledge are gained.

- As part of adaptive management, research must be undertaken to ensure that the standards set are adequate to maintain long-term ecosystem integrity.

- Information and education are essential for successful implementation of new forest practices standards.

- Resource management policies reflect human values, understanding, and knowledge at a particular point and time. They must be reviewed and revised to keep pace with changes in these states.

1.2.2 Complexity of Timber Production Activities

Few people appreciate the complexity of timber production.

Remarkably few people appreciate the complexity of timber production. Focusing on a single facet, such as method of harvesting, is akin to focusing on the surgical procedure while ignoring the patient's state of health and the purpose of the operation. In this report the inherent complexity of forestry manifests itself in three ways.

- First, to offer an integrated, internally consistent approach to timber production, it was necessary for the Panel to address activities from planning through silviculture, harvesting, and log transport. These diverse sets of activities had to be considered in terms of their suitability to the physical setting and ecological systems of Clayoquot Sound.

The report is arranged in a fashion that allows readers to accumulate explanatory background to subsequent sections.

- Second, because these sets of activities are themselves integrated and interdependent, it is potentially misleading to examine any one section of the report in isolation of other sections. The report is arranged in a fashion that allows readers to accumulate explanatory background to subsequent sections.

  A consequence of this organization is that planning—an activity that should embrace and precede all others—is addressed near the end of the report. It has been assigned that position so that readers will appreciate the need for a new planning hierarchy in light of the significant changes that the Panel recommends in silvicultural, harvesting, and transportation systems, and in managing for scenic, cultural, and tourism values.

- Third, complexity almost always is burdened by uncertainty. The approach to forestry recommended by the Panel incorporates a philosophical departure from previous approaches, which itself invokes uncertainty.

Because of this uncertainty and the range and magnitude of forest values involved, the Panel's approach to forest management is "conservative" in the sense of Kaufmann *et al.* (1994):

> "Conservative" management means giving the benefit of doubt to the resource rather than to its extraction or development. (Kaufmann *et al.* 1994:3)

Panel recommendations invoke the precautionary principle: both management and policy development proceed adaptively.

The principle of proceeding cautiously or conservatively in the face of uncertainty has been elaborated formally as the "precautionary principle." The principle applies when there is uncertainty about possible cumulative effects, irreversible changes, adverse interaction, or negative long-term effects (e.g., Bella and Overton 1972; Perrings 1991). The Panel explicitly recognizes the principle in its recommendations that both management and policy development proceed adaptively.

1.3 Terminology

Ecosystem or watershed "health" or "integrity" are bridging concepts.

In this report, frequent reference is made to ecosystem "health" and to ecosystem "integrity." These terms are meant to signify functioning, self-sustaining systems undergoing no systematic changes as the result of unnatural (i.e., human-induced) manipulations. These are not strictly scientific terms. They are what Ehrenfeld (1992) calls "bridging concepts"—concepts which connect a scientific concept about the state or properties of a system with a social value about the normative or desired state. For example, when referring to our bodies, "health" incorporates human values that are not amenable to strictly scientific measurement. "Health" can be used, however, as a useful reference concept for identifying the *stresses* (another bridging concept) to which bodies, watersheds, or ecosystems are subjected. Identifying symptoms of ecosystem stress and response to stress might lead to a set of diagnostic principles for assessing ecosystem state (Schaeffer *et al.* 1988). It is difficult, however, to define a normal state for ecosystems that are also subject to natural disturbances. Scientific methods can describe changes to a system in response to disturbances, and can determine causal mechanisms for most major disturbances (including major human interventions) but the question whether the system is "healthy" (or "unhealthy") remains a question of value and interpretation. This is appropriate. Managing forests (or any other aspect of the natural environment) entails the recognition and incorporation of human objectives for the system, even when a conscious attempt is made to ground management firmly in scientific principles. Used with care, bridging concepts such as "ecosystem health" and "ecosystem integrity" "…can enrich scientific thought with the values and judgements that make science a human endeavour" (Ehrenfeld 1992:142).

1.4 Report Organization

Chapter 1 provides the background and context for the Panel's review of current forest practices standards in Clayoquot Sound and notes how this document relates to previous Panel reports.

Chapter 2 describes the physical characteristics, ecological features, and human values associated with Clayoquot Sound. These characteristics, in combination with the Panel's guiding principles, provide the framework for the review of current forest practices standards.

Chapter 3 describes silvicultural systems historically used in British Columbia, discusses clearcutting as the prevalent system currently used in Clayoquot Sound, and presents the Panel's findings and recommendations relating to silvicultural systems in Clayoquot Sound.

Chapter 4 focuses on yarding methods as a major component of harvesting systems, and presents the Panel's findings and recommendations related to yarding methods in Clayoquot Sound.

Chapter 5 describes road and water transportation systems for wood and wood products in Clayoquot Sound, and presents the Panel's findings and recommendations related to roads and water transportation in Clayoquot Sound.

Chapter 6 describes scenic, recreational, and tourism values and resources in Clayoquot Sound, and presents the Panel's related findings and recommendations.

Chapter 7 summarizes the planning hierarchy and process that the Panel asserts to be critical to the successful implementation of its recommendations. In particular, it describes the system of reserves the Panel considers essential to maintain ecosystem integrity.

Chapter 8 describes the role of monitoring in forest ecosystem management in Clayoquot Sound, and recommends monitoring procedures to assess the success of new forest practices (that follow Panel recommendations) in achieving their intended objectives.

Chapter 9 lists sources cited in the report.

The recommended approach to sustainable ecosystem management is intact and complete only when all chapters are considered.

The necessarily linear nature of a document hinders communication of wholly integrated concepts. It is ineffective and potentially dangerous, for example, to consider silvicultural systems separately from harvesting and transportation systems. Similarly, the silvicultural system recommended by the Panel cannot be separated from the recommended approach to planning. Chapter boundaries are necessarily arbitrary. Although each chapter provides information critical to understanding subsequent chapters, the recommended approach to sustainable ecosystem management is intact and complete only when all chapters are considered.

Appendices to the report include a list of all Panel recommendations in this report (Appendix I), a classification system for the hydroriparian zone (Appendix II), a discussion of inventory requirements to support planning (Appendix III), a glossary (Appendix IV), and a list of Scientific Panel Members (Appendix V).

2.0 The Clayoquot Sound Environment: *hishuk ish ts'awalk*

Sustainability depends on maintaining ecosystem productivity and connections.

From establishing general and guiding principles to making recommendations for sustainable forest practices, the Clayoquot Scientific Panel has followed the premise that sustainability depends on maintaining ecosystem productivity and connections. The Nuu-Chah-Nulth people, original stewards of the resources of Clayoquot Sound, embrace this concept in the term "***hishuk ish ts'awalk***," or "everything is one." Ecosystems, resources, and resource values are interconnected. The Panel asserts that sustainable forest practices in Clayoquot Sound must be judged by the extent to which *all* resources are respected and sustained.

The Panel believes that selecting and implementing the most appropriate and practical methods for growing and extracting wood from Clayoquot Sound must proceed from understanding the physical, biological, and cultural aspects of the environment and the ways in which they are interrelated. These aspects are reviewed in the following sections.

Photo 2.1

Clayoquot Sound is a region with steep mountains, heavy precipitation, and temperate rainforests. Long inlets extend deep into the coastal mountain ranges.

2.1 The Physical Landscape

Understanding the physical characteristics of the landscape is prerequisite to assessing the adequacy of forest practices standards.

Within Clayoquot Sound, more than 80% of the remaining older forests in the General Integrated Management Area are located on slopes steeper than 30° (about 60%) (Sondheim 1994).[5] In a region of heavy precipitation, this combination of large trees and steep terrain poses significant challenges to many forestry activities. Understanding the physical characteristics of the landscape and the forces shaping them is prerequisite to assessing the adequacy of current forest practices standards and recommending their improvements.

[5]For operational expediency, the slope characteristics were based on average values for each of the BTM (baseline thematic mapping) polygons. An alternative and more accurate method would have been to base the slope analysis directly on specific locations as derived from digital terrain mapping.

2.1.1 Climate and Hydrology

The weather and climate of Clayoquot Sound are strongly influenced by the region's proximity to the Pacific Ocean and by its mountainous topography. In winter, a succession of frontal storms moves onto the west coast of Vancouver Island, resulting in prolonged and heavy precipitation. Cells of particularly heavy rainfall embedded in storm systems, and topographic steering of winds create considerable local variation in rainfall intensity. Both abundance and intensity of rainfall probably increase with increasing elevation. Precipitation records for weather stations in the vicinity of Clayoquot Sound show that during winter, daily rainfalls of 10–15 mm are not uncommon and extreme values reach 180–220 mm (Table 2.1). Strong winds commonly accompany winter storms. Heavy rainfall (90–140 mm) also occurs occasionally during summer storms. In general, total precipitation decreases inland.

Table 2.1 **Extreme daily precipitation**
for selected locations on the west coast of Vancouver Island: maximum values for winter (November–February) and summer (June–August).

Weather station	Winter		Summer		Period of record
	Intensity (mm/24 hr)	Date	Intensity (mm/24 hr)	Date	(years)
Tofino	184.2	Feb. 1982	131.3	Aug. 1975	48
Ucluelet (Kennedy Camp)	185.1	Nov. 1978	135.4	July 1972	26
Estevan Point	218.9	Jan. 1944	95.3	Aug. 1909	83
Carnation Creek	222.8	Feb. 1986	97.8	July 1972	20
Port Alberni	127.5	Jan. 1968	52.2	June 1980	30

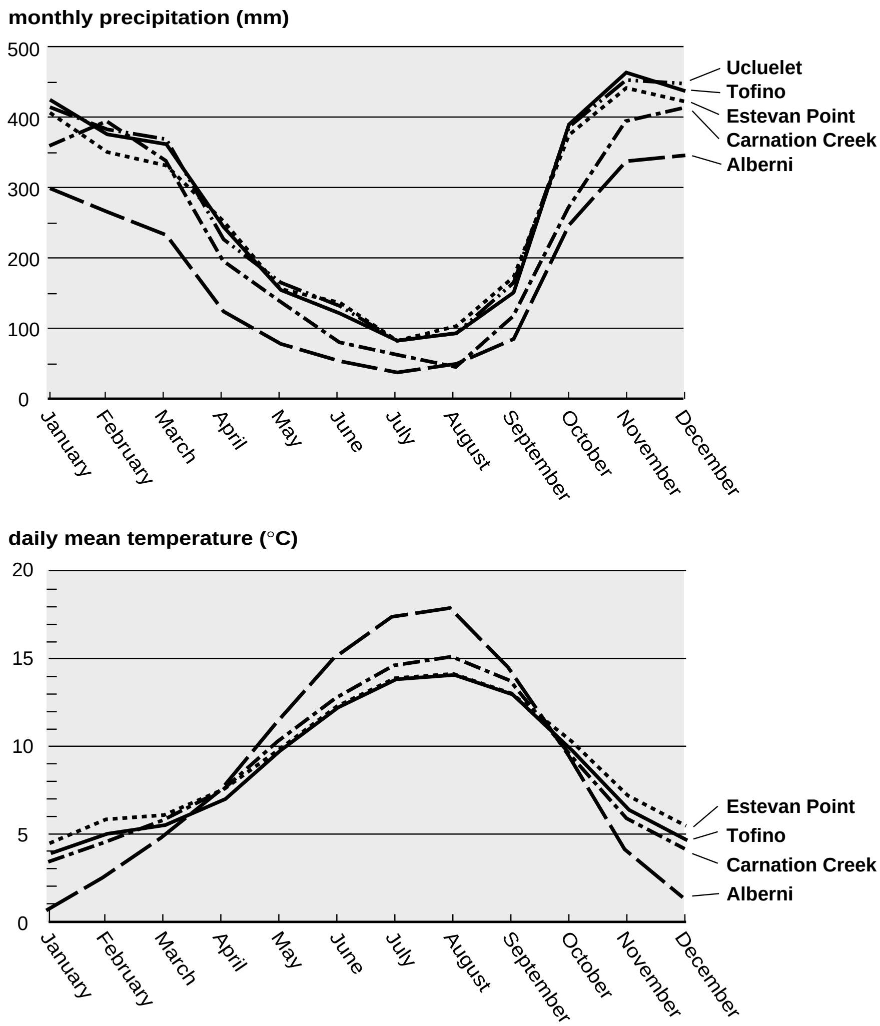
Throughout the year, temperatures are moderated by the ocean, so that winters are relatively mild and summers are relatively cool (Figure 2.1). The elevation at which winter freezing occurs fluctuates widely: rain often falls at high elevations and snow sometimes falls at sea level. Prolonged periods of subzero weather are unusual. Intense winter rain generates the highest stream discharges, particularly when it falls onto melting snow ("rain-on-snow events"). While there is no markedly dry season, the summer months are relatively dry due to prevailing high pressure systems and decreased frequency of storms.

Heavy rainfall delivers large volumes of water onto steep slopes in the mountains of Clayoquot Sound.

Heavy rainfall delivers large volumes of water onto steep slopes in the mountains of Clayoquot Sound. Considerable water is intercepted by the forest canopy, including arboreal mosses and lichens, from where it evaporates. The trees take up more water from the soil through transpiration. Nevertheless, most rainwater is absorbed into the forest soil through which it moves in a network of pores and channels formed by old root channels, animal burrows, and zones of highly permeable soil (Chamberlin 1972). During prolonged or intense rainstorms, most water runs off rapidly through the soil. Unimpeded, rapid drainage through forest soils on steep slopes is a significant factor promoting slope stability (Tsukamoto *et al.* 1982; Sidle *et al.* 1985). Landslides often occur in places where drainage is altered (see Section 2.1.4, Slope Processes).

The extent of forest cover influences the total annual runoff of water, and, in many instances, the timing and peak rate of storm runoff (Hetherington 1987). Construction and maintenance of roads and ditches, and compaction and disturbance of soil alters drainage pathways and hydrological regimes. Standards for location, construction, and maintenance must avoid negative impacts. Rates and patterns of forest removal (rate-of-cut) must be prescribed to minimize disturbance to natural runoff mechanisms and to maintain hydrological regimes within the range of natural variation in a watershed.[6]

Figure 2.1 Mean monthly temperature and precipitation.



[6]In North America, the terms “drainage basin” and “watershed” are used interchangeably to refer to the land surface area drained by a stream system; in Europe, the term watershed refers to the drainage divide between two adjacent drainage basins. In this report, either term refers to drainage basins.

2.1.2 Terrain and Surficial Material[7]

The Clayoquot Sound area encompasses parts of two contrasting physiographic regions: the Estevan Coastal Plain and the Vancouver Island Mountains (Holland 1964). The Estevan Coastal Plain consists of gently undulating or almost flat land that is subdivided into numerous islands and peninsulas by inlets, channels, and Kennedy Lake. The continuity of the plain is further broken by steep, rocky hills, some of which—such as Meares Island—are outliers of the mountains.

The Vancouver Island Mountains are steep and highly dissected.

The Vancouver Island Mountains are steep and highly dissected, with sharp ridgetops and only very small remnants of the gently sloping uplands that are widespread on other parts of Vancouver Island. Valleys are deep glacially eroded troughs, with gentle slopes restricted to valley floors. In the inland parts of the main drainage basins, ridgetops commonly rise to over 1000 m, peaks attain heights of more than 1300 m, and valley sides are commonly steeper than 30° (about 60%). Toward the coast, summit elevations become lower, with ridgetops descending to about 500 m. The coastal inlets extend across this transition zone and well into the mountains.

Both mountains and plain are underlain by a variety of rock types (Jeletzky 1954; Muller and Carson 1969). Most widespread are coarse crystalline metamorphic and intrusive rocks. Older volcanic rocks and sedimentary rocks, including limestone, occupy relatively small areas. All these rocks are cut by numerous steeply dipping faults, most of which run from northwest to southeast, parallel to the general trend of the coast. Erosion of the fault zones has created many tributary valleys and deep gullies. Bedrock outcrops are common on steep slopes and at high elevations. On gentle slopes and in the coastal lowlands, bedrock is generally buried by glacial and post-glacial deposits.

Landforms and land surface characteristics, such as slope stability, are closely related to the distribution and characteristics of surficial materials.

In most parts of Clayoquot Sound, landforms and land surface characteristics, such as slope stability, are closely related to the distribution and characteristics of surficial materials, such as glacial deposits, stream and marine sediments, and colluvium (slope deposits). The physical properties of these materials were determined by their processes of deposition. Deposition took place during the last glaciation, about 12 000 years ago, and continues today (Howes 1981).

Till, the most common glacial material, was deposited directly by melting ice. Basal till, a compact mixture of sand, silt, clay, and stones, accumulated under the ice. Ablation till is the loose debris that melted out on top of the ice. Till covers most gentle to moderately steep slopes in Clayoquot Sound. On steeper slopes, weathered till is naturally susceptible to debris slides and debris flows. Both basal and ablation tills have been modified by gully erosion, most of which probably occurred in early post-glacial time prior to the establishment of a protective cover of vegetation.

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[7]The term "surficial materials" refers to relatively young geological materials, such as glacial till and stream deposits, whereas "soil" refers to the uppermost 1–2 m of these materials that has been modified by physical, chemical, and biological processes.

Glaciofluvial materials, consisting of sand and gravel deposited by glacial meltwater streams, comprise the raised deltas (now prominent terraces) near the heads of most inlets in Clayoquot Sound. These deltas were formed at the end of the last glaciation (about 12 000 years ago), when sea level was as much as 50 m higher than at present (Friele and Hutchinson 1992). Glaciomarine sediments (chiefly silt and sand), which accumulated in shallow marine waters when sea level was higher (Clague *et al.* 1982), now blanket gentle slopes close to sea level. These sediments are most extensive on the coastal plain, but are also present along inlets within the mountains. They are prone to surface erosion and landslides where protective vegetation is removed.

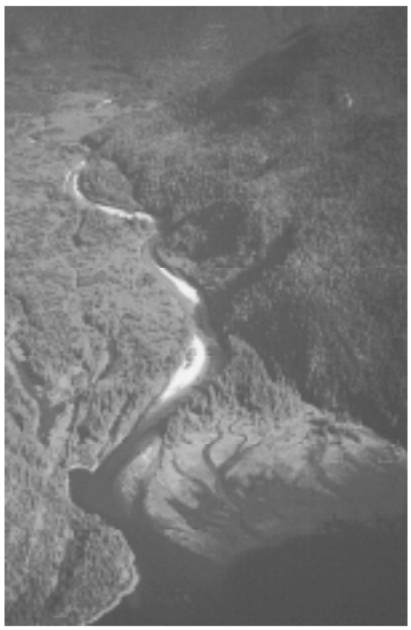

Photo 2.2

Rivers and streams form the core of the hydroriparian system that links uplands with the ocean. Rivers, streams, deltas, and estuaries are sensitive sites which contribute to the biological diversity of Clayoquot Sound.

Shallow surficial materials are prone to mass wasting in the prevailing wet climate.

Since the glaciers receded, weathering, slope processes, streams, and coastal processes (waves and currents) have modified the landscape, resulting in erosional landforms (such as canyons, gullies, and sea cliffs), and the accumulation of colluvium, fluvial (stream) sediments, and marine deposits, including beaches. Downslope movement of weathered glacial materials and bedrock, by processes ranging from rockfall to debris flow, has formed distinctive colluvial landforms such as debris-flow fans and talus cones, as well as a thin covering of rubble on steeper rocky slopes. Fluvial sands and gravels deposited by streams constitute floodplains, river terraces, alluvial fans, and deltas. Post-glacial marine sediments include beach deposits up to 6 m above present sea level that date from a short period of higher sea level 6000 to 5000 years ago (Hebda and Rouse 1979; Clague 1989), and modern beaches.

On the steep terrain of much of Clayoquot Sound, the shallow surficial materials overlying compact glacial till or bedrock are prone to mass wasting in the prevailing wet climate.

2.1.3 Soils

Most of the forest soils in Clayoquot Sound are podzols; folisols and gleysols also occur.

Since the last glaciation, the upper part (about 1–2 m) of surficial materials has been modified by soil-forming processes. Much of the soil-forming activity proceeds invisibly within the forest floor and soil, mediated by microbes, fungi, insects, and other invertebrates.[8] The combination of physical and chemical weathering (breakdown) of mineral material in the moderate perhumid environment produces soils with a higher silt and clay content than the original parent materials. This renders soils more prone to erosion than the surficial materials, particularly if surface organic soil horizons are removed. Most forest soils in Clayoquot Sound are podzols; folisols and gleysols also occur (Jungen and Lewis 1978; Jungen 1985).

Nitrogen and phosphorus commonly limit plant growth.

Podzol soils have developed in till and other surficial materials on well-drained to imperfectly drained slopes which have not been greatly affected by land-shaping processes during the past 12 000 years. Podzols are acidic soils and low in nutrient cations, such as calcium, due to leaching[9] from the year-round heavy rainfall (Lewis 1976). Accumulation of oxides in the lower part of a podzol soil often forms cemented layers of low permeability (“hardpan”), hindering drainage even in gravelly materials with initially high permeability.

The content of plant-available nitrogen and phosphorus, which are both stored largely in soil organic matter, is low in podzols, and nitrogen or both nitrogen and phosphorus commonly limit plant growth. Phosphorus is retained tightly in podzols, either in organic forms or as very slowly soluble mineral forms because of low soil pH. As a result, its release to groundwater and then to streams is minimal. The resulting shortage of phosphorus in west coast streams is the limiting factor for primary production in streams (Stockner and Shortreed 1976, 1978; Mundie *et al.* 1991).

Podzols exert a significant influence on both physical and biological processes. The organic layer (i.e., the forest floor of accumulated forest litter) is usually only 10–30 cm thick, yet it protects against soil erosion, supplies most available nutrients, and supports diverse life in the soil.

At many sites, the forest floor layer constitutes the entire soil over bedrock. Such soils, consisting entirely of forest litter in various stages of decomposition, are termed folisols. These folisols typically occupy 20–40% of the landscape in Clayoquot Sound, being most extensive in rocky terrain, such as in the Bulson watershed. Gleysols are poorly drained mineral soils that occur in flat to depressional areas, commonly on glaciomarine materials and floodplains. The wettest sites have organic soils, ranging from the mucks of western redcedar swamps to the thicker, peaty organics of shore pine bogs and open bogs.

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[8] Invertebrates are creatures without a backbone (vertebrae) (e.g., insects, worms, slugs, spiders, crustaceans).

[9] Leaching is the washing out of nutrients released during weathering and organic matter decay.

It is critical to maintain the organic matter of forest soils.

Maintaining the organic matter of forest soils is critical, because it contains virtually all of the available nutrients, has high water-absorbing and water-retaining capability, improves soil porosity and permeability, and protects the mineral soil from surface erosion.

2.1.4 Land-Shaping Processes

Slope processes, stream erosion and deposition, and coastal processes are continually shaping the land.

Although the present-day landscape of Clayoquot Sound may appear static to the casual observer, slope processes, stream erosion and deposition, and coastal processes, all of which are natural agents of forest disturbance, are continually shaping the land. Slope processes and stream processes are strongly influenced by the passage of water through the landscape, and thus are driven by the intense winter rains and snowmelt.

Slope Processes

Debris slides and debris flows are the most common types of slope movement in Clayoquot Sound.

Debris slides and debris flows[10] are the most common types of slope movement in Clayoquot Sound. A debris slide is triggered when shallow subsurface water saturates the lower part of the soil zone, reducing soil strength sufficiently that the overlying soil and vegetation cover slides downslope (O'Loughlin 1968; Buchanan and Savigny 1989). Usually, the "slip plane" is the sharp boundary that separates the soil from unweathered surficial material or bedrock. Most debris slides involve only a thin (1–2 m) layer of material, yet they result in significant loss of soil and trees, and exposure of unweathered material—usually till or bedrock—in the slide scar. As the sliding, saturated soil moves rapidly downslope, it commonly changes into a debris flow—a highly viscous slurry of soil, stones, trees, and other organic debris that can travel a considerable distance, even on relatively low gradients. Debris flows and slides often enter steep watercourses where they are augmented by streamflow. Debris flows can also start in steep stream channels during floods, when dams of woody debris fail and the sediments that have accumulated behind them begin to move downstream.

Clearcutting and roadbuilding increase the frequency of debris slides and flows.

Debris slides and associated flows are triggered by heavy rainfall on ground already saturated by rain (Church and Miles 1987); by wind stress transmitted to the ground via trees and by tree blowdown (Chatwin *et al.* 1991); by impacts of other gravitational movements such as rockfall or snow avalanches; and by seismic vibrations, which are common (in geological time) on the tectonically active west coast.

[10]In the Pacific Northwest, including British Columbia, debris flows are commonly referred to as "debris torrents."

Instability associated with older, poorly constructed roads is still apparent.

It has repeatedly been demonstrated from other parts of coastal British Columbia (e.g., O'Loughlin 1968; Rood 1984; Sidle *et al.* 1985; Howes 1987) that clearcutting and roadbuilding increase the frequency of debris slides and flows. Decreased soil strength due to root decay (Buchanan and Savigny 1989), increased soil water, soil disturbance associated with yarding, and increased tree movement in wind, particularly on the edges of cutblocks, all contribute to slope failures in clearcuts. Road construction has contributed to instability by loading steep slopes with sidecast material. Roads also intercept and redirect shallow subsurface water. Investigation of slides initiated in clearcuts at a considerable distance downslope of roads often implicates changes to slope drainage brought about by roads. Montgomery (1994), using observations of ridgetop roads, has shown that increased surface runoff from the compacted road surface above can initiate surface erosion or debris slides downslope. Although practices of building, maintaining, and deactivating roads have improved considerably over the last decade (Chatwin *et al.* 1991), a legacy of instability associated with older, poorly constructed roads is still apparent.

Other slope processes active in Clayoquot Sound, such as rockfalls and rockslides are largely restricted to rocky bluffs and mountainsides that are too steep for logging; their occurrence is therefore less affected by human activities.

Steep slopes, climate, and hydrology create conditions of potential instability in surficial materials.

Steep slopes, climate, and hydrology create conditions of potential instability in surficial materials at many sites in the Clayoquot Sound region. Assessing slope stability, avoiding activities on unstable slopes, and carefully prescribing appropriate harvesting practices on steep and marginally stable slopes are essential to avoid increasing erosion rates above natural levels. The location, method, rate, and patterns of tree removal, and the location, construction, and maintenance of roads are particularly significant. The local variability of topography, terrain, and drainage necessitates detailed evaluation of these conditions to permit identification and assessment of potentially unstable areas.

Stream Processes

Within each watershed, the drainage network comprises a variety of channel and lake types, each with distinctive ecological habitats. Streams range from tiny rivulets at the highest elevations, to large channels on the floors of major valleys. All drainage components, even ephemeral channels on steep mountainsides, have riparian areas along streambanks where increased soil moisture supports distinctive vegetation. The presence of water and its influence on adjacent vegetation results in high levels of animal use of riparian areas. Riparian areas are most extensive on valley floors where they commonly include the alluvial flats of floodplains, alluvial fans, and deltas. The morphology of these landforms and the variety of ecological habitats that they support—such as side channels, backswamps, bars, and islands—result from the long-term behaviour of the streams.

Photo 2.3

Streams and rivers provide habitat for aquatic organisms, transport sediments and organic debris, and are a major influence on the character of the Clayoquot Sound ecosystem.

The characteristics of stream channels and floodplains are determined by inputs of water, sediment, and organic debris.

The characteristics of stream channels and floodplains are determined by inputs of water, sediment, and organic debris, and by the morphology and materials of the landscape through which the stream flows (Church 1992). Downcutting by water, the dominant process along fast-flowing streams with steep gradients, forms gullies and bedrock canyons in rugged terrain. On lower gradients, streams have deposited sediment, forming floodplains and alluvial fans. Deltas have developed where the major streams flow into the ocean or lakes.

Sediments are supplied to streams from valley sides by debris slides, debris flows, and other mass movements, and by erosion of channel banks and beds.

Sediments are supplied to streams from valley sides by debris slides, debris flows, and other mass movements, and by erosion of channel banks and beds. Abundant organic debris—including whole trees—enters streams as a result of these processes. Accumulations of large wood pieces lodged in the channel regulate the movement of sediments and smaller organic debris (Beschta 1979; Bilby 1981), and provide habitat for stream fauna. Sediments and organic debris move downstream during periods of high flow associated with storms and spring snowmelt. Sandy and gravelly stream sediments are stored in channel bars and riffles during periods of low water. Frequent movement of the gravels keeps them free of fine sediments, and creates the spawning environment required by salmon and trout. A continual, moderate supply of gravel to the stream is necessary to maintain spawning gravels.

Fine sediment in the channel may degrade the quality of spawning gravels.

Stream channel morphology (e.g., width-to-depth ratio, spacing of riffles, and texture of the sediments constituting the channel bed) depends on the characteristics of sediment and woody debris supplied from upstream, as well as the volume and timing of flows (Keller and Swanson 1979). Changes in the supply of any of these three components may change stream morphology. For example, the entry of debris flows into a channel from natural causes, logging, or roadbuilding, brings both fine (sand, silt) and coarse (gravel, boulders) sediments, as well as fine and coarse organic debris (roots, branches, and logs). Over short periods, fine sediment in the channel may degrade the quality of spawning gravels and, in sufficiently high quantities, affects the foraging success, behaviour, and even the survival of aquatic organisms, including fish. In the long run, increased gravel may build up the channel bed (aggradation), produce channel spillage onto the adjacent vegetated floodplain, and create a wider but shallower channel with decreased capability for rearing fish.

Coastal Processes

The stability of beaches may be related to the presence of large organic debris.

In Clayoquot Sound, much of the coast is rocky and beaches are of limited extent except on the outer coast (Clague and Bornhold 1980). Beaches have developed where sandy and gravelly sediments are supplied by wave erosion of bluffs composed of glacial deposits, where wave action has pushed submarine glacial deposits onto low shores, and where streams deliver sediment to the shore. The supply of beach sands and gravels is not prolific on this coast (ibid.). The stability of some beaches may be related to the presence of large organic debris: log barriers are common along the backshore, and in recent decades, more beach logs may have resulted from escapement from log booms and stream- or river-fed debris following logging. Although beaches are not widespread, they are the foci of many activities in Clayoquot Sound. Rocky shores are equally important: the rocky subtidal zone is a productive habitat, the maintenance of which depends on the absence of fine sediments. On both beaches and rocky coasts, the influx of increased quantities of fine sediment may alter the characteristics or reduce the quality of the coastal environment.

Photo 2.4

Logs have accumulated on many beaches and influence beach stability and species present.

Forest Disturbance

Debris slides, debris flows, rockfalls, and shifting stream channels contribute to the natural pattern of forest disturbance.

Debris slides, debris flows, rockfalls, shifting stream channels on floodplains and fans, and coastal processes such as bluff erosion contribute to the natural pattern of forest disturbance. These disturbances range from minor effects, such as the impacts of a single, bouncing boulder, to destruction of the forest over several hectares resulting from a landslide or channel avulsion.[11]

Relatively immature soils and vegetation occupy these small sites of recent disturbance, adding to forest diversity. However, a dramatic change in the rate of disturbance, or rates of erosion—such as can occur with poorly planned forest harvesting—may change the balance of available habitats and affect the viability

[11] Channel avulsion is an abrupt diversion of the stream channel from one course to another during a flood or as a result of blockage of the original channel by sediment or woody debris.

of many species. Careful planning of the rate and distribution of harvest is necessary to minimize the effect of deliberate forest removal on ecosystems.

Disturbances other than land-shaping processes, such as windthrow, also significantly affect forest development in Clayoquot Sound (Section 2.2).

2.2 The Ecological Landscape

Knowledge of how ecosystems maintain and renew themselves is a necessary prerequisite to selecting silvicultural systems and determining harvesting and transportation systems.

A distinguishing characteristic of an ecosystem is its natural disturbance regime.

There is a continual turnover of living organisms—even in what appear to be stable ecosystems. Forest trees are long-lived but not immortal. Their deaths are most often due to natural changes such as the land-shaping processes noted, windthrow, and fire. Because forest cover is naturally renewed by events that may dramatically alter or disturb existing cover, the common pattern of these events is called the “natural disturbance regime.” One of the distinguishing characteristics of any given ecosystem is its natural disturbance regime, which is governed by the regional climate and physiography. For example, in the wet climate of the west coast portion of the coastal temperate rainforest, fires are smaller on average, and less frequent than on the drier east coast of Vancouver Island. On the west coast of Vancouver Island, windthrow is the principal agent of disturbance, whereas on the east coast of the island, fire often dominates.

Wild forests renew themselves naturally in a manner that depends on the natural disturbance regime of their region. Logging is a recent disturbance that inevitably alters the pattern of renewal. Ecological knowledge can be used, however, to ensure that the changes caused by logging, and the forests that regenerate after logging, are not dramatically different from those created by the natural disturbance regimes. Forest practices that approximate natural disturbance regimes help to retain ecosystem processes and maintain ecosystem productivity and connections.

2.2.1 Biogeoclimatic Units

Based on vegetation and climate, the forests of Clayoquot Sound have been classified in terms of biogeoclimatic units (Meidinger and Pojar (editors) 1991), that is, into “zones,” “subzones,” and “variants” as shown in Figure 2.2. In the Coastal Western Hemlock zone, a fourth hierarchical level (below variant), referred to as the “phase,” is commonly recognized. Phases relate to forest patterns resulting from natural disturbances.

All forests of the Coastal Western Hemlock (CWH) zone are recognized as "coastal temperate rainforest."

All forests of the Coastal Western Hemlock zone are recognized as "coastal temperate rainforest." These rainforests occur in widely scattered locations around the world but the global distribution is centred on the Pacific coasts of North and South America. In North America, which accounts for approximately half of the world's coastal temperate rainforest, rainforest distribution is centred on Vancouver Island. Researchers have distinguished four major subgroups of

In North America, rainforest distribution is centred on Vancouver Island.

coastal temperate rainforest (Kellogg 1992). Forests on Vancouver Island belong to two of these subgroups: perhumid and seasonal temperate rainforests. The boundary between these two subgroups is presently uncertain; forests of the Coastal Western Hemlock zone in Clayoquot Sound are predominantly perhumid temperate rainforests. Seasonal temperate rainforests, if they occur, would be restricted to the valley of the upper Kennedy River.[12]

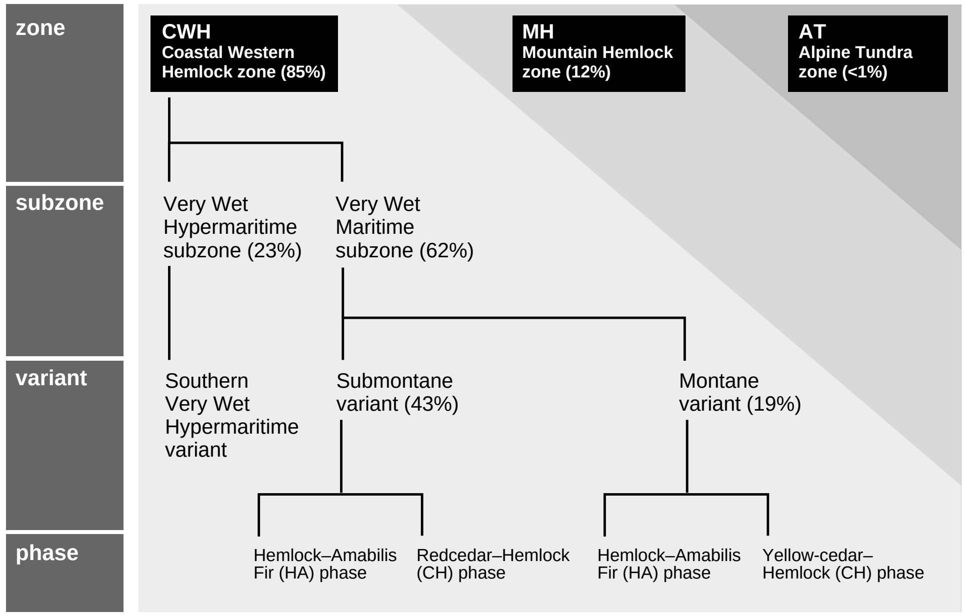
The CWH zone is divided into subzones based on annual and growing season precipitation, and maritime influence.

The Coastal Western Hemlock (CWH) zone includes all forests less than 900 m above sea level in Clayoquot Sound (Figure 2.3). Western hemlock *(Tsuga heterophylla)* is a dominant or codominant tree species throughout; western redcedar *(Thuja plicata)*, amabilis fir *(Abies amabilis)*, yellow-cedar *(Chamaecyparis nootkatensis)*, Sitka spruce *(Picea sitchensis)*, Douglas-fir *(Pseudotsuga menziesii)*, and red alder *(Alnus rubra)* also occur under differing conditions. This zone is divided into subzones based on annual and growing season precipitation, and maritime influence.

The Very Wet Hypermaritime subzone lies along the outer coast of Clayoquot Sound in areas of relatively subdued terrain where the marine influences govern the climate. Temperatures rarely become very hot or very cold, evapotranspiration is low, low cloud and fog are frequent, and the soil remains cool and wet throughout the summer. Extensive bogs with poorly drained organic soils have developed, notably on the low-lying Estevan Coastal Plain. Western redcedar and western hemlock are abundant, lodgepole pine ("shore pine," *Pinus contorta*) and sometimes yellow-cedar occur on bogs, and a band of Sitka spruce forest grows along exposed shores where winds carry salt spray inland. Two variants are described for the Very Wet Hypermaritime subzone; only one, the Southern Very Wet Hypermaritime biogeoclimatic variant, occurs in Clayoquot Sound, at elevations generally below 150 m.

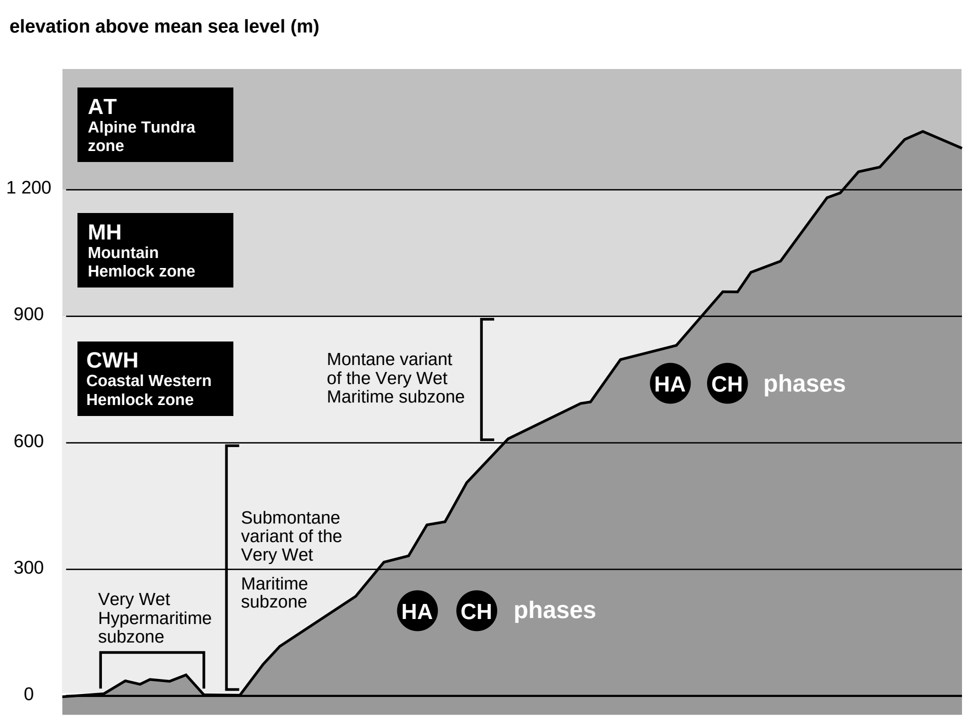
[12]The boundary between the perhumid and seasonal temperate rainforests as illustrated in Conservation International *et al.* (1994) is apparently in error.

Figure 2.2 **Biogeoclimatic units in Clayoquot Sound.**[1]



[1]Percentages calculated from *Clayoquot Sound Sustainable Development Strategy* (Clayoquot Sound Sustainable Development Strategy Steering Committee 1992:31). Lakes cover about 3% of the area.

Figure 2.3 **Location of biogeoclimatic units by representative landscape section.** (Phases defined in Figure 2.2.)



Most of the forests of Clayoquot Sound occur in the Very Wet Maritime subzone; western hemlock, western redcedar, and amabilis fir are characteristic tree species. The subzone is divided into two variants on the basis of elevation. The Submontane variant lies below about 600 m above sea level (Figure 2.3). This variant can be differentiated into two phases (HA and CH) which are associated with different patterns of disturbance.

Windstorms cause major natural disturbances to forests in Clayoquot Sound, and are the most common natural agent of forest disruption and renewal.

The two dominant tree species of the Hemlock–Amabilis Fir (HA) phase appear to be favoured by a disturbance regime in which patches of forest ranging from clumps of a few trees to stands of several hundred hectares are episodically blown down by wind. Blowdowns provide space for the growth of young trees (“advanced regeneration”) that were previously shaded by the windthrown trees. Low mounds of soil produced by the upturned root wads of windthrown trees are a seedbed for western hemlock, amabilis fir and other species. The HA phase appears to be self-perpetuating because the stand structure following windfall (dense canopies with high “sail” area, and shallow-rooted trees often on the tops of hummocks) makes the forest susceptible to further windfall and subsequent recruitment of the same species. Forests of this phase have an understory dominated by *Vaccinium* species and mosses.

The Cedar–Hemlock (CH) phase is dominated by western redcedar with a subcanopy of western hemlock and, frequently, a dense understory of salal. Stands have a more open structure than those of HA-phase forests: the crowns are less dense and many of the western redcedars are spike-topped. Consequently, the canopy offers less resistance to wind. This, along with western redcedar’s somewhat firmer rooting habit, makes CH-phase stands more windfirm than HA-phase stands. Wind is still a major factor in the natural disturbance regime, but the trees blown down in CH-phase forests tend to be isolated individuals; clumped windfalls rarely occur, even along cutblock edges.

Between 600 and 900 m above sea level lies the Montane variant, the second variant of the Very Wet Maritime subzone. This variant is a transition between low- and high-elevation forests. Rising from sea level, the climate becomes steadily cooler and foggier than in the Submontane variant. Fog here is from cloud drift onto mountains; fog at the lowest elevations in the Very Wet Hypermaritime and Maritime subzones (Figure 2.3) results from surface advection over the cool ocean. At higher levels, a short-lived snowpack up to 2 m deep forms in winter; it is often dissipated by major rain-on-snow events. Going upslope, yellow-cedar gradually replaces western redcedar. Two disturbance phases of the Montane variant are discernible as in the Submontane variant. However, in the Montane variant, the HA phase contains a comparatively high proportion of amabilis fir, while the CH phase is dominated by yellow-cedar rather than by western redcedar.

The second major biogeoclimatic zone represented in Clayoquot Sound is the Mountain Hemlock (MH) zone. This zone, where mountain hemlock *(Tsuga mertensiana)* replaces western hemlock, occupies the land above 900 m elevation up to the Alpine Tundra (AT) zone (i.e., to tree line). Yellow-cedar is also abundant, and amabilis fir is common. In the lower part of the MH zone, the forest canopy is closed. Upslope, the forest opens up markedly into a parkland, where individual trees and clumps of trees are interspersed with heath communities. The AT zone occurs above the MH zone and, by definition, is not forested.

The biogeoclimatic classification system reflects ecosystem capabilities and helps to define sustainable limits of resource extraction.

The biogeoclimatic ecological classification system is used to assist planning. By reflecting the capabilities of ecosystems it helps to define the sustainable limits of resource extraction. This classification system guides Pre-harvest Silviculture Prescriptions, including the choice of site preparation method, tree species for regeneration (both preferred and acceptable species), and stocking levels for managed stands (e.g., Klinka *et al.* 1984). It also suggests the natural patterns of disturbance expected on different sites.

2.2.2 Terrestrial Ecosystems: Vegetation

Vegetation development is affected by the natural disturbance regime.

Vegetation development is affected by the natural disturbance regime. Clayoquot Sound forests are shaped by both major stand-initiating disturbances and minor within-stand disturbances. The former are much less common than the latter. The combination of large- and small-scale disturbances creates structurally and biologically diverse environments.

The intensity of disturbance also varies. High-intensity disturbances, such as landslides or very hot fires, kill most of the vegetation in the affected area. Low-intensity disturbances, such as partial blowdown or “cool” wildfires, damage but do not destroy all local vegetation. In Clayoquot Sound, large-scale disturbances such as extensive blowdowns or wildfires are often of low intensity and recur after long intervals—400–1000 years or more. Small-scale, intense disturbances, while more common, are still relatively infrequent; in Clayoquot Sound, hot wildfires are particularly rare.

The big openings created by infrequent large-scale disturbances usually exhibit a high degree of internal heterogeneity. Residual pockets of undamaged vegetation and numerous isolated living trees, as well as abundant standing dead trees (snags) and fallen dead trees (downed wood) often survive these disturbances. These remnants of the old forest provide valuable structural (and, therefore, habitat) diversity within the young, natural forests that subsequently grow in the area (Bunnell and Allaye-Chan 1984; Hansen *et al.* 1991; Swanson and Franklin 1992; Dupuis *et al.* 1995). Individual stumps, logs, and snags can persist for several hundred years.

Clayoquot Sound's almost continuous old-growth forests contain great quantities of biomass.

Clayoquot Sound's almost continuous old-growth forests contain great quantities of biomass, distinguishing them from forests of drier climates, such as interior Douglas-fir forests. The volume of standing live trees on lower slopes of the CWH zone is about 600–900 m^3/ha, and within the less productive MH zone, about 300–500 m^3/ha. The comparable volume of downed wood on similar sites can range from greater than 400 m^3/ha, to less than 70 m^3/ha, respectively.[13] In addition, substantial volumes of standing dead and decaying trees can be found. This massive accumulated biomass supports the numerous species that depend on large living trees or dead wood, and gives the forests their great economic value.

These forests are characterized by uneven canopies with gaps where old trees have died and young ones are regenerating.

These forests are characterized by uneven canopies with gaps where old trees have died and young ones are regenerating in well-developed understory layers, and by trees of a wide range of ages and sizes. Small openings of less than 0.2 ha, where only a few trees have died, are common in old-growth forests (on average, gaps constitute about 14% of the old-growth area).[14] In such openings, the dead trees—which result from various events (e.g., windthrow, snapping part way up the bole, disease)—are often in different stages of decay. The variety of forms of dead wood provides correspondingly diverse habitats for numerous organisms and facilitates a wide range of ecological processes. Canopy gaps are associated with a well-developed and diverse understory vegetation layer which is often more productive than in adjacent closed canopy areas (Alaback 1984; Inselberg 1993).

Photo 2.5

An ecologically healthy forest includes dead and dying trees. Fallen trees create gaps in forests and provide coarse woody debris. The coarse woody debris and the vegetation that subsequently develops in the gap contribute to the diverse structure of old-growth forests.

Canopy gaps created by tree mortality and the subsequent growth in these gaps of younger trees results in an old-growth forest where the death of old trees is roughly balanced by the growth of young ones. In this way, all the trees in the forest can be eventually replaced without a major disturbance. Estimates of the time for the forest to "turn over" through such gap–phase replacement ranges

[13] R.J. Keenan and A. Inselberg, unpublished data, 1992.

[14] K.P. Lertzman and A. Inselberg, unpublished data, 1992.

from 300 to 1000 years for a variety of sites in Clayoquot Sound and related forest types on the Lower Mainland of British Columbia (Lertzman and Krebs 1991).[15]

Most stands are dominated by old trees of species that are among the largest and most long-lived in the world.

Because of the long intervals between disturbances, most stands are dominated by old trees of species that are among the largest and most long-lived in the world (e.g., western redcedar and yellow-cedar; Pojar and MacKinnon (editors) 1994:16). Old-growth forests in Clayoquot Sound can represent true all-aged stands. For instance, in one stand containing amabilis fir, western redcedar, yellow-cedar, and western hemlock, ages were distributed continuously from young saplings to trees almost 1000 years in age.[16] These forests are structurally complex and provide microhabitats for a great variety of plants, animals, fungi, and micro-organisms. Some plant and lichen species in Clayoquot Sound do best in, or are limited to, such old-growth forests. In some cases, the association with old-growth or closed-canopy forests is a function of microclimate.

The forest canopy affects wind, light, diurnal variation in temperature and moisture, and seasonal patterns of snow accumulation and melt both within the stand and in adjacent open areas. This microclimatic influence of the forest canopy extends from less than half a tree height[17] to as much as six to eight tree heights into a stand (and likely as far from a stand into an opening), depending on the variable measured. For most variables, the microclimatic influence of the canopy is negligible beyond two to three tree heights from the stand edge (Chen *et al.* 1995). Examples of direct responses to these microclimatic variables can be seen in the distribution, reproduction, and growth of various species of plants.

Forests offer a wide range of habitats, many of which are important to small, non-vascular plants, lichens, and fungi.

Forests offer a wide range of habitats, many of which are important to small non-vascular plants, lichens, and fungi.[18] Unfortunately, very little is known of the non-vascular flora of Clayoquot Sound. One species of lichen, however, is found only near the shores of Clayoquot Sound (Goward 1994).[19] More is known about the area's vascular plants (herbs, grasses, shrubs, and trees), but no comprehensive survey has yet been attempted. Generally, forests of the CWH zone have fewer vascular plant species than the forests in some other biogeoclimatic zones; nonetheless, a 400 m^2 plot typically contains about 20 different species (Pojar *et al.* 1992).

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[15] Also, K.P. Lertzman and A. Inselberg, unpublished data, 1992; A. Arsenault, unpublished data, 1994.

[16] A. Arsenault, unpublished data, 1994.

[17] All references to tree heights refer to average "site potential tree height." Although taller trees are present, the Panel has assumed that 50 m is representative potential for stands growing on productive sites.

[18] Non-vascular plants include algae, mosses and liverworts.

[19] The *Status Report on the Seaside Centipede Lichen Heteroderma sitchensis* recommends that the Committee on the Status of Endangered Wildlife in Canada list this species as endangered.

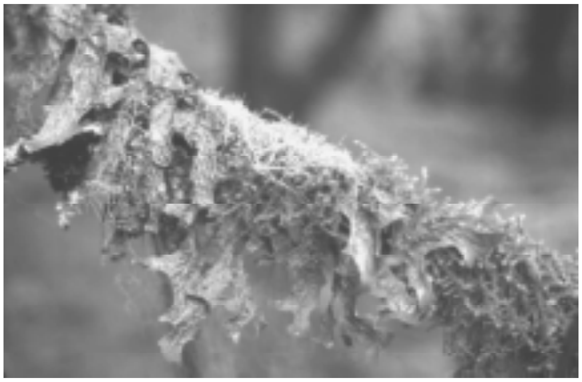

Photo 2.6

Ecosystem management includes maintenance of ecological processes. These processes rely, in part, on contributions made by non-vascular plants such as lichens and fungi.

The ecological importance of the non-vascular flora, the lichens, and the fungi, cannot be overestimated. Slowly decaying mosses contribute to the soil's water-retaining capacity and, after death, form an important component of the soil organic matter. The life of the forest depends on an abundant and active fungal community. Many of the fungal species are partners in mycorrhizae, which are essential for normal growth of trees. Other fungal species decompose dead wood, and hence facilitate nutrient cycling. The life cycles of slime moulds, lichens, and bacteria are also part of the functioning ecosystem.

Many of the area's plant species are used by the Nuu-Chah-Nulth people. For example, salal berries (*Gaultheria shallon*), salmonberries (*Rubus spectabilis),* red huckleberries (*Vaccinium parvifolium*), evergreen huckleberries (*Vaccinium ovatum*), and oval-leaved blueberries (*Vaccinium ovalifolium*) are important edible wild fruits still used by Nuu-Chah-Nulth families. Woods of yew (*Taxus brevifolia*), yellow-cedar, western redcedar, and red alder are important materials for carving by Nuu-Chah-Nulth artists. Basket-makers still harvest tall basket sedge (*Carex obnupta*), American bulrush (*Scirpus americanus*), and the inner bark of western redcedar and yellow-cedar. Important medicinal plants are numerous, and include species such as wild lily-of-the-valley (*Maianthemum dilatatum*), skunk cabbage (*Lysichiton americanum*), red alder, yarrow (*Achillea millefolium*), devil's club (*Oplopanax horridus*), and cascara (*Rhamnus purshiana*).[20]

A very high proportion of Clayoquot Sound forests are in late successional stages as a result of the region's natural disturbance regime. For example, in three undeveloped watersheds (Ursus Creek, Sidney River, Clayoquot River) the percentage of forests in age classes 8 and 9 (greater than 141 years) exceeds 98.5%.[21] This greatly influences the region's biological diversity (see also Section 2.2.3). To maintain biological diversity an ecosystem management policy is required to ensure retention of extensive areas with old-growth attributes and retention of some old-growth attributes across the managed landscape.

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[20]Appendix V of the report *First Nations' Perspectives Relating to Forest Practices Standards In Clayoquot Sound* (Scientific Panel 1995c) contains a detailed list of species important to the Nuu-Chah-Nulth of Clayoquot Sound.

[21]Data supplied by B.C. Ministry of Forests Inventory Branch.

2.2.3 Terrestrial Ecosystems: Fauna[22]

Large, structurally complex trees provide habitats for a wide range of animals.

The diversity of forest fauna is governed by the species and structural diversity of the vegetation. Plants are at the bottom of all food chains; and plants, especially the large, structurally complex trees, provide the required habitats for a wide range of animals, both vertebrates (e.g., small mammals, cavity-nesting birds, amphibians) and invertebrates (e.g., insects, gastropods). The plants of the hydroriparian ecosystem (Section 2.2.4) are an especially diverse component of the vegetation. Non-forest vegetation, such as that found in bogs, on rock outcrops, in subalpine parkland, and in the alpine tundra of Clayoquot Sound, contributes much to the region's diversity of ecosystems and animal species.

Photo 2.7

Tree frogs are part of the biological diversity of Clayoquot Sound. Most amphibians require specific aquatic and terrestrial habitats, including a moist microclimate.

As elsewhere, most of the terrestrial or land-dwelling fauna of Clayoquot Sound is comprised of invertebrates. These species make critical contributions to ecosystem processes such as soil building, decomposition, nutrient cycling, pollination, and seed or spore dispersal. Invertebrates also are key components of terrestrial and aquatic food chains, being important food for vertebrate species. Despite their importance to ecosystem functions, very little is known about the invertebrates of Clayoquot Sound. The Panel is aware of no studies of the soil-dwelling fauna in Clayoquot Sound, but work has occurred in similar ecosystems on northern Vancouver Island (Battigelli *et al.* 1994). Recent work in the Carmanah watershed on canopy-dwelling insects quickly discovered species new to science.[23] Carmanah is close to Clayoquot Sound and similar in vegetation; it is reasonable to assume that the tree canopies of Clayoquot Sound are equally rich in insects and spiders.

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[22]This section is adapted from Bunnell and Chan-McLeod (1995).

[23]R. Ring and N. Winchester, pers. comm., March 1995. Preliminary work in the Sitka spruce canopy in Carmanah indicates a complex community containing many more species than found in Douglas-fir–western hemlock canopies of Oregon (see Schowalter 1989).

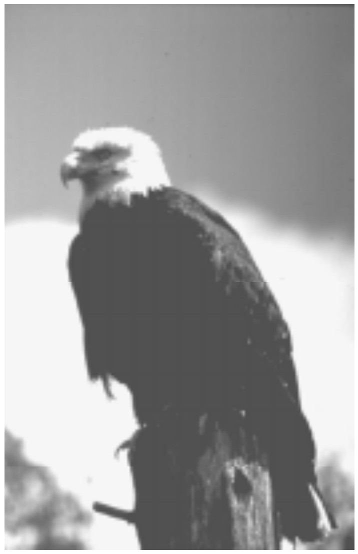


Photo 2.8

Bald eagles are common throughout Clayoquot Sound. Impacts of forest harvesting activities can be reduced by ensuring eagles are not disturbed during sensitive periods.

Clayoquot Sound is particularly rich in vertebrates, especially birds.

The vertebrates of Clayoquot Sound (i.e., amphibians, reptiles, birds, and mammals) are better known. Like the invertebrates, vertebrates are important components of ecosystem processes, particularly decomposition, nutrient cycling, and seed and spore dispersal. They are also links in the food chains that permit a diversity of species to exist in an area. Clayoquot Sound is particularly rich in vertebrates, especially birds. Of the 368 vertebrate species known for the region of coastal temperate rainforest between Alaska and northern Oregon, 297 have been observed in Clayoquot Sound (Table 2.2). Bats have not been studied in the area and several species, as yet unrecorded, may well occur there. About 20 species of marine mammals have been reported from near-shore waters.

Table 2.2 Number of native land-dwelling vertebrates in Clayoquot Sound region and related forest types.

Zone	Amphibians	Reptiles	Birds	Mammals	Total
Forests of Coastal Western Hemlock zone[1]	11	6	138	64	219
Forests of Mountain Hemlock zone[1]	7	4	69	58	138
Coastal temperate rainforest (Alaska to Oregon)[2]	24	6	259	79	368
Clayoquot Sound:					
all species[3]	7	3	258	29	297
blue-listed species[4]	-	-	31	3	34
red-listed species[5]	-	-	8	3	11

[1]Breeding species only. Includes mainland British Columbia as well. All but eight species in the MH zone are also found in the CWH zone.

[2]Includes non-breeding species.

[3]Includes non-breeding species; many birds use the area primarily during migration.

[4]Species considered to be vulnerable or sensitive.

[5]Species that are candidates for designation as endangered or threatened.

Much of the richness of terrestrial vertebrates is attributable to the forest cover.

Among terrestrial vertebrates of Clayoquot Sound, much of the richness in the resident fauna is attributable to the forest cover. Most of the area is classified as Coastal Western Hemlock, which has one of the richest vertebrate faunas among the 14 biogeoclimatic zones in British Columbia. Because of their isolation on Vancouver Island, Clayoquot Sound forests do not show the same richness in amphibian or mammal species as do similar forests on the mainland. The richness is equivalent, however, for the more mobile bird species, many of which feed in the area during migration but are not resident there. Overall, about 62% of the vertebrate species recorded for Clayoquot Sound are forest-dwelling.

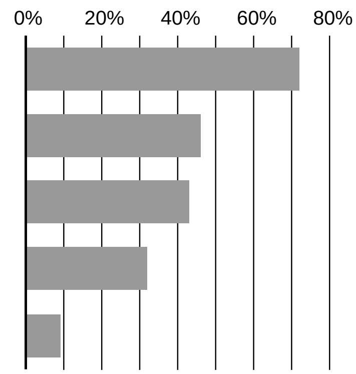
About 72% of the forest-dwelling vertebrates use riparian areas.

The native vertebrate fauna of Clayoquot Sound is shaped by and adapted to an environment strongly influenced by water and dominated by near-continuous, long-lived forests. About 72% of the forest-dwelling vertebrates make significant use of riparian areas (Figure 2.4). Use by all vertebrates of either riparian or shore habitats is still higher—76% for birds and 86% for mammals. Even snakes, such as the common garter snake and western terrestrial garter snake, are predominantly riparian species. The moist environment favours skin breathers such as the terrestrial salamanders. Of the 20 amphibian species found in the entire province, seven are found in the limited area of Clayoquot Sound—again emphasizing the moist, water-dominated character of the environment. Species not closely associated with forest cover, such as the eight loon and grebe species present, are intimately associated with the water systems of the area. Moreover, loons and other lake-dwellers often select waterbodies surrounded by older forests rather than by cutover or open areas.

Many species exploit the estuaries as staging or foraging areas (e.g., sandpipers, godwits, dowitchers), or forage and breed in the near-shore environment (e.g., cormorants, ducks, mergansers). Several of these species are only indirectly affected by forest cover. Nonetheless, the connections from headwater to estuary and intimate linkages between forests and water in riparian areas mean that even loons and gulls can be influenced by the nature and extent of forest practices (see Sections 2.2.4 and 2.2.5).

Figure 2.4 Percentage of forest-dwelling vertebrate species in Clayoquot Sound using different forest components for breeding.

Breed in riparian areas	72%
Breed primarily in older forests (greater than 140 years old)[1]	46%
Breed in downed wood (excludes birds)	43%
Breed or hibernate in cavities (excludes amphibians, reptiles)	32%
Breed primarily in regenerating forests (less than 20 years old)[1]	9%



[1]Few species breed only in one age class of forest, but many breed primarily in older or in younger forests.

Features of the vertebrate fauna reflect close associations with the area's large, long-lived trees and complex forest structure.

Other features of the vertebrate fauna reflect close associations with the area's large, long-lived trees and complex forest structure. The small forest gaps and abundant understory support numerous shrub nesters, such as Wilson's warbler and gray-cheeked thrush, along with cavity-nesting woodpeckers and nuthatches in the adjacent forest. At least 47 species (37 birds and 10 mammals) in Clayoquot Sound use the cavities of large trees—living and dead—to raise their young or hibernate. These species constitute about one-third of the forest-dwelling vertebrate fauna (Figure 2.4). Still more species rely on trees that have fallen to the ground (downed wood). Within the CWH zone, more species than in forests of any other biogeoclimatic zone use downed wood as breeding sites; about 40 of these species occur in Clayoquot Sound. Winter wrens, marten, and black bears nest or den in the root wads or hollows of windthrown trees. A remarkably high percentage (43%) of the amphibians, reptiles, and mammals in forests of Clayoquot Sound use downed wood to breed (Figure 2.4).

About 45% of the area's forest-dwelling vertebrates breed primarily in older forests, while less than 10% breed best in young forests.

Both abundant cavity-sites and significant amounts of downed wood are products of older forests and long intervals between disturbances. Some species in Clayoquot Sound, such as breeding marbled murrelets, are largely restricted to old-growth forests. Others depend on old-growth attributes. For example, bald eagle and great blue heron require large, structurally complex trees as breeding sites, while black-tailed deer profit from closed, older forests with small openings during years of deep snowfall. A few species, such as the western red-backed salamander, require at least limited areas of closed forest tall enough to maintain a humid microclimate. Among forest-dwelling vertebrates in Clayoquot Sound, about 45% breed primarily in older forests, while less than 10% breed best in young forests less than 20 years old (Figure 2.4). Other species are more general in their habits.

Effects of forest openings on animal behaviour vary widely. Many species that use both forest and open areas prefer edge habitats where canopy influence is substantial. For instance, black-tailed deer often feed on early seral vegetation[24] in openings, but prefer to stay within two to three tree heights of the canopy edge (Kremsater and Bunnell 1992). Some smaller mammals usually stay much closer to the edge. Provided appropriate habitat structures are available (e.g., wildlife trees[25] of sufficient diameter), forest birds such as woodpeckers will use openings with minimal canopy influence.

Photo 2.9

Different ages and species of trees occur in old-growth forests of Clayoquot Sound. These uneven-aged stands provide the variety of habitats needed by the many species of plants and animals that inhabit coastal temperate rainforests.

Thirty-three species of vertebrates are largely restricted to the environment and range of coastal temperate rainforest in North America. Populations of these species in the rainforest are thus globally significant. At least 13 of these 33 species occur in Clayoquot Sound. Four of these species are largely restricted to older forests or their attributes (e.g., downed wood) during breeding. Forest

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[24] Early seral vegetation is vegetation appearing soon after disturbance (e.g., fireweed).

[25] Wildlife trees are dead, decaying, deteriorating, or other designated trees that provide present or future critical habitat for the maintenance or enhancement of wildlife.

practices that significantly modify riparian or aquatic ecosystems or simplify the complex structure of the forest can adversely affect these, and less restricted, species. Retaining some near-continuous forest cover, including large live trees, snags, and downed wood, is particularly important.

2.2.4 The Hydroriparian Ecosystem

Waterbodies and the immediately adjacent environment are intimately linked.

Water and the adjacent terrestrial environment have traditionally been treated as two separate systems: aquatic and riparian. This separation disregards the ecological reality that waterbodies and the immediately adjacent environment are intimately linked by the exchange of water, material, and organisms, and by the special character of ecosystems that develop in or around waterbodies. Such ecosystems depend upon the timing of water levels and flows, and the quality of water present. Because of this relationship, the waterbodies and immediately adjacent terrestrial environment should be treated as a single system, here termed the "hydroriparian ecosystem."

Photo 2.10

The hydroriparian ecosystem consists of both aquatic and riparian components.

The hydroriparian ecosystem consists of waterbodies and the adjacent terrestrial environment that is influenced by, or influences, the aquatic system.

The hydroriparian ecosystem has two components, each consisting of an intricate network of connections both above and below ground. The aquatic component comprises the open waters of lakes, streams, and rivers, together with their biota,[26] plus the groundwater with its biota. The terrestrial riparian component, consisting of all land that is adjacent to waterbodies, is both influenced by and influences the aquatic system and its associated biota.

While it is convenient to consider the hydroriparian system in terms of its two

major components, the aquatic component blends into the riparian component where small headwater streams begin as seepage from saturated soil in and around the apparent streambed. Similarly, the aquatic and riparian components blend laterally across sloughs, marshes, bogs, and other wetlands.

[26]"Biota" refers to all organisms—plant, animal, microbe, and fungi—that inhabit a specific region or time period.

The aquatic and riparian components of the hydroriparian ecosystem influence each other strongly.

The aquatic and riparian components of the hydroriparian ecosystem influence each other strongly. Riparian vegetation shades the stream and influences its temperature. It provides the large woody debris that helps to form the structure of the stream channel, and the leaf litter that supports heterotrophic production.[27] The bedrock and surficial material contribute dissolved ions that determine water chemistry. The stream, on the other hand, influences the land by depositing sediment upon it during floods, and by eroding its banks. Around bogs and other wetlands the links are particularly strong and the two components merge.

Trophic processes[28] and aquatic insect faunas strongly reflect the stream and riparian conditions. These processes and faunas gradually change from headwaters to ocean, forming a continuum of changing physical conditions, trophic processes, and communities (Vannote *et al.* 1980). Because various species of fish are adapted to various habitat conditions, they tend to occur in zones within the stream continuum. This zonation reflects connections with both the riparian and aquatic environments.

Small streams are critically influenced by the surrounding vegetation.

Small headwater streams in Clayoquot Sound usually are heavily shaded. Most nourishment for animals in the stream comes from outside the stream itself. The trophic processes within these streams are based on input of insects, leaves, and twigs from adjacent riparian areas. Water temperatures tend to be relatively stable and low throughout the day, and there is relatively little algal growth or primary production within the stream. Small streams are critically influenced by the surrounding vegetation.

Progressing downstream, the nature of trophic processes changes. The stream channel becomes less shaded, the daily range of temperature increases, algal production increases, and more food energy is produced within the stream itself. Insect faunas contain more species that graze algae from stream bottom stones and more species that collect drifting organic matter. The increased daily range of water temperature permits greater diversity of insect lifestyles and species. These small organisms form the bases of several food chains—at the top of which are the commercially or culturally valuable salmonid fish, and herons, eagles, and bears. Maximum faunal diversity tends to occur in the largest, low-gradient streams in Clayoquot Sound, such as the Megin or Kennedy rivers. In these larger streams, the trophic system is driven primarily by processes within the stream, although linkages between streams and adjacent riparian areas are still evident.

In the upper estuary, insect faunas change dramatically and species composition shifts to other forms of macroinvertebrates, particularly crustaceans. The upper part of the stream system, although distant, influences the estuary and the near-

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[27] Heterotrophic production refers to the production of nutrients from complex organic substances (e.g., leaf litter), as compared to the production of complex nutritional organic substances from simple inorganic substances such as carbon dioxide (“autotrophic production”).

[28] Trophic processes refer to the manner and form by which individuals and communities obtain energy (e.g., photosynthesis, scavenging, grazing).

estuary marine environment; for example, by providing organic matter ranging from detritus to whole trees.

Forestry activities may alter not only stream channel morphology and hydrological and sediment regimes, but may also modify trophic processes. In causing these changes, forestry activities may modify life histories and success of various riparian and aquatic species, shift the zones in which maximum biological diversity occurs, and change the distribution of fish (Hartman and Scrivener 1990).

Forests in riparian areas play critical roles.

Forests in riparian areas play critical roles beyond shading, food production, and food-gathering processes. In upslope and riparian areas, plant roots that die and decompose leave channels through the soil, which transport water rapidly to the stream channel. The presence and condition of forest vegetation thus affect the rate of water movement through the soil. Trees along streambanks are the source of whole trees and smaller wood fragments that, when they fall into the stream and lodge, help to store gravel in the stream channel, regulate stream velocity, and influence stream channel morphology. Woody debris in the stream channel provides a variety of habitats for aquatic organisms.

Effects of the aquatic system on the riparian area are no less strong. An obvious factor is the proximity of two distinct habitats (water and land), both critical to semi-aquatic species such as American dippers, mink, and river otter, as well as to aquatic species. An equally strong effect is the continuous or seasonal influence of water which encourages a productive and diverse plant community different from communities found on adjacent hill slopes. This diversity and productivity is reflected in the use of riparian areas by many animal species.

Subterranean water is newly recognized as an important habitat.

Subterranean water is newly recognized as an important habitat containing its own unique communities; groundwater forms two contrasting zones, each with its own biota (Stanford and Ward 1988). The hyporheic (flowing water) zone provides habitat for the immature stages of several insect species which, on reaching maturity, join the biota of the riparian area. The phreatic zone, where groundwaterflows much more slowly, is the habitat of several species of permanently subterranean crustaceans. The waters of these zones are continuous with each other but, except in a narrow transition zone, quite distinct in their chemical properties and their speed of flow. Floodplain plants, part of the riparian biota, obtain their water and mineral nutrients from the hyporheic and phreatic waters beneath them.

Four points about the hydroriparian ecosystem merit emphasis.

The hydroriparian ecosystem is the skeleton and circulation system of the ecological landscape.

- The hydroriparian ecosystem is the focus of activity for a large portion of all fauna, and the site of the most diverse flora in a watershed. The hydroriparian ecosystem is the major travel corridor for many terrestrial and all aquatic organisms—essentially the skeleton and circulation system of the ecological landscape.

- These land-water systems are strongly affected by logging and roadbuilding (Hartman and Scrivener 1990). Such activities can alter channel morphology

(Section 2.1.4), hydrology, and shading or thermal regimes. Changes in the riparian environment that modify physical processes influence the invertebrate faunas and thus may alter fish species composition or shift fish species zones within a stream system.

Natural paths and regimes of subsurface waterflow are important to plants and animals, as well as to slope stability.

- The maintenance of natural paths and regimes of subsurface waterflow is important to plant and animal biological diversity, as well as to slope stability. This is particularly true for wetlands and steep slopes, and for subterranean organisms.
- Each watershed contains its own hydroriparian ecosystem, largely isolated from the hydroriparian ecosystems in other watersheds. Many species in hydroriparian ecosystems, especially wingless aquatic invertebrates, cannot survive outside the system even for short periods. These species are genetically isolated from those in other watersheds for most of the time. Genetic exchange is possible only when uncommon events, such as when exceptionally high floods dilute seawater sufficiently for freshwater organisms to survive drifting between stream mouths, permit intermingled populations. The result is genetic divergence in the isolated populations, leading to high genetic diversity.

These points emphasize the importance of maintaining vegetation in riparian areas, restricting rates of forest removal (rate-of-cut) within watersheds, constructing and locating roads carefully, and treating watersheds as discrete units.

2.2.5 From Stream to Sea

Linkages from terrestrial riparian systems to streams continue to the sea.

Linkages from terrestrial riparian systems to streams extend beyond watersheds and continue on to the sea. The stream system is connected to the ocean through physical processes of water, wood, sediment, nutrient and particulate matter export. The ocean is connected to the stream through migration of fish. All salmonids depend on the freshwater environment for reproduction, and most depend on the ocean environment for their growth. Conversely, some sculpins depend on freshwater environments for growth and on the ocean or estuaries for reproduction.

Stream systems in Clayoquot Sound may contain fish from the following groups of species: Pacific salmon (coho, chum, pink, sockeye, and chinook); trout (steelhead and cutthroat, and non-anadromous forms of these species); char (Dolly Varden); cottids (prickly and coast range sculpins); minnows (peamouth chub); sticklebacks; and lampreys. Within Clayoquot Sound, individual species occur in some stream or stream-lake systems, but not in others. The number of fish of any species varies among stream systems depending upon drainage size and stream characteristics.

Photo 2.11

Streams provide critical spawning habitat for sockeye and other species of salmonids. Activities on land, natural and human, can cause siltation of spawning beds and reduce salmon productivity.

About 100 streams in the Clayoquot Sound area have been identified as containing one or more species of salmon.

About 100 streams in the Clayoquot Sound area have been identified as containing one or more species of salmon; sockeye, chum (in lower stream reaches), and coho are the species most commonly found (Canada 1991). Streams usually contain only one or two species (e.g., chum or coho salmon, cutthroat trout). Some streams and lake systems support several species of fish with populations numbering in the tens of thousands. In most streams, however, populations of individual species are small, less than 100 adults.

Escapement[29] data represent spawning adult numbers rather than accurate measures of fish production.[30] The trends in escapement of salmon reported by the Department of Fisheries and Oceans (Canada 1991) are, for many populations, similar to the trends in run strength reported by the Nuu-Chah-Nulth members of the Panel.

The numbers of some species of salmon in Clayoquot Sound streams have declined.

Estimated average escapements to Clayoquot Sound streams differ among species of salmon (Table 2.3) and have varied widely from year to year. Sockeye and chum have been the most abundant species, and chinook the least abundant (Figure 2.5). Estimated numbers of some species of salmon in Clayoquot Sound streams have declined while those of other species appear to have remained about the same. These data are not precise, but indicate the relative magnitude of runs and long-term trends in populations.[31] Average annual coho and chinook numbers, based on five-year intervals, declined from 1968 to 1992. Available data suggest that pink salmon became virtually extinct after the 1978–82 estimates (Figure 2.5). No trend is apparent, or numbers appear stable, for sockeye and chum salmon.

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[29]Escapement is an estimate of the numbers of adult fish returning to a stream to spawn.

[30]Data of Table 2.3 and Figure 2.5 are derived from Canada (1991) and other records from the Department of Fisheries and Oceans.

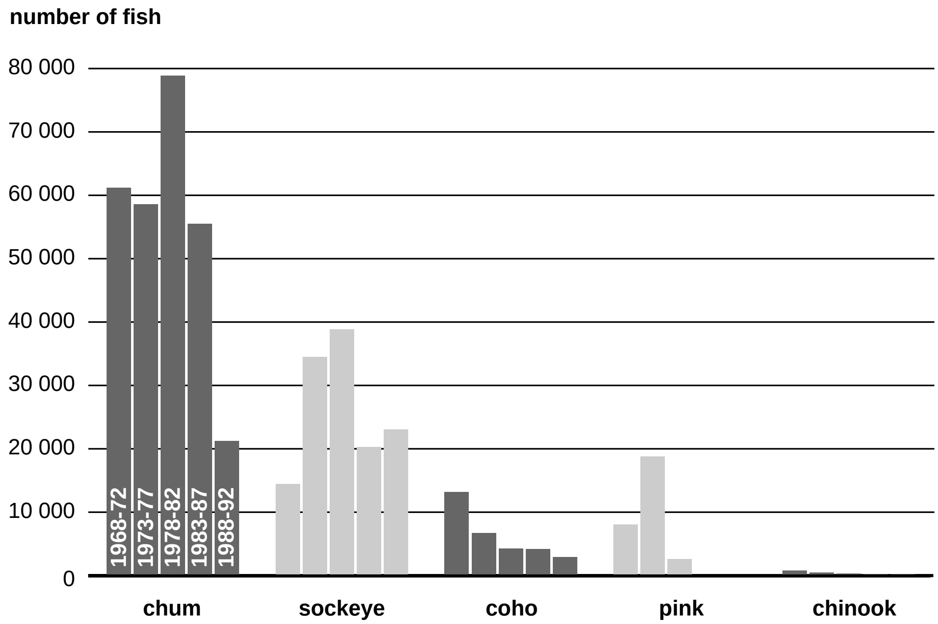
[31]Because escapement data may not be based on estimates from the same streams each year, interpretations must be made cautiously. Effective data gathering and interpretation to estimate spawning runs has been hindered by the limited extent of local monitoring. Nuu-Chah-Nulth experience is that formerly productive streams, excluded from some estimates, are now barren.

Table 2.3 Average annual escapement to Clayoquot Sound streams, Area 24, Tofino, 1968–1992.

	Chum	Sockeye	Coho	Pink*	Chinook
Average	55 070	26 232	6 278	2 701	424
Range	9 506–117 795	6 275–93 960	940–21 875	1 600–26 700	52–1 079

*Data are shown for the "high" years; 0–50 fish for "low" years. No information available for steelhead.

Figure 2.5 Average annual escapement estimates based on five-year intervals, Area 24, Tofino, 1968–1992.



Streams, lakes, and estuaries of Clayoquot Sound all provide incubation and rearing environments for trout and salmon.

Streams, lakes, and estuaries of Clayoquot Sound all provide incubation and rearing environments for trout and salmon. Streams provide incubation environments for five species of Pacific salmon. Coho and chinook salmon remain in streams for a few months after emergence, while young sockeye rear in lakes. Some juvenile coho salmon and cutthroat trout seasonally enter very small tributaries and ponds which are safe aquatic habitat during winters characterized by severe storm events but which are dry riparian areas in summer. In some years, this habitat produces almost one-quarter of all coho smolts (Brown and Hartman 1988).

Many streams contain small resident populations of cutthroat trout and Dolly Varden. The life histories of fish in these resident populations differ from those of the trout and salmon that migrate to and from the sea. Resident populations occupy relatively short lengths of stream channel, typically in low gradient reaches which are located above barriers that block upstream migration. Their migrations are restricted to short movements into and out of nearby side channels or lakes to spawn or to avoid extreme waterflow conditions during winter. Their connections to stocks below the barriers are limited to situations in which fish move, or are washed, downstream below the barriers.

Resident fish may require the highest degree of protection.

Resident fish, such as Dolly Varden, have been isolated from downstream fish for thousands of years, and the population in each stream where resident populations occur may be genetically distinct (Northcote and Hartman 1988). Because resident populations spend most of their life within relatively short reaches of stream channel, and are genetically isolated, they are especially vulnerable. They have no refuge from damage to their stream channel, and no opportunity to rebuild their populations by immigration from the sea or adjacent streams. For these reasons, resident fish may require the highest degree of protection. However, because the fish are small and do not provide a commercial or recreational fishery, they generally have been overlooked in protection measures. It is likely that many such resident fish stocks have suffered from habitat damage resulting from past logging practices.

Although we tend to think of fish as occupying either a marine or freshwater environment, or migrating from one environment to the other, the distinction in habitat use is often less clear than that. Chum salmon spawn in the lower reaches, within 0.6 km of the sea in most streams where they occur, and spawn in the intertidal zone in some streams (e.g., Carnation Creek, Barkley Sound).[32] Chum egg-to-fry survival in the intertidal zone is comparable to that in freshwater sections of the creek (Groot 1989). A part of the juvenile coho population in coastal streams may undergo some maturation in the estuarine zone. Prickly sculpins may use both estuarine and stream environments at different times in their lives. Other species, predominantly marine, move into estuaries during some phases of their life history (e.g., herring use estuaries as feeding areas). Such combined use of freshwater-marine, estuary-freshwater, marine-estuary, or marine-freshwater systems reveals that these environments are functionally linked for many species of fish, and emphasize the important role of estuaries.

Events far upstream, well removed from spawning areas, can influence downstream characteristics and organisms.

The number and importance of land-to-sea connections are becoming better understood. Events far upstream, well removed from spawning areas, can influence downstream characteristics and organisms. Transport of organic material (e.g., detritus, twigs, small woody debris, and whole trees) downstream to estuaries enforces both trophic and structural links among freshwater, estuarine, and marine environments. Activities carried out upstream or on the shore zone may affect marine conditions and organisms. The Nuu-Chah-Nulth have observed that upstream or onshore activities that affect water quality, by addition of sediment or dissolved organic material, may disrupt herring spawning. They are strongly concerned that log dumping may affect herring spawning and geoduck numbers.

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[32]Barkley Sound is a source of detailed data on instream fish natural history. Because Barkley Sound is immediately adjacent to Clayoquot Sound, the Panel deems that this information is relevant to Clayoquot Sound. See Hartman and Scrivener (1990) for a summary presentation.

Woody debris, far out at sea, provides cover and food for more than 100 species of invertebrates and 130 species of fish.

Some relationships between the terrestrial and marine environments have been recognized only recently. Large, sunken woody debris plays a vital role in the ecology of the ocean. As well, windrows of debris and trees, far offshore where water converges and downwells, provide cover and food for more than 100 species of invertebrates and 130 species of fish (Sedell and Maser 1994). These observations emphasize the importance of maintaining the integrity and natural processes of stream systems along their entire length. Forestry practices need to retain sufficient vegetative cover and natural drainage patterns to maintain soil stability, natural stream discharge regimes, and habitats of stream-dwelling organisms.

Some of the watersheds within Clayoquot Sound contain lakes. These waterbodies reflect the regional climate and geology, and are relatively oligotrophic or low in nutrients. Lakes within the drainage systems modify the conditions of the streams that pass through them. They dampen floods, alter water temperatures, intercept sediment, and store large woody debris. Trophic processes in lakes differ from those in the streams. Production, almost entirely autotrophic, maintains planktonic algae in the lakes. The insect and crustacean faunas of the lakes are almost entirely planktonic as opposed to being benthic, as in streams.[33]

Fish faunas within lakes include commercially and recreationally valuable species.

Fish faunas within the lakes include some of the commercially and recreationally valuable species, such as sockeye and coho salmon juveniles, trout and Dolly Varden, as well as non-commercial species such as three-spined stickleback, peamouth chub (Kennedy Lake), and sculpins. The peamouth chub and stickleback are, predominantly, lake species. The stickleback is a significant species because it may compete with juvenile sockeye in Kennedy Lake.

Lakes, as a whole, may be less vulnerable than streams to ecological impacts from logging activities. However, high levels of suspended sediment in the streams may lead to increased suspended sediment in the lakes. At high concentrations such material would reduce plankton production in the lake. Shore zones, in much the same way as streams, are vulnerable to the effects of forest removal at the shoreline.

2.3 Human Values in the Landscape

Clayoquot Sound is important to people for cultural, spiritual, and scenic values, and for recreational and tourism use.

Many aspects of the Clayoquot Sound environment are important to people—both First Nations and others—for cultural, spiritual, and scenic values, and for recreational and tourism use. The resources in Clayoquot Sound also provide economic benefits for residents and the province of British Columbia.

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[33]Plankton are the chiefly microscopic organisms drifting or floating in the sea or fresh water; benthic organisms are the flora and fauna found at the bottom of a sea, lake, or stream.

2.3.1 First Nations' Values

First Nations' values are discussed more fully in the Panel report: *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b).

Nuu-Chah-Nulth people represent roughly half of the area's current resident population.

The Nuu-Chah-Nulth, traditional landowners and resource users of Clayoquot Sound, represent roughly half of the area's current resident population. Nuu-Chah-Nulth people view the forest and its resources as gifts of the Creator, to be used with respect and to be maintained by careful stewardship through the legislative power of tribal government found within "***h̲ah̲uulhi***."[34] Traditional practices of resource management include harvesting of selected trees and other forest products; highly selective controlled burning to promote production of berries, to provide grazing areas for deer, and to produce firewood; and monitoring and controlled use of all lands and waters and their resources through stewardship of hereditary chiefs.

Photo 2.12

A culturally modified western redcedar tree from which a strip of bark was removed many decades ago.

Within each community, chiefs' territories—rivers and fisheries, hunting and gathering areas, and portions of the ocean—are delimited by boundary markers such as easily recognizable topographic features. While permanent Nuu-Chah-Nulth villages are situated along the coast of Clayoquot Sound, economic and cultural activities (e.g., hunting, fishing, plant gathering, and spiritual practices) occur throughout the region, from the ocean and offshore islands to remote places in the mountains. For example, culturally modified trees,[35] places of spiritual significance (especially caves, streams, pools, waterfalls, and offshore islands) which are often personal to individuals and

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[34] ***H̲ah̲uulhi*** refers to the plenary authority exercised by Nuu-Chah-Nulth hereditary chiefs over the people, land, and resources of their tribal territories.

[35] Trees with evidence of bark stripping, planking, or test holes.

families, and areas used for traditional activities are scattered widely across the landscape. These places *and* the area's forests and water resources are essential for Nuu-Chah-Nulth economic, cultural, and spiritual well-being, yet both have been threatened, depleted, or damaged by the activities of non-indigenous peoples.

2.3.2 Values of Non-Indigenous Peoples

Most residents are economically dependent on local forest and marine resources.

In addition to the Nuu-Chah-Nulth, Clayoquot Sound is inhabited by non-indigenous people who live primarily in or near Tofino and Ucluelet. Most of these residents depend on local forest and marine resources which form the basis for timber, tourism, fisheries, and aquaculture industries (Clayoquot Sound Sustainable Development Strategy Steering Committee 1992). The economic importance of these resources extends to Port Alberni and the Alberni Valley, where jobs are supported by the forests of Clayoquot Sound. Many of these people accept clearcuts, associated roads, and other scenic modifications as part of using the forest resource for timber.

Photo 2.13

Forest harvesting provides economic benefits for many people in Clayoquot Sound. To some, clearcuts are an acceptable consequence of resource extraction.

Ecological integrity of the forest ecosystem is essential to meeting economic, spiritual, and recreational needs.

Besides the economic benefits, non-indigenous residents value many aspects of the environment and scenery of Clayoquot Sound and some people choose to live in Clayoquot Sound for other than financial reasons. The environment contributes to their quality of life and is important for their spiritual and social well-being.[36] Like the Nuu-Chah-Nulth, the future of non-indigenous people is intimately tied to the landscape. The long-term viability of these communities and livelihood of the population depend upon sustaining the resources of Clayoquot Sound. Over the long term, ecological integrity of the forest ecosystem is essential to meeting their economic, spiritual, and recreational needs.

[36]The Panel's discussion of the values of non-indigenous peoples is largely limited to those values associated with scenery and recreation or tourism. That limitation is not intended to deny other values (see Sections 1.1 and 6.0).

2.3.3 Scenic Values

Landscape appearance is important to residents and visitors to Clayoquot Sound, for aesthetic reasons and as an indicator of forest health.

Landscape appearance is important to Nuu-Chah-Nulth, other residents, and visitors to Clayoquot Sound, both for aesthetic reasons and as a potential indicator of the health of the forest resource. In a study of marine tourism opportunities and during focus groups held as part of tourism resource inventories, most tourists and recreationists in British Columbia identified scenery as the resource that is most important to their activity (ARA Consulting Group 1991, 1993).

Photo 2.14

Coastal vistas are an important resource which draws many visitors to Clayoquot Sound.

Clayoquot Sound has highly valued scenic resources. Dramatic mountain topography, and alpine, river, and lake landscapes are visible from Pacific Rim National Park and Highway #4. Both lakes and streams provide opportunities for specific uses and for appreciation of particular types of scenery. Some rivers are important for fishing, and many are used as sources of fresh water. Because of the riparian vegetation, rivers provide a diverse and intimate landscape experience. Lakes, especially those which are easily accessible, can also be important as sources of fresh water, and for fishing, swimming, and boating. The coast includes major fjords, distinctive islands, and archipelagos, and numerous smaller features such as beaches, waterfalls, and rock formations. In some locations, steep terrain drops directly into the water; in other areas, lower land in the foreground allows views to alpine peaks in the distance.

Logging has had major effects on scenery in parts of Clayoquot Sound. Some mountainsides have been so extensively clearcut that it will take years to recover their former scenic values. Nuu-Chah-Nulth people speak often about the wounds that logging has inflicted on the land. Photographs of past logging activities have been used effectively by environmental groups in their lobbying to change forest practices. There are two primary sources of negative visual impacts in Clayoquot Sound: the size of many previous clearcuts, and unvegetated slopes resulting from sidecasting[37] and slides associated with roads on steep slopes.

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[37] "Sidecasting" refers to the release or placement of earth materials downslope from a road, landing, or facility excavation; it is the means for building the filled portion of "cut-and-fill" surfaces.

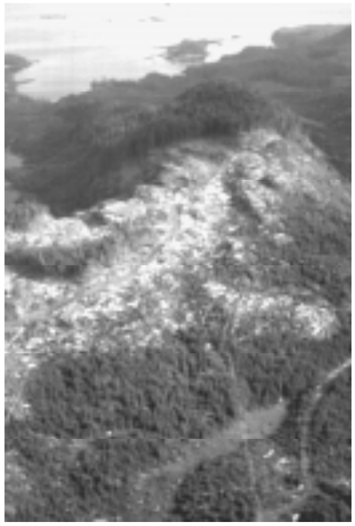


Photo 2.15

Scenic resources can be greatly diminished through inappropriate forest practices.

People in the forest industry rated logged scenes with the same low scores as other respondents.

There is a growing amount of literature focused on how landscapes are perceived, and relating perceptions to psychological factors. Perception studies most often use photo-questionnaires, in which respondents rate a series of photographs. This method provides a reliable measure of preference (Kaplan 1979). While some studies have noted minor variations in preferences among different socioeconomic groups (e.g., members of environmental groups had a lower than average preference for dominantly altered scenes; Dearden 1984; McCool *et al.* 1986), more remarkable is the similarity of preferences among respondents. For example, in a study in the Kootenays, people in the forest industry rated logged scenes with the same low scores as other respondents (Berris and Bekker 1989).

Natural-appearing landscapes are preferred over dominantly altered ones.

Studies that have focused on forested landscape scenes have found that natural-appearing landscapes were preferred over dominantly altered ones (Miller 1984; McCool *et al.* 1986; Berris and Bekker 1989). Scenes with depth, distant views, steep mountain faces, snow-capped peaks, water, and especially a combination of these attributes, were particularly liked. Generally, logging meeting the B.C. Ministry of Forests visual quality objectives of "retention" or "partial retention" was found to be significantly more acceptable than cutblocks which are rated "modification" or greater.[38]

[38]Visual quality objective (VQO) defines a level of acceptable landscape alteration resulting from timber harvesting and other activities. In the "Preservation VQO" class, alterations are not visible. In the "Retention VQO" class, alterations are not visually evident to the casual forest visitor. "Partial Retention VQO" is when alterations are visually subordinate to the natural landscape. In the "Modification VQO," alterations are visually dominant, but should borrow from natural line and form. In the "Maximum Modification VQO," alterations are dominant and out of scale, but appear natural in the background. "Excessive Modification" is not a VQO, but may be used to describe a presently unacceptable visual condition.

Selection silvicultural systems are perceived as unaltered landscapes.

The least preferred scenes contained recent, ill-fitting, and/or dominant human-caused alterations in the foreground or middleground. Ill-fitting cutblocks are characterized by straight edges and rectilinear corners, large size, high colour and texture contrast, and notched skylines. Individual cutblocks are not as noticeable in areas where landform and vegetative cover are diverse, or where there is already a high level of alteration or development. Studies have also shown that selection silvicultural systems are perceived as unaltered landscapes (McCool *et al.* 1986; Bekker 1987).

Although perceptions based on purely visual factors are generally consistent across the population, the types of scenery that people seek for their activity vary among tourist and recreational groups (ARA Consulting Group 1992; Catherine Berris Associates Inc. 1993). To some groups (e.g., kayakers), unaltered scenery is the most important consideration. To other groups, such as those on cruise boats, varied dramatic scenery such as diverse topography, water, and mountain peaks is most important.

Perception is an active process in which people obtain and interpret information.

In the consideration of scenic values, implications go beyond the purely visual. Perception is an active process in which people obtain and interpret information about their environment based on their knowledge and experience. In addressing scenic values, the perceptions of people are being considered; what people know about forest practices will affect their response. The goal of scenic resource management, therefore, in striving to satisfy visual preferences, is also to provide a personal and social comfort level with what is happening in the landscape.

Given the importance of scenery to resident and non-resident users of Clayoquot Sound and the existing and potential economic value of tourism to the area, it is critical that the scenic resources be appreciated, understood, and properly managed in the long term. This will provide people with a desirable environment for their activities and indicate that spiritual and forest health also are being acknowledged in planning.

2.3.4 Recreational and Tourism Values

There are outstanding opportunities for recreation and tourism in Clayoquot Sound.

There are outstanding opportunities for recreation and tourism in Clayoquot Sound. Natural history excursions along coastlines and to old-growth forests, wildlife tours, air tours, and activities such as kayaking, sailing, and hiking are well established and expanding. These activities depend greatly on the natural resources of Clayoquot Sound, including vegetation, wildlife, and scenic resources. They also provide economic opportunities.

Photo 2.16

Kayaking is a popular recreational activity enjoyed by both residents and tourists in Clayoquot Sound.

Tourism, an extremely important industry in British Columbia, generated $5.81 million in 1993 (B.C. Ministry of Finance and Corporate Relations 1994:97). The province has strong international appeal for tourism, particularly because of the dramatic coastal and mountain scenery and natural resources. There have been major recent international trends towards ecotourism. A proposed definition for ecotourism in Canada is "an enlightening nature travel experience that contributes to conservation of the ecosystem while respecting the integrity of host communities" (Scace *et al.* 1992). By definition, then, ecotourism is sustainable development. It can also provide an economic justification to conserve areas that might not otherwise be protected. Clayoquot Sound has the potential to expand its ecotourism activities.

Tourism can have significant negative impacts on terrestrial and marine resources and on local communities.

Ecotourism is a highly vulnerable activity because it has the most to lose when practised in an ill-conceived, uncontrolled, or insensitive manner. In the face of explosive growth in international tourism, many of the world's most beautiful and valued places are being overrun by visitors and suffering incalculable damage. Examples include extensive human pollution in the waters of the Mediterranean Sea and Acapulco Bay, garbage and overuse of wood in the Himalayas, and destruction of wildlife habitat in the Galapagos. Both the number of visitors and their activities have contributed to problems. Because tourism can significantly damage terrestrial and marine resources, and local communities, the impacts of tourism should be monitored.

Distinctive trends in recreation and tourism have resulted from new technology and changes in public interests. New technology in kayaks, surfboards, and wetsuits has been one source of increased participation in sea kayaking and surfing, especially on "boogie" boards, on the west coast of Vancouver Island. Changes in public interests have made activities such as wildlife-viewing tours more popular in recent years. When managing resources, it is important to recognize that demands will change over time.

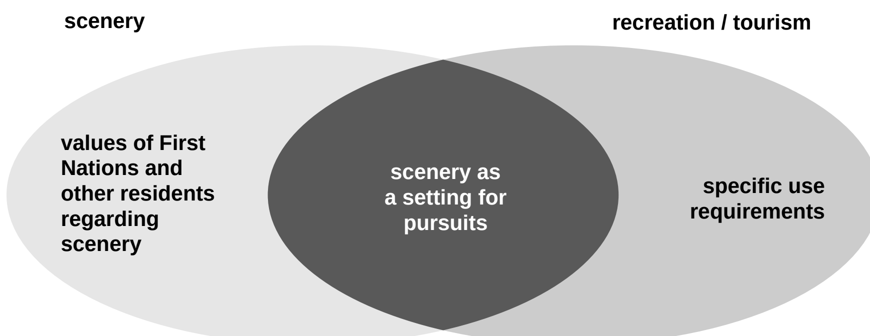
Recreation and tourism overlap considerably in Clayoquot Sound.

Recreation and tourism overlap considerably in Clayoquot Sound. Traditionally, recreation has been considered the non-commercial pursuit of activities, while tourism has been considered to be commercially based, involving expenditures for items such as travel, accommodation, meals, or guided activities. Different groups use various methods to define tourism, including time or distance away from home, or dollars spent. No matter which definition is used, recreation and tourism overlap because most recreational pursuits also involve travel and some expenditures. Tourist activities generally require the same resources as recreational activities. For example, kayakers on their own and those with a guide seek the same resources to support their activity. In this report, where the term recreation is used alone, it is intended to include recreation and tourism.

Recreation and tourism rely strongly on scenery.

Recreation and tourism rely strongly on scenery, as described in Section 2.3.3. Figure 2.6 shows the interrelationship of recreation, tourism, and scenery in Clayoquot Sound. Recreation and tourism are represented as one circle. The interests related to recreation or tourism and scenery overlap because recreational and tourist groups value scenery for their activities. Additional considerations about scenery include the values of First Nations and other residents. Concerns that are specific to recreation and tourism include use factors such as a sufficient landbase to support activities, an appropriate level of activity in key areas (e.g., a high level of use is not acceptable for wilderness activities), and infrastructure for specific activities (e.g., docking facilities for sport fishing).

Figure 2.6 **The interrelationship of tourism/recreation and scenery in Clayoquot Sound.**



Forest practices can affect recreational values.

Forest practices can affect recreational values in a range of ways and to varying degrees, depending on the location, extent, and rate at which trees are removed and new growth is established. Specific sites can become unattractive for recreation if logging occurs too close to them. Wilderness values can be diminished if logging becomes too noticeable. Sounds that accompany logging can be a problem if recreation and logging are occurring simultaneously in one area. Depletion of the resources that support a specific activity (e.g., sport fishing) create a major problem for recreation and tourism. Conversely, previously cut forests, and possibly depleted streams, can regain recreational values as trees mature and streams recover.

Many people form an impression of forest practices through recreational activities.

Many people form an impression of forest practices through their recreational activities. In the past, many recreationists have been alarmed by the effects of logging. Appropriate forest practices provide an opportunity for interpretation and education, another form of recreation, in areas where people can be shown sustainable forest practices.

3.0 Silvicultural Systems

Silvicultural systems describe the process of cutting, regenerating, and tending a stand of trees to produce timber and other forest products.

In forestry terminology, silvicultural systems describe the series of treatments by which a stand is harvested, regenerated, and tended to produce timber and other forest products. In its second report, the Panel recommended a broad set of management objectives for forestry operations in Clayoquot Sound based on principles of sustainable ecosystem management (Scientific Panel 1994a). These objectives differ from those of conventional forest management; they refine and extend the objectives specified for Clayoquot Sound in *Clayoquot Sound Forest Practices Standards* (B.C. Ministry of Forests 1993a). The silvicultural systems and harvesting methods required to meet the refined objectives also differ.

The silvicultural system recommended by the Panel (Section 3.4) is intended to meet the objectives of sustainable ecosystem management while providing land managers some flexibility in their actions. **The recommended silvicultural system and planning process are inseparable parts of an integrated approach to ecosystem management.** Success of the silvicultural system recommended by the Panel depends on the specification of harvestable and reserve areas as described here (Section 3.4) and under planning (Chapter 7).

Selecting a silvicultural system is a separate decision from the rate at which a forest is harvested—the "rate-of-cut." The choice of silvicultural system is based on site-specific characteristics and management objectives for a specific area of land. The determination of rate-of-cut, while considering these factors, employs larger planning units such as a watershed or collection of watersheds, and is calculated as an area.

Rate-of-cut and allowable annual cut (AAC) are distinct. AAC is expressed as volume and should be an output of the planning process. Rate-of-cut is based on area and is an input limitation.

The rate-of-cut and allowable annual cut (AAC) are also distinct. AAC is expressed as volume and, although currently an input, should be an *output* of the planning process based on the area that can be cut under rate-of-cut provisions. The determination of AAC also considers operational and social factors, such as access development, employment, and community stability. Rate-of-cut is based on area and is an *input* to the planning process, constrained by hydrological, fisheries, and other considerations. Confusion arises because the AAC can vary from year to year, in which case the volume removed may also be referred to as rate-of-cut. In fact, the earliest methods for regulating forest harvest were area-based. They were supplanted by volume-based methods in late eighteenth-century Prussia when economic considerations began to dominate forest management.

While the two decisions—choice of silvicultural system and rate-of-cut—are distinct, they are not independent. For instance, a silvicultural system that generates wood fibre in as short a time as possible facilitates a high rate-of-cut. Because the rate-of-cut and the silvicultural system recommended by the Panel address the area of forest remaining after harvest, they are considered together. They are inseparably related to the recommended approach to planning, which also is area-based and specifies allowable annual cut as an output of the planning process.

3.1 Conventional Silvicultural Systems

Four conventional silvicultural systems have been used in North America.

The dominating objective of conventional silvicultural systems has been to create appropriate conditions for regenerating selected tree species. Silvicultural systems are named by the cutting method used to achieve that objective.

Clearcutting, seed tree, and shelterwood are even-aged systems because they create stands in which trees are predominantly one age class. The selection system is an uneven-aged system because it maintains or creates forests with trees of many ages. These silvicultural systems are considered to be discrete; each is suited to particular tree species, specific sites, and specific management objectives. These four systems have been defined in many silvicultural textbooks, and are described briefly here.

The clearcutting silvicultural system removes all trees in a given area in one cutting.

The clearcutting silvicultural system removes all trees in a given area in one cutting, after which an even-aged stand is established by planting or natural regeneration. Clearcuts generally exceed 1 ha (and may be much larger), so that most of the opening is not shaded or sheltered by the surrounding forest.[39]

The seed tree silvicultural system leaves selected standing trees scattered throughout a cutblock to provide seed sources for natural regeneration. The number of trees left depends on many factors, but generally does not exceed 30 trees/ha. The biggest, straightest, most windfirm, and best-looking trees are retained to provide seed; they may be cut at a later date or left as residual old trees in the regenerating stand. The seed tree system results in the growth of an even-aged or mostly even-aged stand with scattered veterans or older trees.

The shelterwood silvicultural system removes the existing stand in a series of two or more cuttings, typically five to ten years apart, that open the stand to encourage regeneration. An essentially even-aged stand develops under the temporary shelter of the remaining trees. The number of “leave trees” retained as shelter during the regeneration period generally ranges from 30 to 100 trees/ha. Leave trees may be dispersed throughout the cutblock or clumped in patches or strips (in group or strip shelterwoods, respectively). Leave trees are cut after regeneration is established.

Selection silvicultural systems involve repeated cuttings, each of which removes some trees in all merchantable size classes in a stand, either as individuals, in small groups, or in strips. In selection systems, young trees are planted or regenerate naturally among the remaining older trees. This periodic cutting and continual regeneration of trees maintains an uneven-aged stand structure. At the completion of the planned cuttings, all or most original trees may have been cut.

Single tree selection and group selection are two variations of the selection system. Single tree selection involves harvesting trees from each diameter class

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[39] An equidimensional 1 ha opening measures 100 m on a side; that is, approximately two site potential tree heights on many Clayoquot Sound sites. Except on moderate to steep south-facing slopes, more than half the clearing would be in shadow for more than half the year.

more or less uniformly throughout the stand. Mature trees are removed, at intervals, as scattered individuals or in groups of two or three trees. Single tree selection is impractical when applied to old-growth forests of large trees because it is usually impossible to remove single stems safely. Group selection involves the harvesting of groups of trees in patches of less than one hectare distributed throughout the stand. Group selection creates a patchwork of small openings providing favourable microclimates for tree species that regenerate better with more shade or shelter than is present in larger openings. Group selection differs from small patch clearcutting in that a series of entries, creating an uneven-aged structure, is planned; it differs from shelterwood in that extensive forest cover is retained. In strip selection, a variation of group selection, trees are removed in strips.

Harvesting done without planning for subsequent regeneration cannot be considered a "silvicultural system."

It should be noted that harvesting done without planning for subsequent regeneration and tending of the next crop of trees cannot be considered a "silvicultural system." For example, "selective logging" merely designates a type of cutting that removes only certain species above a certain size or value. The term is often associated with "highgrading," or cutting only the most valuable trees in a stand. Thus, selective logging is *not* synonymous with selection logging and is *not* a silvicultural system. Similarly, clearcutting areas of forest without considering the regeneration and growth of the next stand cannot be considered a silvicultural system.

Currently, silvicultural systems in coastal British Columbia are usually described as either clearcutting or "alternative silvicultural systems." The latter term refers to all systems other than conventional clearcutting (e.g., seed tree, shelterwood, selection, clearcut-with-reserves, and other reserve systems; point 4 below).

Four important points can be drawn from this review of conventional silvicultural systems.

Conventional silvicultural systems are evaluated in terms of the numbers of young trees of desired species present some time after logging.

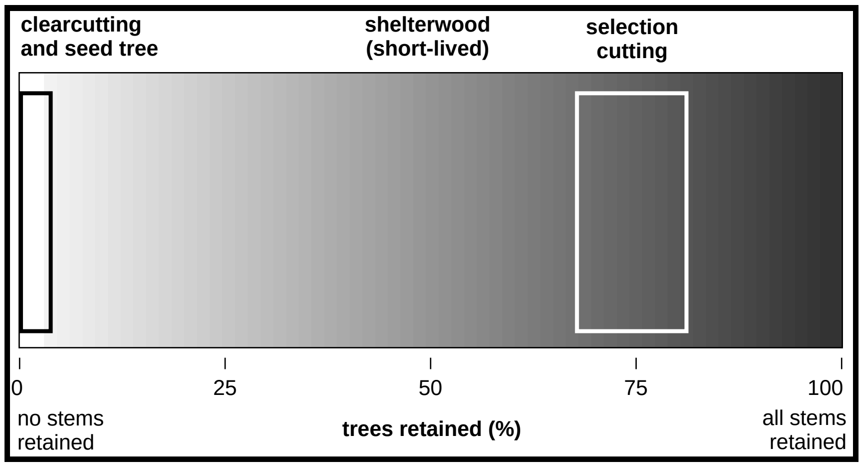
1 Conventional silvicultural systems are designed to encourage a specific environment for regenerating a subsequent stand. The success of these systems is evaluated in terms of the numbers of young trees of desired species present some time after logging.

2 Because of their focus on regeneration, conventional silvicultural systems have historically incorporated a relatively narrow set of post-logging treatments appropriate to the particular system. Clearcutting, for example, is usually followed by specific methods of site preparation, slash disposal, regeneration, control of competing vegetation, and other practices such as pre-commercial thinning (spacing).

Conventional silvicultural systems retain almost all or almost none of the original stems.

3 Some conventional silvicultural systems retain, for some period, a portion of the original stand. However, the degree of retention is limited largely to two extremes: almost all or almost nothing (Figure 3.1). Clearcutting and seed tree systems typically retain 5% or less of the original stems. The same is true of the shelterwood system, except during the short intervals between initial and final cuts. Shelterwoods represent only a short-lived mid-range of retention as the retained trees are typically cut after regeneration has been successfully established. Where trees are not large, selection systems retain 70–80% of the stems after the first entry; 80% may be impractical and unsafe in old-growth forests of Clayoquot Sound. Within a selection system, the percentage of original stems retained declines with each subsequent entry and the stems removed are gradually replaced with younger trees.

Figure 3.1 Extremes of retention in conventional silvicultural systems.



Attempts to express the expanding objectives of forestry using conventional terms have proven cumbersome and confusing.

4 Attempts to express the expanding objectives of forestry using conventional terms have proven cumbersome and confusing. In the terminology used in British Columbia, the trees retained for other objectives (e.g., wildlife trees, visual quality) are sometimes referred to as “reserves” and the modified silvicultural systems are referred to, for example, as “clearcut-with-reserves” or “seed-tree-with-reserves.”

Clearcut-with-reserves describes a system in which some scattered individual trees or small groups of trees are left within a clearcut area to provide for wildlife or other values. The approach has also been called “green tree retention” and “wildlife tree retention,” among other terms.

3.2 Current Silvicultural Systems in Clayoquot Sound

Clearcutting is the overwhelmingly dominant silvicultural system used in Clayoquot Sound.

Clearcutting is the overwhelmingly dominant silvicultural system used in Clayoquot Sound. As shown in Table 3.1, with the exception of 11.5 ha cut in an alternative silvicultural system research trial in 1992, all of the area logged between 1988 and 1993 was clearcut. The average harvest was 950 ha/yr during this period, but the area cut has declined from over 1200 ha in each of 1988 and 1989 to less than 600 ha in 1992 and 1993.

Table 3.1 Logging in Clayoquot Sound, 1988–1994.

Year	Volume cut (m^3)	Total area cut (ha)	Area clearcut (ha)
1988	959 311	1 280	1 280
1989	958 035	1 320	1 320
1990	762 689	950	950
1991	777 375	970	970
1992	452 800	570	558
1993	428 400	520	520
1994 (estimate)	421 547	510[1]	408[2]

[1]Estimate based on volume per hectare.

[2]Estimate based on 1994 approvals; final figures not yet available. The 102 ha not included as clearcut is classed primarily as clearcut-with-reserves.

Source: *Clayoquot Sound Land-Use Decision Update* (British Columbia 1994) and B.C. Ministry of Forests, Port Alberni Forest District, unpublished data.

The IRT has established a goal that 25% of the harvest volume proposed in 1995 logging plans will be logged by alternative silvicultural systems.

Including 1994 developments, six cutblocks have been logged or are currently being logged in Clayoquot Sound using alternative silvicultural systems. As shown in Table 3.2, these include an experimental selection silvicultural system trial undertaken by the B.C. Ministry of Forests in 1992 and two blocks described as clearcut-with-reserves that were being logged in the fall of 1994. Three additional clearcut-with-reserves blocks have been approved by the Interagency Review Team (IRT) in Clayoquot Sound for logging in late 1994/early 1995. These blocks are described in Table 3.3. The IRT has established a goal that 25% of the harvest volume proposed in 1995 logging plans will be logged by alternative silvicultural systems.

Table 3.2 Completed or currently active cutblocks using alternative silvicultural systems in Clayoquot Sound.

System	Location	Description	Tenure[1]
Single tree and group selection[2]	Cat's Ears Creek	• A research/demonstration project of the B.C. Ministry of Forests FFIP[3] involved two blocks on very steep terrain. • Individual trees and small patches of trees were marked for falling, and were yarded by Sikorsky S-61 helicopter in 1992. • The total area from which trees were removed was 11.5 ha. • Falling and removal of individual trees and groups of trees could not be done as planned.[2]	B.C. Ministry of Forests SBFEP TS A35014
Clearcut-with-reserves	Matlset Creek	• Block Mat 100 is on moderately steep slopes in the headwaters of Matlset Creek. • The block is 12.5 ha with approximately eight small patches of reserved trees within the cutting area. Reserves range from single trees to 0.2 ha. Some 176 trees larger than 30 cm were marked as wildlife trees within the reserves prior to cutting. • The block is inaccessible by road and was being yarded in October 1994 by Sikorsky S-61 helicopter.	MacMillan Bloedel TFL 44 CP 12 Block Mat 100
Clearcut-with-reserves	Cypre River	• Cypre River Block 121 is on moderately steep slopes in the upper reaches of the Cypre watershed. • The block was being logged in October 1994 by grapple yarder. • The block is 33.5 ha. There are reserve patches along three steep gullies and the main stream of Cypre Creek, and scattered individual trees on the lower slopes of the cutblock. The reserve area is approximately 6 ha. Individual trees to be reserved within the block and along the boundaries were marked prior to cutting.	MacMillan Bloedel TFL 44 CP 900 Block 121

[1]CP - Cutting Permit; SBFEP - B.C. Ministry of Forests Small Business Forest Enterprise Program; TFL - Tree Farm Licence; TS - Timber Sale.

[2]Although the system was termed "single tree," in practice it proved impossible to remove single trees safely.

[3]FFIP is the "Fish/Forestry Interaction Program," a long-term research program initiated by the federal and provincial governments and continued by the B.C. Ministry of Forests, studying the implications for fish of logging on steep hillsides.

Source: Information provided and reviewed by B.C. Ministry of Forests, Port Alberni Forest District; MacMillan Bloedel, Kennedy and Estevan Divisions; and Interfor, Tofino Division.

Notes: 1. The Panel has visited and reviewed cutblocks in the Tofino Creek watershed and at Dawley Passage that have been described as "clearcut-with-reserves." The Panel does not consider these blocks to be sufficiently different from conventional clearcutting to be included in this table. The Panel also reviewed a number of small cutblocks in Stewardson Inlet and considers these to be unusually small clearcuts, but not a group selection system because a series of entries creating an uneven-aged forest is not planned. These blocks also are not included in the table.

2. The Panel is aware of, but has not visited, a number of blocks in Clayoquot Sound that may meet the definitions of clearcut-with-reserves, but that were not described as such at the time the blocks were approved.

Table 3.3 Blocks approved for future logging with alternative silvicultural systems in Clayoquot Sound.

System	Location	Description	Tenure[1]
Clearcut-with-reserves (1 block)	Fortune Channel	• Block 1-67 is approved by the IRT and expected to be logged in late 1994/ early 1995. • It is 18.8 ha on flat and gently sloping terrain divided into four cut areas. • Individual trees and clumps of trees within the blocks are marked as wildlife trees and will be retained. The total area to be logged is 18.4 ha. • It is planned for yarding by hoe forwarding and grapple yarding.	MacMillan Bloedel TFL 44 CP 12 Block 1-67
Clearcut-with-reserves (2 blocks)	Kennedy Flats	• Two cutblocks, M3A and M3B, have been approved by the IRT and are scheduled for logging in November 1994. • Both blocks are on gentle slopes and were originally part of one larger block. They are separated by a strip of forest representing a section of riparian Forest Ecosystem Network (FEN). • Both blocks incorporate a “take and leave pattern” of cut and reserve areas, and retention of marked trees along the cutting edges is planned. • Block M3A has a total area of 4.7 ha with 3.1 ha to be logged in three patches and 1.6 ha to be reserved in three leave areas. • Block M3B is split by a riparian corridor FEN and retention of scattered individual trees and a corridor of trees between two parts of the block is planned. The total area is 4.4 ha with 3.8 ha to be logged in four patches and 0.4 ha to be reserved in one leave area. • The area will be yarded with a grapple yarder and backhoe tailspar.	International Forest Products TFL 54 CP 100 Blocks M3A and M3B

[1]CP - Cutting Permit; SBFEP - B.C. Ministry of Forests Small Business Forest Enterprise Program; TFL - Tree Farm Licence; TS - Timber Sale.

Source: Information provided and reviewed by B.C. Ministry of Forests, Port Alberni Forest District; MacMillan Bloedel, Kennedy Lake Division; and Interfor, Tofino Division.

Notes: 1. The Panel is aware that a number of blocks involving alternative silvicultural systems are in various stages of planning but have not yet been approved by the IRT.

2. The draft *Coastal Biodiversity Guidelines* (April 1994) state that “the goal of a Forest Ecosystem Network is to maintain a network of old-growth, mature forests, and special habitats (such as riparian zones, cliffs and critical habitats for threatened/endangered species) and provide some forest-interior conditions within each landscape” (B.C. Ministry of Forests 1994b:7). See also the glossary of the *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:179).

Alternative silvicultural systems have been used on at least 59 cutblocks on British Columbia's coast.

At least 59 other cutblocks on Crown land on British Columbia's coast have been identified where alternative silvicultural systems have been used in the last five years (Moore 1994). Two recent examples of clearcuts-with-reserves can be found near Clayoquot Sound. At McTush Creek, approximately 25 trees/ha have been left dispersed within cutting areas which are separated by patch reserves; the cutblock was yarded with a hoe chucker and grapple yarder. At Gretchen Creek, approximately eight small patch reserves have been left within a cutblock yarded with ground-based yarding equipment. (Yarding methods are illustrated and discussed in Chapter 4).

Clearcutting-with-reserves in cutblocks in the Nimpkish Valley and at Sandcut Creek near Jordan River, and group selection at Lagins Creek and other "reserve" systems at Naden Harbour (both sites on the Queen Charlotte Islands) have been implemented in conditions generally similar to those of Clayoquot Sound. Cable yarding in non-clearcut blocks has been carried out in a research trial near Roberts Creek on the Sunshine Coast, and at Copper Canyon Road near Chemainus. Helicopter yarding has been used in a research trial involving alternative silvicultural systems on very steep slopes at Rennell Sound in the Queen Charlotte Islands. The Montane Alternative Silvicultural Systems (MASS) research site near Courtenay, initiated by MacMillan Bloedel, demonstrates the use of ground-based yarding equipment in old-growth forest on gently sloping terrain for both shelterwood and clearcut-with-reserves systems.

3.2.1 Advantages and Disadvantages of Clearcutting

Clearcutting has been the system of choice in coastal old-growth forests. Often-cited reasons include safety, ease, and financial return.

Several reasons are cited for the use of clearcutting as the silvicultural system of choice in coastal old-growth forests, such as those of Clayoquot Sound. They include the following:

- Clearcutting simplifies the logistics of harvesting, site preparation, and other management practices with consequent economic efficiency.
- Clearcutting requires fewer roads and gives access to more timber volume per length of road than other conventional systems. (Clearcutting does not necessarily reduce length of active road; see F3.13 and discussion of grapple yarding in Chapter 4.)
- Clearcutting is the system with which there is the greatest operational experience and expertise.
- Clearcutting is the system best suited to the large equipment required to move large logs.
- Safety risks are better understood with clearcutting than with other systems.
- Clearcutting is the easiest way to minimize the risk of trees blowing down because it removes all trees from relatively large areas.

- Clearcutting can increase populations of those wildlife species (e.g., deer) that prefer early successional habitats, *so long* as appropriate amounts of suitable forest are nearby.
- Clearcutting provides tolerable (but not optimal) conditions for establishing seedlings of most commercial tree species and favours rapid growth of species that require little shade.
- Clearcutting allows the use of prescribed fire (or slashburning) to prepare sites for regeneration, to improve access for tree planters, and to reduce fire hazard following logging.
- Clearcutting allows the use of genetically improved growing stock through planting.
- Clearcutting is useful for the control of dwarf mistletoe that might infect young trees.

Clearcutting also has disadvantages.

Clearcutting also has disadvantages. As clearcutting was practised in Clayoquot Sound in the past, these include the following:

- Clearcutting affects streamflow by significantly changing patterns of evapotranspiration, snow accumulation, and snowmelt.
- Clearcutting leads to increased instability and soil erosion on steep slopes. This often results in increased sediment in streams, which degrades aquatic habitats, and creates long delays in re-establishing forest cover, with attendant losses in productivity.
- Clearcutting exposes organic soils (folisols) and other thin soils to sunlight and wind, resulting in desiccation and subsequent soil loss from steep rocky areas, fissured limestone, and bouldery ground.
- Clearcutting removes all trees older than the length of the cutting cycle. Therefore, all plant and animal species that require old trees can no longer be sustained on that site.
- Clearcutting replaces naturally uneven-aged forests with even-aged forests that greatly reduces structural and age-class diversity and, often, changes tree species composition. This affects vertebrates and probably other species adapted to natural disturbance regimes (Bunnell 1995a).
- Clearcutting removes all living trees and standing dead trees, thereby removing both present and future sources of large, decaying trees. This removal affects many wildlife and fish species that require specific structural components of forests (e.g., snags, downed wood, woody debris in streams), as well as other organisms such as epiphytes and fungi. (See Sections 2.2.2 and 2.2.3.)

- The large tracts of young, even-aged forest that grow following clearcutting have fewer gaps than natural, uneven-aged forests. These gaps are important to a variety of species.
- Clearcutting has damaged areas of cultural significance to the Nuu-Chah-Nulth, and has removed culturally modified trees.
- Clearcutting is unattractive to many people, particularly when cutover areas are large, where cutting is highly visible (such as on steep slopes), and when clearcutting occurs close to communities and recreational areas.

The disadvantages of clearcutting compared to other silvicultural systems are greater when clearcuts are large, road networks are extensive, and heavy machinery has disturbed and compacted the soil. Retaining trees avoids some disadvantages while providing greater opportunity for maintaining important forest components such as culturally modified and wildlife trees. Recent changes in silvicultural practices in Clayoquot Sound, such as incorporating "reserves" in clearcutting systems (see Tables 3.2 and 3.3), are intended to reduce these disadvantages.

3.2.2 Standards for Silvicultural Systems

Most standards regulating forest practices in coastal British Columbia assume that clearcutting is the silvicultural system of choice.

Most existing standards regulating forest practices in coastal British Columbia, including Clayoquot Sound, assume that clearcutting is the silvicultural system of choice. The *Coast Planning Guidelines Vancouver Forest Region* (October 1993), *British Columbia Coastal Fisheries/Forestry Guidelines* (July 1993), and *Development Plan Guidelines for the Vancouver Forest Region* (December 1993), for example, do not mention evaluation of other silvicultural systems. Rather than restricting clearcutting or requiring other silvicultural systems, most standards merely restrict the sizes and patterns of clearcuts, and the rate of clearcutting, or regulate practices occurring within clearcuts.

Three significant exceptions address other silvicultural systems.

Three significant exceptions address other silvicultural systems. The proposed standards to be implemented under the *Forest Practices Code of British Columbia Act* (July 1994) require that all relevant silvicultural systems should be considered to ensure that forest management objectives are met, and restrict the use of clearcutting on some sites. The *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* state that "Unless otherwise authorized in the Standards, a clearcutting silvicultural system must not be prescribed for sites with very unstable terrain, sites where clearcutting is incompatible with retention of visual quality objectives, wildlife habitat areas where canopy retention is essential for population maintenance, and old-growth management areas" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:75). The standards also state that silvicultural systems that have a reasonable likelihood of creating serious forest health problems in the residual stand or understory, or precluding successful regeneration of the preferred and acceptable species, must not be prescribed.[40]

The draft *Coastal Biodiversity Guidelines* state that "Silvicultural systems that retain more of the natural forest structure will maintain more historic levels of biodiversity" (B.C. Ministry of Forests 1994b:14). The guidelines note that every effort should be made to retain important attributes of historic forests such as snags and large living trees, and that harvesting, site preparation, and stand tending practices should be modified so that the value of the early seral habitat is improved and mature forest attributes develop faster in the managed forest (ibid.:14–15). The guidelines further recommend that some safe snags and large, living trees should be retained during all forestry operations (ibid.:14).[41]

The most recent *Pre-harvest Silviculture Prescription Procedures and Guidelines for the Vancouver Forest Region* require that all silvicultural systems be considered, and that the reasons for choosing a particular system be documented (B.C. Ministry of Forests 1994d:11).

Standards specific to Clayoquot Sound refer to silvicultural systems other than clearcutting.

Standards specific to Clayoquot Sound also refer to silvicultural systems other than clearcutting. The *Clayoquot Sound Land Use Decision Background Report* states that "single tree selection and group selection systems will be utilized in sensitive areas within the scenic corridors" (British Columbia 1993a:12).[42] No reference is made to use of silvicultural systems other than clearcutting in the General Integrated Management Area.

The *Clayoquot Sound Forest Practices Standards* state that "alternative silvicultural systems will be tested and utilised where objectives and strategies limit clearcuts" (B.C. Ministry of Forests 1993a:4). The alternative systems, which could include clearcut-with-reserves, single tree, or group selection systems, "will primarily be used to allow harvesting in areas of high value for other resources such as landscape, biodiversity, water quality, or areas with a risk of soil mass movement or erosion" (ibid.). As indicated in Tables 3.2 and 3.3, two such cutblocks were being logged with alternative silvicultural systems in 1994, and three more blocks were approved by the IRT for logging with alternative silvicultural systems in late 1994 or 1995. The helicopter logging at Cat's Ears Creek (Table 3.2) was an experimental program implemented prior to the *Clayoquot Sound Land Use Decision* and the specification of forest practices standards for Clayoquot Sound. Several other blocks using alternative silvicultural systems are in various stages of planning and review for logging in 1995 and 1996.

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[40]The Panel is aware that standards proposed in the *Forest Practices Code of British Columbia Act* of July 7, 1994, are still evolving, and has reviewed only standards proposed to that date.

[41]The Panel is aware that the draft *Coastal Biodiversity Guidelines* (April 21, 1994) will be incorporated into, and replaced by the biodiversity guidebook to be implemented with the Forest Practices Code.

[42]Single tree selection is impractical in old-growth forests of large trees because it is usually impossible to remove single stems safely.

The *Interim Measures Agreement* does not mention alternatives to clearcutting, but restricts harvesting systems[43] in the Clayoquot River Valley and on Flores Island to "longline and full suspension aerial cable yarders, and/or helicopter/balloon type systems" (British Columbia and the HawiiH 1994:12).

The *Government of British Columbia Response to the Commission on Resources and Environment's Public Report and Recommendations Regarding Issues Arising from the Clayoquot Land Use Decision* states that "innovative harvesting systems will be emphasized in areas requiring sensitive treatment" but also makes no reference to the use of alternative silvicultural systems in Clayoquot Sound (British Columbia 1993c:7).

Characteristics of Clearcuts as Defined in Standards

The most obvious features of a clearcutting silvicultural system are the absence of trees in logged openings and the size, shape, and distribution through time of the openings or clearcuts.

Approaches to clearcutting are changing.

Patterns of clearcuts observable today reflect the history of clearcutting practised over several decades.

Approaches to clearcutting are changing. Current standards in Clayoquot Sound are different from earlier (1980–1990) standards which permitted larger areas to be logged without retaining intervening forests. However, the effects of areas clearcut under current standards are difficult to separate from the larger landscape effects created by past clearcutting practices. The dominant pattern of clearcuts observable today reflects the history of clearcutting practised over several decades under evolving standards and practices. The five characteristics defining the nature and scale of clearcutting operations and relevant standards follow. The changing nature of standards is noted.

Photo 3.1

Past clearcutting practices sometimes covered large areas and had significant impact on the environment.

[43]A harvesting system is the mix of felling, bucking, and yarding methods used in logging a stand of timber, as compared to a silvicultural system which describes the planned cycle of activities by which a stand is harvested, regenerated, and tended over time. Yarding methods are discussed in detail in Chapter 4.

Trees Removed

Silvicultural regulations throughout British Columbia require that all trees taller than 3 m be felled within the clearcut area. Worker safety regulations require that all snags and "danger trees"[44] within the area be felled, including all snags and trees along the block perimeter that pose a hazard to workers. In effect, all live and dead trees within the cutblock taller than 3 m (and many smaller than 3 m) are felled during clearcutting, or are knocked down during yarding, regardless of whether they are used.

Individual Cutblock Size

Before 1992 there was little effective restriction on cutblock size.

Before 1992, there was little effective restriction on cutblock size. Although the *Coast Logging Guidelines* specified a *maximum* cutblock size of 200 acres (80 ha) (B.C. Ministry of Forests 1972), these guidelines were not enforced after 1980 and individual block sizes could then exceed 100 ha. Under the 1992 *Coast Planning Guidelines Vancouver Forest Region* the *average* cutblock size could not exceed 40 ha (B.C. Ministry of Forests 1992a). Larger cutblocks were permitted for reasons such as salvage of blowdown and trees killed by insects, disease, or wildfire, provided all government agencies to which the harvest plan was referred approved, and that the average of 40 ha was not exceeded. The more recent *Coast Planning Guidelines Vancouver Forest Region* (October 1993) and the proposed provincial Forest Practices Standards to be implemented under the *Forest Practices Code of British Columbia Act* restrict all new clearcuts to a *maximum* of 40 ha; smaller sizes are preferred.

Standards for block size are also specified for Clayoquot Sound. The *Clayoquot Sound Land Use Decision Background Report* states that clearcutting in Clayoquot Sound will be restricted to "smaller dispersed clearcuts" that will be reforested on average within three to five years of logging (British Columbia 1993a:12). The *Government of British Columbia Response to the Commission on Resources and Environment's Public Report and Recommendations Regarding Issues Arising from the Clayoquot Land Use Decision* states that clearcut blocks will not exceed 40 ha and will normally be 10–40 ha in size (British Columbia 1993c:7). The *Clayoquot Sound Forest Practices Standards* document (June 1993) reiterates these standards for block size.

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[44] A hazardous or danger tree is a tree or any part of a tree that has sufficient structural weakness to pose a high risk of falling and causing personal or property damage (as defined in B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:182).

Table 3.4 Area approved for logging in Clayoquot Sound, 1988–1993.

Year	Total area approved (ha)	Number of cutblocks	Average cutblock size (ha)
1988	920.6	27	34.1
1989	1201.7	40	30.0
1990	916.6	31	29.6
1991	558.7	25	22.4
1992	398.7	24	16.6
1993	682.7	49	13.9

Source: B.C. Ministry of Forests, Port Alberni Forest District.

Note: The number and area of blocks approved for cutting in a calendar year is not the same as the number and area actually logged in that calendar year. Some blocks approved in 1992, for example, were not logged until 1993 or 1994. The areas approved in a calendar year provided a better database for analysis of block size and adjacency, and have been used here and subsequently in this report. The area actually logged in each calendar year is shown in Table 3.1.

The average size of approved cutblocks has decreased from 34.1 ha in 1988 to 13.9 ha in 1993.

The average size of approved cutblocks in Clayoquot Sound has decreased in each of the last six years from 34.1 ha in 1988 to 13.9 ha in 1993 (Table 3.4). As individual block size has decreased, the number of cutblocks approved each year has increased: 27 cutblocks (totalling 920 ha) were approved in 1988, 49 cutblocks (totalling 682 ha) were approved in 1993. Thus, the approved cutblock sizes have been smaller than the limits set in the various current standards, but more cutblocks have been approved.

Although well intentioned, the effect of these guidelines is potentially detrimental.

Although well intentioned, the effect of these guidelines is potentially detrimental (see Section 3.3, F3.13). For a given level of timber harvest, many dispersed, small cutblocks usually extend over a greater proportion of a watershed and require longer distances of active road than do fewer, large clearcuts. When clearcutting is the system of choice and roads are used for log transport, patterns created by dispersed, small cutblocks are more harmful to water regimes and to some vertebrate species than are those created by fewer, larger clearcuts of the same total area. Furthermore, species such as black bear and Roosevelt elk become more vulnerable to hunting as more extensive road systems make these species more accessible.

Block Adjacency

Standards for block adjacency address how soon a potential cutblock adjacent to a previously logged block can itself be logged. The trend has been to increase that period, thus reducing the chance of creating one large area of even-aged forest.

Prior to implementation of the initial *Coast Planning Guidelines Vancouver Forest Region* (March 1992), there were few effective restrictions on the total contiguous area that could be logged as adjacent clearcuts. The *Coast Logging Guidelines* (1972) required leave areas between cutblocks but these guidelines were not enforced after 1980.

Once "green-up" is achieved, the adjacent area can be cut.

The current *Coast Planning Guidelines Vancouver Forest Region* (October 1993) state that "reforestation of harvesting openings should attain the free growing stage prior to commencement of harvesting on adjacent leave areas" (B.C. Ministry of Forests 1993b:4). That is, an area of forest adjacent to an existing cutblock should not be logged until the cutblock is fully stocked with "a crop of healthy, ecologically adapted trees, the growth of which is not impeded by competition from plants, shrubs, or other trees" (ibid.:1). Free-growing seedlings must be a minimum of five years of age since establishment and be 150% above (i.e., 50% taller than) competing vegetation within a 1 m radius. Once this "green-up" is achieved, the adjacent area can be cut.

The time required to achieve green-up is 5 –10 years or more.

The same requirements are included in the proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* to be implemented under the *Forest Practices Code of British Columbia Act* (July 1994). In most cases, the time required to achieve green-up is more than five years and in some cases more than 10 years. The *Coast Planning Guidelines Vancouver Forest Region* (1993) and the proposed Forest Practices Standards both allow this green-up constraint to be waived in special circumstances where resource agencies approve. The *Clayoquot Sound Forest Practices Standards* allow the green-up period to be lengthened to address other resource management considerations such as scenic values (B.C. Ministry of Forests 1993a:5). The draft *Coastal Biodiversity Guidelines* suggest "longer green-up periods, approaching the mid-rotation age, should be used to prevent extensive, contiguous areas being converted to early seral habitats" (B.C. Ministry of Forests 1994b:10).

The *Government of British Columbia Response to the Commission on Resources and Environment's Public Report and Recommendations Regarding Issues Arising from the Clayoquot Land Use Decision* states that clearcut blocks will be interspersed with mature stands of comparable area that will not be logged until the adjacent clearcut area has reached an unspecified minimum height. The *Clayoquot Sound Forest Practices Standards* document reiterates the standards for cutblock size, distribution, and adjacency that are presented in the *Coast Planning Guidelines Vancouver Forest Region.*

Recent approvals in Clayoquot Sound have been consistent with the various standards, and the green-up period has been lengthened.

Recent approvals in Clayoquot Sound have been consistent with the various standards, and the green-up period has been lengthened. In 1988 and 1989, 71% of cutblocks approved for clearcutting (47 of the 66 cutblocks) were adjacent to areas logged less than 10 years previously. In 1993, only 33% were adjacent to areas less than 10 years old, and 75% of those cutblocks were small blocks to salvage blowdown.[45] Sixty-six percent of the cutblocks approved for clearcutting during 1993 had standing timber all around them or were adjacent to stands over 10 years old.

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[45]Based on analysis of data provided by B.C. Ministry of Forests, Port Alberni Forest District.

Rate-of-Cut and Total Area Cut in a Watershed

The rate at which timber is removed from a watershed ("rate-of-cut") and the amount of timber removed are of concern because of potential impacts on the hydrological regime and associated impacts on fish and other stream biota. Presently there are no specific standards for rate-of-cut.

Knowledge about the hydrological impacts of forest harvesting is derived from many observations, but is best revealed in experimental studies deliberately planned to evaluate effects of specific forest practices. The earliest such studies were conducted in the first years of this century, but the first long-term studies in forests similar to those of Clayoquot Sound were not established until the late 1950s, in Oregon (Harr 1976). The only long-term study in British Columbia is that at Carnation Creek, on the southeast shore of Barkley Sound immediately adjacent to Clayoquot Sound, established in 1971 (Scrivener 1988). Major conclusions drawn from studies in coastal forests of the Pacific Northwest follow:

Forest harvest increases average total runoff.

- Forest harvest increases average total runoff (millimetres per year). This result has been observed in all experimental studies and the fundamental reason is reduction of forest transpiration. Effects may persist for 25 years or more, but in some studies they have disappeared more rapidly. Reduced leaf or needle area during early succession may account for the persistence of mean runoff effects but changes in plant species composition may complicate the response.
- Late summer low flows increase following logging, but may decrease (in comparison with pre-harvest flows) after 5–10 years, probably due to the establishment of different species, especially in the riparian zone (Hicks *et al.* 1991).

Clearcutting increases storm runoff volumes and may increase storm peak flows.

- Clearcutting increases storm runoff volumes and may increase storm peak flows. These effects have been observed to disappear after about 10 years in the absence of roads (analysis of data from Jones and Grant 1995). Effects are notable where more than about 20% of the watershed is cleared within a decade or two; that is, when the rate of clearance exceeds about 1% per year, on average. The apparent limit of 1% per year may reflect the small number of appropriate studies more than a real lower bound for significant response.
- The most prominent stormflow increases occur in small, early autumn storms (Hetherington 1982). This is most likely due to increased late summer soil moisture levels, possibly augmented by hydrophobic soil surface conditions. Where major midwinter storms occur in already saturated watersheds, forest cover does not appear to influence the stormflow response.

Roads increase storm runoff and advance runoff timing by extending the surface drainage network.

- Roads increase storm runoff and advance runoff timing. These effects are caused by the extension of the surface drainage network produced by road ditchlines, and by the increase in the essentially impervious surface area. Effects are particularly marked on slopes where roadcuts intercept downslope subsurface drainage (e.g., Ziemer 1981). Road effects are permanent.

- Road extent and layout influence the severity of storm runoff response.

- Rain on snow may produce increased storm runoff following forest harvest (Harr 1986) due to the snow surface area in clearings being exposed to high winds and warm air advection. However, the effects of rain on snow are complex. A warm storm on a mature forest canopy carrying a high snow load may create similar effects because of the high snow surface area on the trees (Beaudry and Golding 1985).

- In coastal temperate rainforests, cloud and fog condensation provide significant inputs of water to the system (Section 2.2.1). Tall old-growth canopies are particularly effective at capturing this moisture and thus play an important role in the natural hydrological regime of places like Clayoquot Sound. Old-growth forests can substantially increase the net precipitation in regions with frequent low clouds and fog, such as Clayoquot. This is because of the very large volume of space occupied by canopies and the high surface area of foliage, branches and stems. These structures become condensing surfaces for large amounts of precipitation in the form of “fog drip” (Harr 1982).

The foregoing summary provides a concise, qualitative view of the pattern of hydrological response associated with forest harvesting (including roadbuilding). It does not provide adequate basis for quantitative prescriptions to mitigate forest harvest effects, for the following reasons:

- The experimental studies are necessarily long term, and are extremely expensive. The total number of studies remains few, and forest terrain is remarkably variable. Quantitative extrapolation of results from the experimental studies to other sites is potentially misleading.

- Within the experimental studies, treatments vary from study to study, and are confounded with terrain variations. Moreover, few of the experimental trials approximate the conditions of operational logging.

- Many of the experimental studies have been inadequately controlled, particularly with respect to the length of the pre-harvest “calibration” period. Almost none has been adequately analyzed.

- Various treatment effects, especially roads and forest removal, have consistently been confounded.

Furthermore, the preponderance of analyzed results in the Pacific Northwest is derived from unglaciated terrain in Washington and Oregon states, with more or less deeply weathered soils and relatively short slopes. The shallow, glaciated soils and long slopes of Clayoquot Sound probably create a hydrological system considerably more sensitive than has been analyzed in most experimental studies.

A watershed-based rate-of-cut of 1% per year, appears to meet the needs of ecosystem management with regard to hydrology, habitat, and long-term sustainable wood supply.

A watershed-based rate-of-cut of 1% per year, while not unequivocally supported by data, appears to meet the needs of ecosystem management with regard to hydrology, habitat, and long-term sustainable wood supply. The rate of 1% per year appears appropriate as derived from hydrological considerations above, but also incorporates concerns about temporal distribution of seral stages for biological diversity and temporal distribution of wood supply for socioeconomic stability. The rate is consistent with the ecological desirability of ensuring harvested areas support a range of seral stages with a variety of different-aged forest habitats for wildlife, plants, and other organisms. It also is consistent with principles of sustainable ecosystem management where the intent is to provide a level of harvestable products that can be sustained over the long term (the sustainable long-term timber supply will be lower than historical annual cut levels in Clayoquot Sound).

At present no standards establish a rate-of-cut or restrict the total area cut in a watershed. The *British Columbia Coastal Fisheries/Forestry Guidelines* recommend that an assessment of the "cumulative effects" of logging should be carried out on all watersheds larger than 500 ha that contain Class A[46] streams when:

- harvest area since 1965 plus proposed harvest area exceeds 20% of the total watershed area (i.e., 20% of the watershed area carries forests less than 25 years old); or
- there is evidence of significant stream channel instability; or
- landslides are frequent. (B.C. Ministry of Forests, B.C. Ministry of Environment, Lands and Parks *et al.* 1993:3)

The total area that has been clearcut may, nevertheless, amount to significantly more than 20% of the *forested* area of the watershed, particularly if logging occurred prior to 1965, or if a large portion of the watershed is not forested.

[46]The guidelines define three stream classes. Stream Class A includes streams or portions of streams that are frequented by anadromous salmonids and/or resident sport fish or regionally significant fish species, or streams identified for fishery enhancement in an approved fishery management plan; stream gradient is usually less than 12%. Stream Class B includes streams or portions of streams populated by resident fish not currently designated as sport fish or regionally significant fish; stream gradient is usually 8–20%. Stream Class C includes streams or portions of streams not frequented by fish; stream gradient is usually greater than 20%. The Panel is aware that major changes in the approach to stream classification are being considered in the context of the proposed standards under the Forest Practices Code.

Where "cumulative effects" analysis is carried out, it could limit the total area clearcut in a watershed during a given time period.

The *British Columbia Coastal Fisheries/Forestry Guidelines* recommend first that a watershed sensitivity analysis, following procedures set out in Wilford (1987),[47] be carried out to identify watersheds sensitive to cumulative effects. It further recommends that where a watershed is identified as sensitive, a cumulative effects analysis[48] be carried out by a hydrologist to determine how additional planned harvest might affect the area. Cumulative effects analysis could lead to a recommendation to limit the total area clearcut in a watershed during a given time period.

Several watersheds in Clayoquot Sound meet criteria specified for cumulative effects analysis.

Several watersheds in the Clayoquot Sound decision area, including some areas with active logging, meet criteria specified in the *British Columbia Coastal Fisheries/Forestry Guidelines* for cumulative effects analysis. At the time of writing, an adequate watershed sensitivity analysis has been undertaken only for the Atleo River watershed.

Guidelines for rate-of-cut based on other criteria have been suggested. The draft *Coastal Biodiversity Guidelines* state that "No more than 30% of the forests in each landscape [generally a watershed or a group of watersheds] should be younger than 20 years old" (B.C. Ministry of Forests 1994b:10). These draft guidelines state that "These younger forests should also be well distributed across the landscape." These guidelines are based on the *forested* area in a watershed rather than the *total* watershed area. The total area cut over longer time intervals is not limited. The *Guidelines to Maintain Biological Diversity in TFL 44 and 46* in Clayoquot Sound state that "optimally more than 40% of the watershed should consist of mature and old-growth forest," and the area less than 15 years old should not be more than 20% of the watershed area (B.C. Ministry of Forests 1991a:7–8).

Other Current Restrictions on Clearcutting

British Columbia Coastal Fisheries/Forestry Guidelines ***effectively prohibit clearcutting within at least 10 m from the edge of most fish-bearing streams.***

Under the *British Columbia Coastal Fisheries/Forestry Guidelines*, clearcutting is not permitted adjacent to most Class A streams or large Class B and C streams. On Class A streams, the guidelines "generally" require that a streamside management zone, from which no trees are cut, be retained along both sides of each stream (B.C. Ministry of Forests, B.C. Ministry of Environment, Lands and Parks *et al.* 1993:18). The width of this undisturbed area is specified as equal to the width of the stream, but at least 10 m.[49] Very small Class A streams may be exempted from the 10 m "leave" requirement if fisheries agencies concur. On

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[47]The *Watershed Workbook Forest Hydrology Sensitivity Analysis for Coastal British Columbia Watersheds* (Wilford 1987) is currently undergoing revision as *Watershed Assessment Procedure* for publication as a Forest Practices Code guidebook. An interim version was published as *Watershed Assessment Procedure (Interim Methods)* in July 1994 (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994b).

[48]Cumulative effects are not explicitly defined in the *British Columbia Coastal Fisheries/Forestry Guidelines,* but the term connotes the summed effects of repeated harvest operations at different places in the watershed. Further discussion under F3.19.

[49]Note that distances provided refer to each side of the stream.

Class A streams wider than 30 m, the streamside management zone must be 30 m. Some trees may be cut in the outer 20 m of the zone provided that "structural and functional characteristics of the original stand are maintained and site disturbance is minimal" (ibid.).

An undisturbed streamside management zone of 10 m is also required on large Class B and C streams where tree root networks or large organic debris (LOD) stabilize streambanks or the stream channel, or where mature streamside trees represent potential LOD for downstream Class A streams in the future (ibid.). On streams wider than 10 m, the streamside management zone is widened. Thus, these guidelines effectively prohibit clearcutting within at least 10 m from the edge of most Class A streams and some Class B and C streams.

The proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* to be implemented under the *Forest Practices Code of British Columbia Act* (July 1994) require that a riparian management area (RMA) be established along each side of a stream.[50] The RMA includes both a reserve zone, in which no harvesting is permitted, and a management zone in which some removal of selected trees or groups of trees is permitted. The widths of the reserve zone, the management zone, and the total RMA required depend on the stream channel width, the presence of fish, and whether the stream is in a community watershed.

For example, for a 5 m wide stream with fish present, flowing through a proposed cutblock, the standards prescribe a 50 m RMA consisting of a 10 m no-logging reserve zone and a 40 m management zone along each side of the stream. If a proposed cutblock contains a 5 m wide stream with no fish present, the required RMA is 30 m, consisting of a 10 m reserve and a 20 m management zone. These general requirements may be altered to accommodate site-specific conditions.

If implemented, these proposed standards will increase the width of riparian areas in which clearcutting is not permitted.

RMAs are also required on streams less than 3 m in width that have no fish present. These RMAs consist of management zones in which some logging is permitted; no reserve areas are required. RMAs are also required in gullies. Cutting is not permitted in these areas unless a gully assessment procedure has been completed. If implemented, these proposed standards will increase the width of riparian areas in which clearcutting is not permitted and will increase the number of trees left along streams and gullies in clearcut areas. The proposed standards also place restrictions around wetlands, lakes, and other waterbodies.

The draft document *Visual Landscape Management Guidelines for Visually Sensitive Areas within Provincial Forests* states that partial-cutting[51] systems may maintain a particular visual quality objective more readily than clearcutting (B.C. Ministry

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[50] The Panel is aware that the standards for RMAs are under review and may change.

[51] Partial cutting is an ill-defined term commonly encompassing both genuine silvicultural systems (e.g., selection cutting) and selective harvest (not a silvicultural system).

of Forests 1993g:22). The guidelines, however, do not require that silvicultural systems other than clearcutting be used on any site.

The Vancouver Forest Region requires licensees to complete an evaluation of terrain and stability conditions where proposed cutblocks and roads are located within terrain stability classes IV and V,[52] Es1 and Es2 units;[53] areas exhibiting natural instability, extensive gullying, or slopes steeper than 60%; and other specific areas designated by the district manager. Roads will not be authorized where the assessment indicates a moderate to high potential for road-induced landslide activity. If these sites cannot be logged "with yarding systems that do not require roads, then they should be reclassified as inoperable and reductions in the allowable annual cut will be recommended" (B.C. Ministry of Forests 1992b:1).

This regional policy implies that sites on steep slopes can be clearcut if they are not roaded…

This regional policy does not explicitly exclude clearcutting of sites with a high potential for landslides. On the contrary, it implies that such sites can be clearcut if they are not roaded, but are yarded by skyline or aerial methods (see Chapter 4 for a description of yarding methods). This policy does not adequately consider the role of tree root strength in maintaining the stability of such soils. In applying this policy over the past two years, district managers have generally not approved logging of sites with high potential for post-logging slides. Logging of sites with moderate instability potential has generally been approved under various constraints.

The *Clayoquot Sound Forest Practices Standards* require terrain stability assessments "on all roads and cutblock areas over sixty percent [slope gradient] and any other areas required by the referral agencies" (B.C. Ministry of Forests 1993a:5). B.C. Ministry of Forests terrain specialists are required to do an additional review of all development in stability class IV (moderate to high potential for post-logging instability) terrain. Whether clearcutting of such slopes is approved depends on the recommendations of the terrain specialists.

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[52] A classification of terrain stability is described in *Coastal Terrain Stability Classification,* attached to the November 18, 1992 letter from the regional manager, Vancouver Forest Region (B.C. Ministry of Forests 1992b). (This attachment will be replaced in 1995 by a Forest Practices Code guidebook on mapping and assessing terrain stability. It is not anticipated that the five-class terrain stability classification will change.)

[53] "Es1" areas are "environmentally sensitive" areas of land mapped during forest inventory (1:20 000 scale) where the sensitivity of soils is high. Most (90%) of the volume of timber growing on these sites is assumed to be unavailable and is not included in allowable cut calculations. "Es2" areas are also sensitive but the area may either be partly logged or logged under various constraints. Other types of environmentally sensitive areas include "Ea," where snow avalanches are a concern, or "Ew," where wildlife habitat is particularly important.

…and appears to ignore the unusual susceptibility to landslides or soil mass movement of slopes in Clayoquot Sound.

The proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* require detailed terrain stability field assessment of stability class V (unstable) slopes prior to approval of a Pre-harvest Silviculture Prescription, but it does not require field assessment of stability class IV (marginally unstable) terrain. The proposed standards in the Code further state: “Unless otherwise authorized in the Standards, a clearcutting silvicultural system must not be prescribed for sites with very unstable terrain” (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:75). “Very unstable” is undefined. The proposed standards thus appear to permit clearcutting on slopes with some degree of instability, including class IV, and partial cutting on very unstable (class V) slopes. Doing so, they appear to ignore the unusual susceptibility to landslides or soil mass movement of slopes in Clayoquot Sound and elsewhere on the coast.

3.2.3 Summary

The past five years have brought significant change to harvesting activity in Clayoquot Sound.

The past five years have brought significant change to harvesting activity in Clayoquot Sound. Since 1988, the area and volume of timber harvested have decreased 60% and 56%, respectively, while the number of cutblocks has risen by 81%. Until 1990, clearcutting was the only silvicultural system applied; since then, only five operational cutblocks have attempted alternatives (Cat’s Ears Creek was a research trial). This will change dramatically in 1995 if the goal set by the Interagency Review Team—to have 25% of the harvest volume removed by alternative silvicultural systems—is realized.

Most forest practices standards for coastal British Columbia assume that clearcutting is the silvicultural system of choice. Following that premise, most standards regulate the size and pattern of clearcuts across the landscape, the rate-of-cut, and practices within clearcuts. A notable exception is the draft *Coastal Biodiversity Guidelines* (April 1994) which call for retaining more of the natural forest structure during harvesting.

Proposed provincial standards require consideration of all relevant silvicultural systems.

Proposed provincial standards under the *Forest Practices Code of British Columbia Act* (July 1994) require consideration of all relevant silvicultural systems to ensure that forest management goals are met.

Standards specific to Clayoquot Sound are more explicit:

- The *Clayoquot Sound Land Use Decision* (April 1993) calls for single tree and group selection systems in sensitive areas within scenic corridors, but makes no reference to silvicultural systems other than clearcutting in the General Integrated Management Area.
- The *Clayoquot Sound Forest Practices Standards* (June 1993) call for alternative silvicultural systems where objectives and strategies limit clearcuts. Such action would allow harvesting in areas of high value for other resources and in areas with a risk of soil mass movement or erosion.

- The *Government of British Columbia Response to the Commission on Resources and Environment's Public Report and Recommendations Regarding Issues Arising from the Clayoquot Land Use Decision* (June 1993), while not referring to alternative silvicultural systems, requires the application of innovative harvesting systems in areas requiring sensitive treatment. The *Interim Measures Agreement* (March 1994) outlines similar requirements for the Clayoquot River Valley and Flores Island specifically.

Clayoquot Sound contains many areas where clearcutting increases the risk of damaging forest values.

Standards that refer to alternative silvicultural systems do so as a means of achieving harvesting on sites where clearcutting would be unacceptable. Clayoquot Sound, because of its frequently steep terrain, often shallow soils, and considerable precipitation (see Section 2.1), contains many areas where clearcutting increases the risk of damaging important forest values.

3.3 Findings Regarding Silvicultural Systems

There has been relatively little scientific study or systematic documentation of the effects of forest practices in Clayoquot Sound.

The Panel has based its findings on careful review of existing standards and other relevant documentation, field review of sites within Clayoquot Sound, field experience in Clayoquot Sound and other coastal areas, and review of scientific literature from similar coastal areas. Despite the attention focused on Clayoquot Sound, there has been relatively little scientific study or systematic documentation of the effects of forest practices in Clayoquot Sound itself. Some findings (e.g., those on windthrow and hydrological regime) are thus reasoned estimates derived from similar areas, rather than documented research results in Clayoquot Sound.

Past Standards and Practices

Prior to the early 1990s, clearcutting within individual watersheds in Clayoquot Sound proceeded rapidly.

F3.1[54] Prior to the early 1990s, clearcutting within individual watersheds in Clayoquot Sound proceeded rapidly. This practice, referred to as progressive clearcutting, has resulted in some watersheds being occupied by extensive, contiguous areas of young trees. Residual patches of old forest within the clearcuts tend to be isolated and strongly influenced by the adjacent clearcut openings. For the most part, the residual patches consist of unmerchantable trees on poor, rocky, or wet sites. Impacts of Past Standards and Practices

F3.2 Extensive clearcutting has created forest landscape patterns very different from those produced by natural disturbances in Clayoquot Sound (Section 2.2.2). Clearcut openings are unnaturally large, have had significant impact on the forest environment, and exhibit low internal heterogeneity. The array of young, even-aged forests produced by extensive clearcutting exhibits a conspicuously unnatural landscape pattern.

[54] Prefix F refers to finding.

Clearcutting in Clayoquot Sound has resulted in stand structures that differ from those created by the natural disturbance regime.

F3.3 Clearcutting in Clayoquot Sound has produced stand structures that also differ from those created by the natural disturbance regime. Due to high utilization standards, less downed wood is retained in recently cut areas than occurs naturally.[55] Within a conventional clearcutting system, snags are not retained; without attention to their future provision, large snags will be completely eliminated after the first rotation and sizable downed wood will be gone after two rotations (Spies and Cline 1988; Morrison and Raphael 1993).[56]

F3.4 In the Clayoquot Sound General Integrated Management Area, about 80% of the remaining older forests is on slopes steeper than 30° (about 60% slope) (Sondheim 1994). Many of these slopes have a moderate to high likelihood of failure following clearcutting. Where slopes fail and landslides occur, regeneration on part of the site may not be possible for decades.

Extensive clearcutting and related road construction in Clayoquot Sound are associated with substantial disturbance of stream channels.

F3.5 Extensive clearcutting and related road construction in Clayoquot Sound are associated with substantial disturbance to the morphology of stream channels. Both excessive scour and accelerated sedimentation are observed in rivers in the region. Where these phenomena have been studied systematically (most locally, at Carnation Creek), they are invariably associated with significant disturbance of the hydrological regime, including increased volumes and higher peak rates of runoff. These effects appear to strongly influence the abundance of some fish species. The condition of streams in logged drainage basins and observed effects on aquatic ecosystems are consistent with effects widely observed elsewhere when more than about 20% of watershed area has been roaded and clearcut within one or two decades (Jones and Grant 1995).

Photo 3.2

Poor road location or construction has had serious consequences.

[55] R.J. Keenan and A. Inselberg, unpublished data, 1992.

[56] The tendency for second-growth stands to contain fewer large snags and woody debris is also evident in the Panel's inspection of the recently harvested Montane Alternative Silvicultural Systems (MASS) and Bowser sites.

Predominance of Clearcutting

Clearcutting continues to be the predominant silvicultural system in Clayoquot Sound.

F3.6 Clearcutting continues to be the predominant silvicultural system in Clayoquot Sound. Since the *Clayoquot Sound Land Use Decision* in April 1993, and the release of the *Clayoquot Sound Forest Practices Standards* in June 1993, five cutblocks with a total area of 71 ha have been proposed and approved for alternative silvicultural systems. Two of these were being logged in the fall of 1994; the others are approved by the Interagency Review Team for harvest in late 1994/early 1995. At the time of writing, several other blocks that will employ alternative silvicultural systems are in various stages of planning and review.

Current Silvicultural Systems Standards

F3.7 Current standards for silvicultural systems in Clayoquot Sound, detailed in Section 3.2 can be summarized as follows:

- clearcutting, in which all trees are cut down and the area is planted or allowed to regenerate following logging, is generally assumed to be the system of choice;
- individual cutblocks are restricted to a maximum of 40 ha;
- a green-up period of 5–10 years is required before adjacent areas are logged unless other green-up criteria, such as visually effective green-up (VEG),[57] are specified;
- analysis of “cumulative effects” is required when the area cut in a watershed exceeds 20% of the total watershed area in 25 years, when significant channel instability is evident, or when landslides are frequent;
- clearcutting is restricted on some areas within a cutblock (e.g., in the 10 m [or greater] streamside management areas on Class A streams and on some large Class B and C streams); and
- terrain stability classes IV and V, Es1 and Es2 units, and other areas must be assessed before roadbuilding or clearcutting.

Standards are expected to change.

Standards have changed rapidly over the past three years and will change further with implementation of the proposed Forest Practices Code.

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[57]VEG is the stage at which a regenerating stand is perceived by the public as being “greened-up.” When VEG is achieved, re-established forest cover generally blocks views of site disturbances such as stumps, slash, road cuts, and exposed rock and soil.

Current Practices

Current clearcutting in Clayoquot Sound meets or exceeds existing standards for individual block size and adjacency (green-up).

F3.8 Current clearcutting in Clayoquot Sound meets or exceeds existing standards for individual block size and adjacency (green-up). The average size of approved cutblocks decreased from 34.1 ha in 1988 to 13.9 ha in 1993. The percentage of approved cutblocks having standing timber all around them increased from 29% in 1988 to 66% in 1993.

F3.9 On some recent cutblocks (e.g., Cypre River; see Table 3.2), current practice provides greater protection of streamside or riparian areas than current standards require (e.g., *British Columbia Coastal Fisheries/Forestry Guidelines* 1993).

On some cutblocks current practice in Clayoquot Sound has been ahead of emerging standards.

F3.10 On other cutblocks (e.g., Matlset Creek Block 100; see Table 3.2), current practice in Clayoquot Sound also has been ahead of emerging standards (such as the draft *Coastal Biodiversity Guidelines*) by exploring clearcut-with-reserves and other alternative silvicultural systems. The Interagency Review Team in Clayoquot Sound has set a goal to have 25% of planned harvesting incorporate alternative silvicultural systems by 1995.

F3.11 Panel field observations, and other recent audits of streamside management, have found inconsistent compliance with current standards and guidelines (Sierra Legal Defence Fund 1994; Tripp 1994a, 1994b).[58]

Impacts of Current Standards and Practices

Large openings with complete removal of forest cover are still possible under current standards for clearcutting.

F3.12 Large openings with complete removal of forest cover are still possible under current standards for clearcutting, which permit new 40 ha openings after as little as 5–10 years of green-up of adjacent cutblocks. Such extensive cumulative openings are unprecedented to very rare in the pre-logging history of Clayoquot Sound forests.

F3.13 Current standards restricting the size of clearcut openings and applying green-up constraints on the harvesting of adjacent cutblocks has potentially unfavourable consequences if the same total area is logged over the same time period. Such practices produce more clearcut openings that are more widely distributed than in the past, even though individual clearcuts are smaller (see Table 3.4).

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[58] The Sierra Legal Defence Fund assessment found minor or major infractions of the *British Columbia Coastal Fisheries/Forestry Guidelines* (3rd Edition, October 1992) on each cutblock examined. Tripp's assessment found a high level of compliance with current standards on cutblocks reviewed in Clayoquot Sound.

The environmental effect of many small openings may be greater than the effects of fewer, larger ones.

In the short term, the environmental effects of many small openings may be greater than the effects of fewer, larger ones. Numerous small, dispersed cutblocks affect a larger proportion of the watershed by:

- nearly always requiring more kilometres of *active* road, with the associated potential for sediment production from the road running surface;
- producing more forest edge habitat (benefiting some species and harming others);
- increasing fragmentation of the forest which can harm species requiring more continuous forest cover;
- increasing risk of windthrow;
- encouraging unnaturally dense ungulate populations which may impede or damage regeneration; and
- increasing the likelihood of highgrading of particular species, sizes, or age classes of timber.

Reducing clearcut size alone does not address critical long-term issues.

Reducing clearcut size alone does not address critical long-term issues such as the cumulative effects of logging in a watershed, or the need to maintain structural features of old-growth forests.

Difficulties with Current and Evolving Standards

F3.14 Despite the predominance of steep slopes and terrain in stability classes IV and V in the General Integrated Management Area (see F3.4), clearcutting is not explicitly prohibited by existing standards. As noted in Section 3.2.2, the November 18th letter from the regional manager, Vancouver Forest Region (B.C. Ministry of Forests 1992b) appears to allow clearcutting using non-conventional (roadless) methods on unstable and marginally stable terrain (class V and class IV, respectively). The proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* do not exclude clearcutting on slopes with some instability. In the *Clayoquot Sound Forest Practices Standards* (June 1993), the decision about whether clearcutting or harvesting by other systems can occur on stability class IV and V terrain depends on the results of terrain stability assessments and recommendations by terrain or geotechnical specialists.

In Clayoquot Sound, adherence to the above requirements may not sufficiently reduce logging-related mass movement such that landslide frequency remains within the range of natural variability. On slopes with visible indicators of instability, results from slope stability assessments will probably prevent harvesting. Sites that are stable before logging but that become potentially unstable following logging are more difficult to recognize.

Present standards that control the removal of forest do not appear to be sufficiently rigorous to achieve slope stability objectives for Clayoquot Sound.

On-site assessments are an inexact technique because many of the conditions that influence slope stability (e.g., subsurface soil and hydrological conditions) may not be apparent from surface observations. The assessment procedure can reduce the risk of post-logging slides and related site degradation and deleterious downslope effects, but it does not eliminate the possibility of logging-induced slope failure. Forest cover greatly influences slope stability and the present standards that control the removal of forest appear not to be sufficiently rigorous to achieve slope stability objectives for Clayoquot Sound.

Rate-of-cut constraints may not allow the volume specified by the AAC to be harvested.

F3.15 The joint objectives of maintaining a predetermined allowable annual cut (AAC) for Clayoquot Sound and applying more restrictive standards on forest harvesting are not compatible with watershed-based rate-of-cut constraints. Simply, rate-of-cut constraints may not allow the volume specified by the AAC to be harvested. This incompatibility illustrates: (1) the inherent conflict between the regulatory and proprietary roles of the B.C. Ministry of Forests; and (2) the problems that ensue from stipulating allowable cuts as a predetermined input to resource planning processes, rather than as an output of them.[59] To the Panel's knowledge the combined effects of all existing and evolving standards have not been analyzed.

Because of wide variations in local site conditions, guidelines cannot be rigidly prescribed.

F3.16 Because of wide variations in local site conditions, guidelines cannot be rigidly prescribed. Adaptations are often necessary, and responsibility rests with managers to ensure that such adaptations conform to the intent of the guidelines. Interpretations and applications of guidelines (e.g., *British Columbia Coastal Fisheries/Forestry Guidelines*) have been inconsistent. Evaluations have shown that the guidelines are not consistently well implemented.[60]

F3.17 No procedure for effectively monitoring the success of alternative silvicultural systems is currently in place. Current practices are evaluated primarily by their success in attaining regeneration objectives.[61]

[59]Problems noted in general finding 9 and general recommendation 2 of the Panel's second report: (Scientific Panel 1994a). See also Section 7.2.1 of this document.

[60]See footnote 58.

[61]Current regeneration requirements are specified in the *Correlated Guidelines for Tree Species Selection and Stocking Standards for the Ecosystems of B.C.* (B.C. Ministry of Forests 1993c) and a companion document *Minimum Heights Required for Free Growing Standards Specified by Silviculture Practices Regulation* (B.C. Ministry of Forests 1994c:Section 11).

Rate-of-Cut

There are no standards defining rate-of-cut in Clayoquot Sound.

F3.18 There are no standards defining rate-of-cut in Clayoquot Sound. Emerging standards sometimes conflict with one another. For example, guidelines on rate-of-cut in a watershed recommend the following maxima:

- 20% of the total watershed area in 25 years *(British Columbia Coastal Fisheries/Forestry Guidelines,* July 1993);
- 30% of the forested area in 20 years (draft *Coastal Biodiversity Guidelines,* April 1994); and
- 20% of the total watershed area in 15 years (*Guidelines to Maintain Biological Diversity in TFL 44 and 46,* December 1991).

These differences occur in part because the guidelines address somewhat different objectives (e.g., hydrological regime in the *British Columbia Coastal Fisheries/Forestry Guidelines* and distribution of age classes in the draft *Coastal Biodiversity Guidelines*). The guidelines cannot all be sustained unless the most restrictive guideline preempts the others. It is not clear, however, that any of these guidelines conforms with scientifically established principles.

F3.19 The *British Columbia Coastal Fisheries/Forestry Guidelines* recommend that cumulative effects analysis be undertaken in watersheds with a high rate-of-cut and in areas exhibiting stream channel or slope instability. The analysis is implemented through the “watershed sensitivity” analysis specified in the *Watershed Assessment Procedure (Interim Methods)* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994b).[62] The procedure was originally developed to estimate the summary effect upon hydrology of the total area logged over time. In practice, attention has come to be focused upon sediment production because of its observed effect upon stream channel morphology and aquatic habitat. Yet effects on streamflow remain important. In particular, the increased runoff and increased flood incidence that accompany logging and road construction increase the duration of stresses on aquatic biota caused by moderate to high streamflows. Watershed sensitivity analyses have not been undertaken adequately in Clayoquot Sound watersheds (except in the Atleo River) even though some meet criteria for such analyses under the guidelines.

[62]The *Watershed Assessment Procedure* does not actually assess cumulative effects, which refers to the combined effect of several different physical and/or biological factors on watershed processes and biota (Scientific Panel 1994a:29). Appraisal of the additive effect of modification of the runoff regime or contribution of sediment from several different sources as outlined in the watershed assessment procedure represents an analysis of watershed “sensitivity” with respect to water- and sediment-generating mechanisms in the watershed. The *British Columbia Coastal Fisheries/Forestry Guidelines* recommend that watersheds found to be “sensitive” be further subjected to “cumulative effects” analysis, procedures for which are not specified.

Watershed sensitivity assessments have not been carried out consistently.

F3.20 Watershed sensitivity assessments recommended in the *British Columbia Coastal Fisheries/Forestry Guidelines* and implied in the draft *Coastal Biodiversity Guidelines* and the *Guidelines to Maintain Biological Diversity in TFLs 44 and 46* remain difficult to carry out consistently because:

- the guidelines and assessment procedures are currently under development with frequent revision; and
- the various guidelines remain inconsistent (see F3.18).

F3.21 No restrictions deriving from rate-of-cut considerations have been placed on logging in Clayoquot Sound watersheds that meet the criteria for watershed sensitivity analysis or cumulative effects analysis given in the *British Columbia Coastal Fisheries/Forestry Guidelines.*

F3.22 Analysis of watersheds to determine the distribution of age classes (a product of rate-of-cut) has been undertaken in some areas in Clayoquot Sound.[63] In some watersheds currently being logged (e.g., the Cypre River), the area harvested within the last 15 years exceeds 20% of the total watershed area. No restrictions derived from age-class considerations have been placed on Clayoquot Sound watersheds.

Conventional Systems and Terminology

Terminology used to describe conventional silvicultural systems is inadequate to address multiple objectives.

F3.23 The terminology used to describe conventional silvicultural systems, which focuses primarily on regeneration objectives, is inadequate to describe new silvicultural systems that address multiple objectives. For example, "clearcut-with-reserves" emphasizes clearcutting and leads to confusion regarding whether the reserves are within or outside the cutblock.

F3.24 Of the conventional silvicultural systems, selection cutting creates environments most similar to those in unmanaged forests of Clayoquot Sound. Selection systems provide more opportunities than do clearcuts and shelterwoods for maintaining diverse components of the pre-harvest forest. Group selection is far easier and safer to implement than single tree selection in old-growth forests of Clayoquot Sound. As historically practised, however, selection systems do not necessarily retain the snags, blowdowns, upturned root systems, and similar structures that are found in natural forest openings.

F3.25 "Alternative silvicultural systems" lumps together all systems other than conventional clearcutting, including but not limited to: seed tree, shelterwood, selection, clearcut-with-reserves, and other reserve systems.

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[63]B.C. Ministry of Forests, Port Alberni Forest District.

Alternative Silvicultural Systems

Maintaining the natural size- and age-class distributions of trees helps to retain the natural functioning of the forest-dwelling biota.

F3.26 Maintaining the natural size- and age-class distributions of trees helps to retain the natural functioning of the entire forest-dwelling biota. Adopting a silvicultural system that maintains or creates forest and stand structures more closely resembling those resulting from natural disturbance regimes (see Sections 2.2.2–2.2.5) would address many of the apparent disadvantages of conventional clearcutting.

F3.27 Appropriate stand tending practices between harvests can help to maintain or create the kinds of forest structure and habitat diversity occurring in natural forests. Innovative, small-scale efforts to hasten development of old-growth attributes in young forests have been attempted in Douglas-fir stands on Vancouver Island (Nyberg *et al.* 1986; Petersen 1991). Other work on Vancouver Island has erected artificial snags.[64] Studies also have evaluated effects of site preparation and vegetation management on important habitat features (Hamilton 1990; Hamilton *et al.* 1991).

Forest structure can be retained either by retaining individual trees or by retaining small areas of undisturbed forest.

F3.28 Forest structure can be retained either by retaining individual trees scattered throughout a cutblock ("dispersed retention") or by retaining small areas of undisturbed forest ("aggregated retention").[65] A combination of retained patches with some isolated windfirm trees in the intervening spaces will produce a structurally diverse young stand with some characteristics of both the pre-harvest forest and a stand managed for timber production.

Dispersed retention ensures that a large proportion of the cutblock will be influenced by the smallest number of surviving trees; as few as 5–10% of the trees dispersed over the whole cutblock influence nearly 100% of the area to some degree. This may sometimes be desirable, as when shelter is required to establish young trees. However, dispersed retention also tends to disperse impacts of harvesting throughout the stand so that little of the forest understory remains undisturbed during logging.

Aggregated retention generally allows more forest ecosystem components to be retained than is possible with dispersed retention.

Aggregated retention generally allows more forest ecosystem components to be retained than is possible with dispersed retention. Patches of undisturbed forest, with understory vegetation and forest floor intact (in other words, designated "no-work" zones), are sites where wildlife trees can be safely retained. Aggregates can also protect culturally modified trees. Aggregated retention provides opportunities for even-aged silviculture to be practised between logging entries on harvested areas, but maintains all-aged forests in the aggregates.

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[64] J. Deal, pers. comm., February 1995.

[65] See Tables 3.2 and 3.3; outside Clayoquot Sound dispersed retention was implemented at McTush; aggregated retention at Gretchen Creek.

Over the last few years, retention systems in the U.S. Pacific Northwest have shifted from an emphasis on dispersed retention of individual trees to aggregated retention of small patches of forest in cutover areas (e.g., Forest Ecosystem Management Assessment Team 1993).

Photo 3.3

Dispersed retention is the retention of scattered individual trees throughout the cutting unit.

Photo 3.4

In aggregated retention, trees are retained as patches in small undisturbed areas. Aggregated retention is easier to implement than dispersed retention.

Experience demonstrates that various levels of retention can be undertaken.

F3.29 Operational experience with silvicultural systems other than conventional clearcutting in Clayoquot Sound is limited to one small research trial in 1992 (Cat's Ears Creek; Table 3.2) and five approved cutblocks since the *Clayoquot Sound Land Use Decision* (Tables 3.2 and 3.3). Experience on the Queen Charlotte Islands (Haida Gwaii), elsewhere in coastal and interior British Columbia, and in the U.S. Pacific Northwest, however, demonstrates that various levels of retention can be undertaken with ground-based, cable-based, or helicopter logging methods (see, for example: Moore 1991; Green and D'Anjou 1993; Beese 1994; Coates and Steventon 1994; and Chapter 4). Experience has been acquired on steep slopes (e.g., Cat's Ears Creek in Clayoquot Sound, Gregory and Hangover creeks in the Queen Charlotte Islands).

In the U.S. Pacific Northwest, the move towards silvicultural systems other than clearcutting has been achieved much more quickly than expected and problems have been overcome more easily than anticipated (e.g., the recent experiences of the Plum Creek Timber Company; B.C. Ministry of Forests 1993e).

Other Considerations

Planning, education, and training are critical to the success of any silvicultural system or harvesting method.

F3.30 Planning, education, and training are critical for successfully implementing any silvicultural system or harvesting method. Alternatives to current clearcutting practices have been undertaken with a variety of harvesting methods in five coastal forest districts, but represent only a small portion of current practice (Moore 1994). Operational experience is lacking. Operator and faller training, and different approaches to planning, layout, and administration are essential, but not limiting requirements for employing alternatives to clearcutting practices.

Safety concerns are inherent in any silvicultural system.

F3.31 Safety concerns are inherent in any silvicultural system. The hazards of clearcutting are better understood than those of other systems. Dispersed retention makes it extremely difficult to safely retain wildlife trees (see Wildlife Tree Committee 1993), especially in older forests; safety concerns are much easier to address using aggregated retention. Current safety regulations are based on two principles which must be observed regardless of the silvicultural system used:

- procedures must be developed and implemented to minimize risk to workers; and
- workers must have the right to refuse to carry out procedures that place them at undue risk.

Silvicultural systems that retain larger numbers of trees also maintain higher scenic values.

F3.32 Alternative silvicultural systems are less visually dominant than clearcutting. Generally, silvicultural systems that retain more trees also maintain higher scenic values. Because some residents and visitors value completely unaltered areas, the distribution of the total harvested area needs to be limited where maintaining unaltered scenery is a priority.

F3.33 Windthrow of retained trees has been viewed as a potential problem on many sites, especially over certain ranges of retention. Windthrow is a natural phenomenon, and not a sign of failure.

Windthrow is difficult to predict because it is influenced by many factors, including:

- the species and history of the individual trees being retained;
- the nature and depth of the soils in which trees are growing;

- the openness of the canopy after harvest in relation to the pre-harvest condition;
- topographic position; and
- chance weather events.

Substantial operational experience is being gained in managing windthrow.

In coastal British Columbia, substantial operational experience is being gained in managing windthrow, designing windfirm boundaries, and selecting trees and forest patches to be retained (Stathers *et al.* 1994). The more effective techniques include feathering edges, topping and limbing trees, leaving aggregations of retained trees, and considering rooting substrates and topographic location when selecting species and individuals to be retained.

Current experience suggests that windthrow resulting from logging is uncommon in stands with high retention.

Current experience suggests that windthrow resulting from logging is uncommon in stands with high retention (more than about 70% retention) because the canopy retains its integrity. It is also uncommon at very low levels of retention (1–5%) when the trees retained are deliberately chosen for windfirmness and sites are sheltered from severe storms. Little experience has been acquired with intermediate levels of retention. Aggregations of retained trees provide more wind-resistant units and decrease the risk of windthrow induced by logging. The risk of loss to windthrow is greater in HA-phase stands than in CH-phase stands (see Section 2.2.1).

3.4 Recommendations Regarding Silvicultural Systems

In its second report, the Scientific Panel recommended that sustainable ecosystem management be the overriding management objective for Clayoquot Sound, and that all other management objectives be subordinate to maintaining healthy, functioning ecosystems (Scientific Panel 1994a). This emphasis on the ecosystem rather than on specific products represents a philosophical departure from the past.[66]

The Panel recommends a silvicultural system defined by the type and amount of forest cover retained.

To implement this new approach, the Panel recommends a silvicultural system defined by the type and amount of forest cover *retained* within watersheds and cut areas. This “variable-retention silvicultural system” emphasizes retaining trees and patches of forest in a managed forest to protect a variety of values and ecosystem components. The retained trees and forest patches create forest characteristics similar to patterns and remnant structures left after natural disturbances (Maser *et al.* (editors) 1988; Franklin 1990).

[66]To review the objectives of sustainable ecosystem management, refer to Chapter 7, Planning for Sustainable Ecosystem Management in Clayoquot Sound.

The goal of the system is to maintain ecological integrity.

The goal of the variable-retention system is to maintain ecological or ecosystem integrity. The Panel defined "maintaining ecological integrity" as ensuring that ecosystem processes and states do not depart from the range of natural variability exhibited before logging (Scientific Panel 1994a:Section 4); that is, maintaining functioning, self-sustaining ecosystems with characteristics similar to the original ones. The variable-retention system can address various management objectives within this goal, and accommodate a range of site conditions. The system differs from conventional silvicultural systems (Section 3.1) on four major points (see contrasting points on pages 47–48).

The number of young trees is an incomplete index of success.

1 Regeneration of the area logged is an important, but not dominating objective. The primary objectives are to retain natural functions in the managed forest, and to retain the natural range of stand and forest structure. These objectives have important implications for the manner in which trees are prescribed to be cut or retained and for the way in which success is evaluated. The number of young trees is an incomplete index of success.

2 Because the primary objective is to provide a range of forest values by emulating natural forest structure, post-logging treatments also must consider objectives other than regeneration and wood fibre production. For example, treatment of logging debris, tree species selection, and pre-commercial and commercial thinning practices must incorporate biological diversity objectives and visual concerns, as well as more traditional silvicultural objectives. Different values can be emphasized at different stages of stand development.

The variable-retention system offers a range of retention levels.

3 The variable-retention system offers a range of retention levels, including the broad mid-range that is not well represented in conventional silvicultural systems (Figure 3.1). The retention gradient ranges from complete clearing of trees on some areas to nearly full retention on others. The system also provides for permanent retention of trees and other structures after regeneration is attained, contrary to conventional shelterwood harvesting.

4 The variable-retention system does not describe cutting practices by using traditional terminology which reflects different objectives. It simply describes the degree and pattern of retention. The retained trees, which are not cut after regeneration is attained (as they would be in traditional seed tree or shelterwood systems), can be dispersed across the opening, aggregated in groups, or combined in a mix of dispersed and aggregated retention.

3.4.1 The Planning Context

The Panel recommends a three-tiered planning hierarchy within Clayoquot Sound, with subregional-, watershed-, and site-level planning units.

Implementation of Panel recommendations concerning silvicultural systems, harvesting methods (Chapter 4), and transportation systems (Chapter 5) requires a new approach to forest planning, which is the subject of Chapter 7. The following summary provides essential context for the Panel's recommendations on silvicultural systems. The Panel recommends a three-tiered planning hierarchy within Clayoquot Sound:

- Subregional level: planning units based on groups of contiguous watersheds forming natural units generally greater than 50 000 ha within which overall land use objectives are formulated and monitored.
- Watershed level: planning units of one or more watersheds of typically 5 000–35 000 ha. Within watershed planning units, reserve areas (where no harvesting is permitted) and harvestable areas (from which a sustainable flow of forest products are removed) are identified and a rate-of-cut is determined; and
- Site level: working units, discrete land units within harvestable areas, are specified by the type of management activity carried out: for example, "cutting units" where activities such as logging, planting, and stand tending are planned, "recreation units," or "wildlife units." These units will vary in size. Cutting units are the actual operating blocks, commonly 1–40 ha, within the harvestable areas. Logging is typically implemented within two years of initial site-level planning.

At the watershed planning level, reserves are identified where no cutting is allowed.

At the watershed planning level, *reserves* are identified where no cutting is allowed. These reserves include hydroriparian areas, representative areas of late-successional forest, all unstable slopes (stability class V), critical wildlife habitat, culturally important sites, and visible areas of very high scenic value. Some of the late-successional forest habitat must provide forest-interior conditions for species whose survival depends on such conditions.

Also at the watershed planning level, harvestable areas are identified and rate-of-cut is determined.

Also at the watershed planning level, *harvestable areas* are identified and rate-of-cut is determined. Harvestable areas contain timber that can be harvested while maintaining the integrity of forest ecosystems. Harvestable areas undergo more intensive planning at the site level. The rate-of-cut specifies the area within these harvestable areas that can be cut within defined periods of time.

Selecting and implementing an appropriate silvicultural system requires careful consideration at both watershed and site planning levels. Whereas harvestable areas and rate-of-cut are determined at the watershed level, the silvicultural system is applied at the site level.

3.4.2 Recommendations Within the Planning Context

Because some Panel recommendations are novel, their implementation and regulation must proceed adaptively.

The following Panel recommendations represent changes from past timber harvesting practices in Clayoquot Sound. They are based on the best current ecological knowledge of how forest and stream ecosystems function. This incorporates scientific knowledge and Nuu-Chah-Nulth traditional ecological knowledge. They also reflect the experience with alternative silvicultural systems in coastal British Columbia, the United States, Australia, and Europe during the last decade.[67] Because these recommendations are relatively novel, both their implementation and regulation must proceed adaptively.[68] There is limited experience with, or scientific study of, a variable-retention silvicultural system such as that recommended here.

Rate-of-Cut[69]

Evidence is insufficient to prescribe a definitive rate-of-cut for Clayoquot Sound forests.

It is not reasonable to prescribe a definitive rate-of-cut limitation for Clayoquot Sound forests on the basis of the available regional evidence. It is, however, very clear that substantial caution must be exercised with respect to hydrological response as the cumulated area harvested increases. This is apparent from all operational experience in British Columbia, and is acknowledged in the *British Columbia Coastal Fisheries/Forestry Guidelines.* On this basis, an appropriate strategy for managing hydrological response is to set interim standards for the proportion of area that can be logged that reflect the experience discussed in Section 3.2.2, and to establish a program to monitor the hydrological response.[70] Accordingly:

Within the watershed planning unit, determine a rate-of-cut based on the watershed area.

R3.1[71] Within the watershed planning unit, determine a rate-of-cut based on the watershed area.[72] Specifically:

- Limit the area cut in any watershed larger than 500 ha in total area to no more than 5% of the watershed area within a five-year period.
- In primary watersheds[73] of 200–500 ha in total area, limit the area cut to no more than 10% of the watershed area within a 10-year period.

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[67]Some features of the system, especially with high retention, approximate the "Plenterwald" of Montane areas in Switzerland and Germany, with which there is more than 100 years of experience.

[68]Adaptive management rigorously combines management, research, and monitoring so that credible information is gained and management activities can be modified by experience. Adaptive policy acknowledges institutional barriers to change and designs means to overcome them.

[69]See discussion in Section 3.2.2, Rate-of-Cut and Total Area Cut in a Watershed.

[70]See Section 8.2.2.

[71]Prefix R refers to recommendation.

[72]The rate-of-cut and allowable annual cut (AAC) are distinct (see Section 3.2.2).

[73]A primary watershed is one that drains directly to the sea. A secondary watershed is one in which the main stream drains to (is tributary to) a primary channel (main stream of a primary watershed); a tertiary watershed drains to a secondary channel, and so on.

(This prescription provides flexibility for harvesting within small watersheds.)

- In any watershed larger than 500 ha in total area, and primary watersheds of 200–500 ha in total area in which harvest has exceeded 20% of the watershed area in the most recent 10 years, allow no further harvest until the watershed conforms with the specified rate-of-cut.

- In any watershed specified in the previous recommendations and in which the recent harvest is greater than 5% in the last five years, but less than 20% in the last 10 years, allow no further cutting until a watershed sensitivity analysis and stream channel audit have been completed.[74] If these assessments indicate significant hydrological disturbance, substantial or chronic increase in sediment yield, or significant deterioration in aquatic habitat, cease harvesting until undesirable conditions are relieved. Otherwise, harvest may continue at a rate which will bring the drainage unit within the recommended rate-of-cut limits within five years.

In any harvested watershed larger than 500 ha total area, require a watershed sensitivity analysis and stream channel audit once every five years.

- In any watershed larger than 500 ha in total area (and primary watersheds of 200–500 ha in total area) in which harvest has occurred, require a watershed sensitivity analysis and stream channel audit once every five years. Where such assessments identify hydrological disturbance, substantial increase in sediment yield, or significant deterioration in aquatic habitat, cease harvesting until these conditions are relieved. If such conditions are recognized at any other time, sensitivity analysis and/or stream channel audit shall be undertaken immediately.[75]

- In watersheds where the harvestable area is less than 30% of the total area, allow resource managers to use professional judgement to vary these standards without changing the intent to regulate rate of harvest to minimize hydrological change.

- Periodically review these recommendations and reformulate as the results of monitoring accumulate.

- In watersheds important for their scenic values, complying with the visual landscape management objectives may restrict the rate-of-cut below the limits specified above.

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[74] Watershed sensitivity analysis is discussed in Section 3.3, F3.19; a stream channel audit is an inspection of a stream reach in which specified conditions (e.g., channel average width, volume of stored organic debris, sediment texture) are measured or classified according to defined procedures to permit comparison with previous inspections or with a prescription for desired channel condition. See Section 8.2.2.

[75] This recommendation is included for completeness. Literal application could trigger continual analysis everywhere; the Panel assumes its recommendations will be implemented with good judgement and common sense.

Size of Cutting Unit and Adjacency

R3.2 Within the harvestable areas, determine the size and configuration of cutting units based on consideration of topography, site and stand conditions, adjacent reserve areas, visual landscape management objectives and design principles, and operational constraints.

Proposed rate-of-cut limits obviate the current arbitrary limits on the size and adjacency of individual cutting units within a watershed.

Once an annual rate-of-cut (in hectares per year) from the watershed is determined, no arbitrary limit on the size and adjacency of individual cutting units within a watershed is needed because the rate-of-cut limits proposed (R3.1) restrict the amount and rate of disturbance within a watershed. Exceptions occur where size and adjacency must be considered in relation to visual landscape management objectives. Riparian and other reserve areas established at the watershed planning level will protect values that require reserve forest.

A New Terminology for Silvicultural Systems

Conventional terms are inappropriate.

R3.3 Adopt new terms to describe non-conventional silvicultural systems. Conventional terms are inappropriate to describe systems designed to protect multiple values, maintain ecosystem function, and produce a diversity of forest products.

Adopt a Variable-Retention Silvicultural System

Replace conventional silvicultural systems in Clayoquot Sound with a variable-retention silvicultural system.

R3.4 Replace conventional silvicultural systems in Clayoquot Sound with a "variable-retention silvicultural system." The purpose of this system is to preserve, in managed stands, far more of the characteristics of natural forests.

The variable-retention system provides for the permanent retention after harvest of various forest "structures" or habitat elements such as large decadent trees or groups of trees, snags, logs, and downed wood from the original stand that provide habitat for forest biota.

Forest structures are retained to meet the following specific ecological objectives:

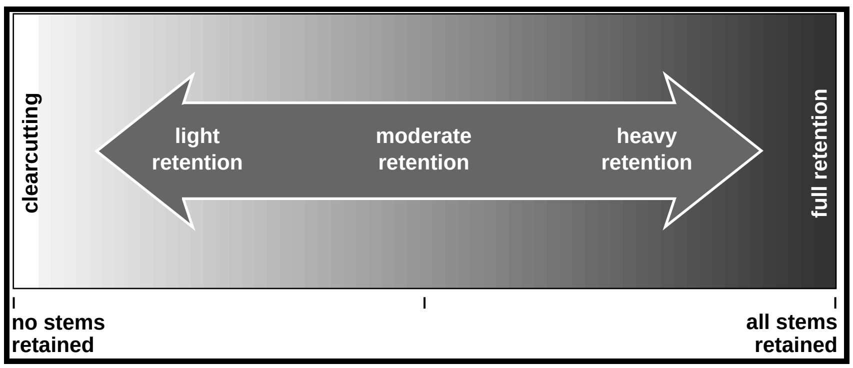
- to provide, immediately after harvest, habitat (e.g., large trees, snags, and logs) important to the survival of organisms and processes that would otherwise be lost from the harvested area either temporarily or permanently;

Retention silvicultural systems meet many ecological objectives, and facilitate protection of culturally important sites, and scenic and recreational values.

- to enrich current and future forests by maintaining some remnant structural features and organisms from the previous stands. These features might otherwise be absent from the cutting unit for decades after logging; and
- to improve "connectivity" between cutting units and forest areas by facilitating the movement of organisms through the cutover areas.

Retention silvicultural systems facilitate protection of culturally important sites (e.g., culturally modified trees), and scenic and recreational values. The variable-retention silvicultural system provides for a range of retention levels (Figure 3.2). The type, amount, and spatial pattern of the retained material depend on site characteristics and management objectives.

Figure 3.2 Variable-retention system provides a continuum of options.



Prescribing the Variable-Retention System

Specify prescriptions for retention in terms of the types, spatial distribution, and amount of forest structures that are to be retained.

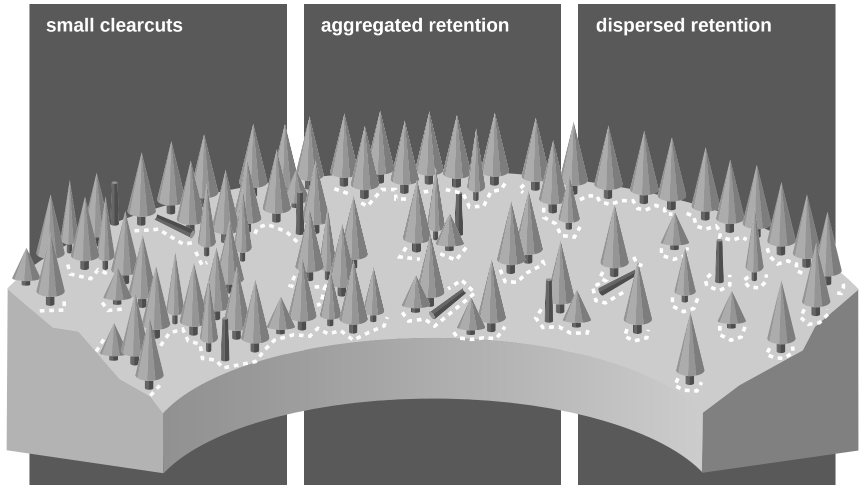
R3.5 Specify prescriptions for variable-retention cutting units in terms of the types, spatial distribution, and amount of forest structures that are to be retained.

"Types of structures" refers to the kind of material that is selected for retention (e.g., snags, large live trees).

"Spatial distribution of structures" refers to whether retained trees are *aggregated* in small intact patches or strips of forest, or are *dispersed* as individual structures over the cutting unit (Figure 3.3). Aggregates are particularly useful in providing opportunities for safely retaining snags and "danger trees" important to biological diversity.

"Amounts of structures" refers to their density or cover within the cutting unit. The amount of live tree retention is described in terms of *numbers of stems* when retention is *dispersed*, and in terms of *area* when retention is *aggregated*.

Figure 3.3 Small clearcuts, aggregated and dispersed retention under a variable-retention silvicultural system.



On cutting units with significant values for resources other than timber or with sensitive areas, implement high levels of retention — at least 70%.

R3.6 On cutting units *with* significant values for resources other than timber (e.g., visual, cultural, or wildlife resources), or *with* sensitive areas, implement high levels of retention. Examples of sensitive areas include dry floodplains (outside of riparian reserves), areas with high visual landscape management objectives (currently described by visual quality objectives of "preservation, retention, or partial retention"; see Section 2.3.3), steep slopes, and marginally stable slopes and soils (stability class IV). On such units:

- retain at least 70% of the forest in a relatively uniform distribution;
- when harvest occurs in small patches, limit opening sizes to 0.3 ha or less;
- retain at least some larger diameter, old, and dying trees; snags; and downed wood throughout the forest (but not necessarily in harvested patches); and
- identify "no-work zones" representing a minimum of 15% of the cutting unit area (i.e., areas including snags and other danger trees) before any harvesting takes place.

Photo 3.5

In areas with sensitive sites or high values for resources other than timber, high levels of retention—at least 70% of the forest—are recommended.

On cutting units without significant values for resources other than timber, or without sensitive areas, implement low levels of retention—at least 15%.

R3.7 On cutting units *without* significant values for resources other than timber, or *without* sensitive areas (e.g., with no steep slopes or unstable soils), implement low levels of retention. On such units:

- retain at least 15% of the forest;
- retain most material as forest aggregates of 0.1–1.0 ha well dispersed throughout the cutting unit;
- ensure aggregates are representative of forest conditions in the cutting unit (i.e., should not be disproportionately located in less productive portions of the cutting unit);
- retain aggregates intact as “no-work zones”;
- regardless of retention level, ensure that no place in an opening is greater than two tree heights from the edge of an existing aggregate or stand; and
- when dispersed retention is employed, select the most windfirm, dominant trees present on the unit.

Photo 3.6

In areas not on sensitive sites and without significant values for resources other than timber, low levels of retention—at least 15% of the forest—are recommended.

R3.8 Tailor prescriptions for retention to stand characteristics, topographic conditions, and other resource values on the working unit.

Retain a representative cross-section of species and structures of the original stand.

- In general, retain a representative cross-section of species and structures of the original stand.
- Select specific structures and patches to meet ecological objectives (e.g., provide future habitat for cavity-using species).
- Select patches to protect culturally important features (e.g., culturally modified trees, recreation sites, scenic features).
- Determine appropriate amounts of retention based on ecological sensitivity and forest values within the working unit.

Openings must not exceed four tree heights across.

R3.9 Exempt very small working units (i.e., less than four tree heights across) from the minimum 15% retention requirement in R3.7.

Do not salvage blowdown in retention cutting units except where it threatens desired values.

R3.10 Do not salvage blowdown in retention cutting units except where it threatens desired values (e.g., by establishing the potential for unnaturally large or frequent debris flows, especially ones that might threaten special sites such as spawning areas). Areas of blowdown provide live trees, snags, downed wood, or wood in streams which are habitat for many organisms in present and future stands. Abundant coarse woody debris is an important element in the forests and stream channels of Clayoquot Sound (see Sections 2.2.2 through 2.2.4); its removal is potentially disruptive to the objectives of retention and, in most cases, is unnecessary.

R3.11 Design the size, shape, and location of areas to be harvested within a cutting unit to comply with topography and visual landscape management objectives established for the area.

Implementing the Variable-Retention System

Develop restoration plans for areas where forest values have been degraded.

R3.12 Develop restoration plans for areas where forest values have been degraded. Restoration plans should initially target:

- the restoration of hydroriparian zones; and
- large areas which have been clearcut in the past without retention of late successional features (e.g., large, old living trees; snags; and downed logs).

One feature of these plans would be to restore or hasten late successional conditions within the harvestable area through either extended "rotations" or appropriate stand tending (e.g., R3.16).

Augment clear understanding of retention objectives with judgement and local experience.

R3.13 In applying the variable-retention system, augment understanding of retention objectives with judgement and local experience. For example, use aggregated retention, mitigative measures, and local knowledge to reduce risks of windthrow, especially when mid-levels of retention are prescribed.

R3.14 Initiate training programs in new techniques (e.g., wildlife tree assessment, no-work zones, and riparian management) for forest workers.

Provide incentives for tenure holders to implement the variable-retention system.

R3.15 Provide incentives for tenure holders to implement the variable-retention system and to apply greater than minimum levels of retention. For example, incorporate flexibility in the stumpage appraisal system so that innovation is not discouraged by undue reliance on historic costs.

R3.16 Encourage innovative approaches to silvicultural practices throughout the stand rotation to promote diverse forest structure and habitats, and to attain structural features of old-growth forests. For example, patches of wide spacing during pre-commercial and commercial thinning can encourage more rapid development of characteristics similar to old growth in both the overstory and understory.

Post-harvest silvicultural treatments should approximate natural patterns.

R3.17 Post-harvest silvicultural treatments should approximate natural patterns. For example, regeneration of naturally occurring species mixes should be encouraged and prescribed burning should be limited to small areas.

Devise methods of monitoring success of retention silvicultural prescriptions that reflect their multiple objectives.

R3.18 Devise methods of monitoring (Chapter 8) the multiple objectives of retention silvicultural prescriptions (i.e., expand the Pre-harvest Silviculture Prescription (PHSP) beyond the current emphasis on attaining regeneration).

R3.19 Implement an adaptive management strategy to incorporate new knowledge and experience. Establish research and monitoring programs to assess effectiveness of these initial recommendations in meeting ecological, cultural, scenic, and economic objectives, and to improve recommendations on an ongoing basis.

Both management and policy must be adaptive.

R3.20 Because innovative practices may have unanticipated consequences, policy also must be adaptive. Establish policies to modify standards and practices when consequences contrary to the objectives of sustainable ecosystem management are clearly documented or when alternative approaches for achieving objectives are recognized. Act to ensure that monitoring procedures anticipate surprise and that regulations can be quickly modified to reflect new information.

R3.21 Phase in the variable-retention silvicultural system in Clayoquot Sound over a five-year period, according to the following schedule of *minimum* achievements:

- 20% of the annual area harvested by end of 1996;
- 50% of the annual area harvested by end of 1998; and
- 100% of the annual area harvested by end of 1999.

R3.22 Fast-track watershed-level planning. While the Panel recognizes that some harvesting by the variable-retention system will be undertaken *before* appropriate watershed-level planning can be completed, harvest without requisite watershed-level planning should be minimized.

4.0 Harvesting Systems

A harvesting system typically consists of four phases: falling and bucking, yarding, loading, and hauling.

A harvesting system typically consists of four phases: falling and bucking, yarding, loading, and hauling. Because the capabilities and limitations of methods and equipment used in the yarding phase are critical in attaining variable-retention silvicultural objectives, they are the focus of this chapter.

Three major categories of factors affect the selection of harvesting systems in Clayoquot Sound:

Yarding methods are critical to attaining variable-retention silvicultural objectives.

- characteristics of the physical environment, including climate and hydrology, terrain and topography, and soils (Section 2.1);
- timber characteristics, including tree species, size, age, and condition, and the prescribed silvicultural system (Chapter 3); and
- other factors, such as mill requirements, public perceptions, and regulatory requirements, including roading constraints (Chapter 5).

4.1 Current Harvesting Technology and Equipment

4.1.1 Description of Yarding Methods[76]

There are four major categories of yarding methods.

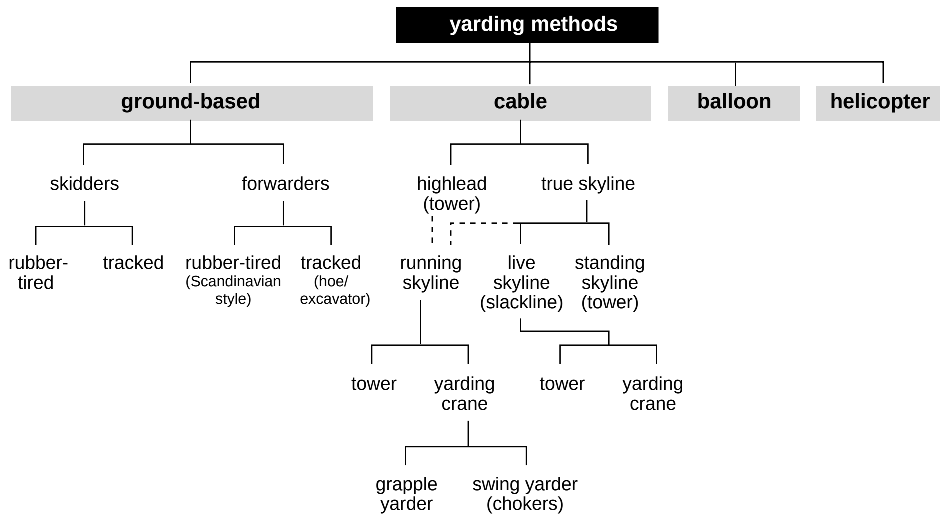
Yarding methods can be grouped into four categories, based on machinery used for moving logs from where trees are felled to the road, landing, or other point at which they are loaded for further transport:

- ground-based yarding (e.g., skidders, hoe forwarders, crawler tractors);
- cable yarding (e.g., highlead, skyline);
- balloon yarding (a hybrid between cable and aerial yarding); and
- helicopter yarding (commonly referred to as helicopter logging or heli-logging).

Figure 4.1 illustrates this classification of yarding methods; many innovative variants and adaptations exist. The requirements and range of applications of each yarding method are discussed following Figure 4.1 and summarized in Table 4.1.

[76]Illustrations of yarding methods in this section are from Binkley and Studier (1974).

Figure 4.1 Classification of yarding methods.



Ground-Based Yarding

In ground-based yarding, the machine travels to the log, then moves it to a landing.

In ground-based yarding, the machine travels to the log, then moves it to a collection point (landing). "Skidders" move on tracks or wheels to the logs and skid or drag them, usually with one end raised above the ground, to the landing. "Forwarders" transport logs without dragging them. Rubber-tired (Scandinavian style) forwarders carry relatively short logs in bunks. "Hoe forwarders" (or "hoe chuckers") use a modified backhoe or hydraulic loader to lift, then swing or slide logs to a yarding or skidding corridor,[77] to roadside, or to a landing.

Because skidders pull logs, they are constrained by slope and slope configuration, and can cause high soil disturbance. Rubber-tired forwarders are more constrained by slope than skidders. Hoe forwarders remain stationary as they swing logs and can operate on steeper slopes (up to 30–35%) with lower potential for soil disturbance. While both skidders and forwarders are sufficiently manoeuvrable to remove logs from the site with limited damage to residual standing timber, their potential to damage tree roots and soil during yarding must be considered.

Applicability of ground-based methods is limited by slope, soil, and weather conditions.

Ground-based methods, especially skidders, are weather sensitive. During heavy or prolonged rain their operation may be suspended because the soil loses strength, resulting in increased potential for soil and/or root damage.

[77] Yarding corridors (also called yarding "roads") refer to the roughly linear paths that logs travel as they are pulled by cables (lines) from the location of felling and bucking to the landing, or other area where logs are collected for loading. Skidding corridors are analogous but refer to designated routes used by ground-based equipment.

Cable Yarding

Cable yarding methods are characterized by stationary yarders which move logs by cables from where the trees were felled, along yarding corridors to a landing or to roadside. The amount of soil disturbance from cable yarding is a function of the extent to which logs remain in contact with the ground as they travel from the cutblock to the landing. This extent of contact ranges from full suspension to partial suspension to ground lead.[78]

Two basic types of cable yarding can be differentiated: highlead and skyline.

Highlead

The highlead method, where chokers are attached directly to the mainline, can provide no more than partial suspension of logs as a consequence of tower height and topography (Figure 4.2). The method has no lateral yarding capability[79] beyond the length of the chokers.

Highlead yarding has no lateral yarding capability beyond the length of the chokers.

Highlead yarding is usually limited to yarding distances of 200–300 m (dependent on log lift[80]). Log lift, log control, and production rate decrease rapidly with increased yarding distance. Typical production values range from a low of 100 m^3/shift for poor lift and long distances, to about 220 m^3/shift for short distances and good lift.[81] Highlead systems usually require a crew of five to six people. Highlead towers access fan-shaped to roughly circular areas with yarding corridors radiating out from a central landing (Figure 4.3).

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[78]With “full suspension,” logs are suspended in the air as they travel from where they are hooked up (in the cutblock) to the landing. With “partial suspension,“ one end of the log is in contact with the ground while the logs are yarded (dragged) to the landing. With “ground lead,” little or no lifting force is applied where the chokers attach to the logs; there is insufficient clearance between the ground and the loaded cable path to lift the end of the logs off the ground. Logs then commonly hang up behind stumps, and ground disturbance can be severe.

[79]Lateral yarding (also referred to as lateral reach or lateral reach capability) refers to the ability to yard logs from the stand into a main yarding corridor.

[80]Lift refers to the lifting force applied to a log by a cable yarding system. Lift varies continuously along the path travelled by the yarded log.

[81]Production figures (m^3 of logs yarded to a landing) are for a regular 8-hour shift less travel time.

Figure 4.2 Highlead yarding with chokers attached to the mainline via butt rigging.

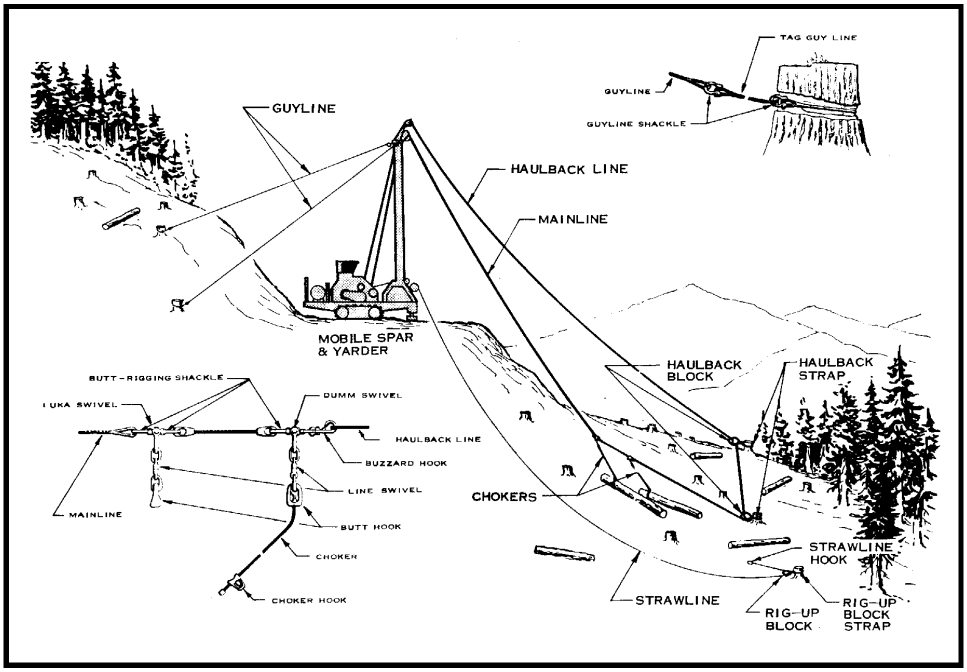
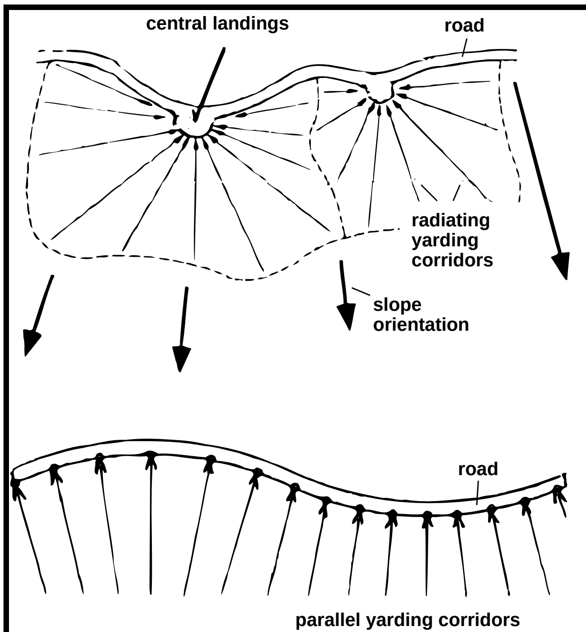


Figure 4.3 Yarding corridor patterns: radiating versus parallel.



Central landings require a large decking area or a dedicated log loader to prevent excessive congestion in the landing. Typical for highlead or skyline towers.

Parallel (to sub-parallel) yarding corridors allow logs to be decked along the road. The corridor orientation varies somewhat in response to concave and convex slope forms. Yarding and loading phases can be undertaken at different times. Typical for yarding cranes.

Skyline

Skyline yarding can be divided into "true" skylines and running skylines. True skylines include both live skyline (slackline) and standing skyline. Running skylines, like highlead, have two main operating lines: a mainline and a haulback line. However, in a running skyline configuration, the haulback doubles as a skyline to support a carriage or log grapple thus providing additional log lift. The configuration and movement of the cable and carriage define the type of skyline (Figures 4.5, 4.6, and 4.7).

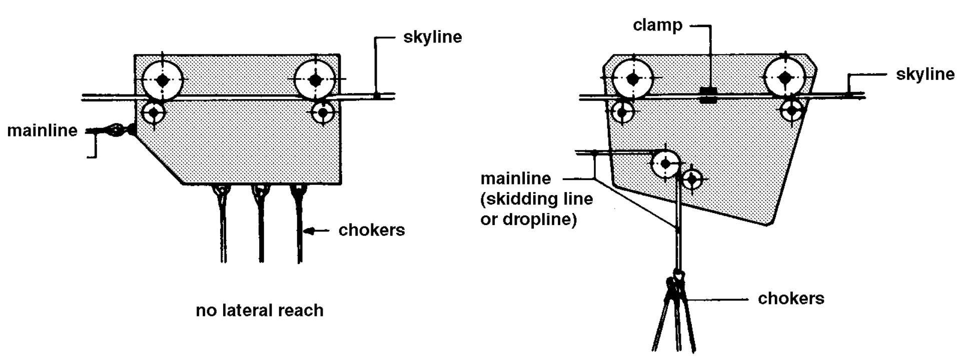
Skyline systems can yard up to 1000 m or more, given appropriate topography.

Skyline systems can use a relatively short crane (15–17 m) built on an excavator-like undercarriage (called a yarding crane or swing yarder) or a 27–30 m steel tower (called tower skyline). Either machine can yard up to 1000 m or more, given appropriate topography. Yarding cranes, which were developed in the 1960s, are very mobile, require two to four guylines, and can rotate without affecting these lines. By comparison, tower skylines require six to eight guylines, are stationary, require a larger crew to operate, and take more time to move. However, the taller towers have two advantages over yarding cranes: they permit higher log payloads and make yarding possible in broken terrain or other difficult topography.

Attaching chokers to a dropline or skidding line allows for lateral yarding.

Carriages are available in a range of types and sizes; they can be mechanically operated from the yarder or radio-controlled by the yarder and rigging crews. The carriage determines the ability of the skyline to yard logs laterally from the adjacent forest as well as from within the yarding corridor. Simple carriages with chokers directly attached, an uncommon configuration now, do not have lateral yarding capability. Carriages with chokers attached to a dropline[82] or skidding line, which can itself be pulled out (Figure 4.4), have lateral yarding capabilities typically ranging up to 30 m. Both tower skylines and cable cranes can use these carriages.

Figure 4.4 Simple carriages with and without lateral yarding capability.

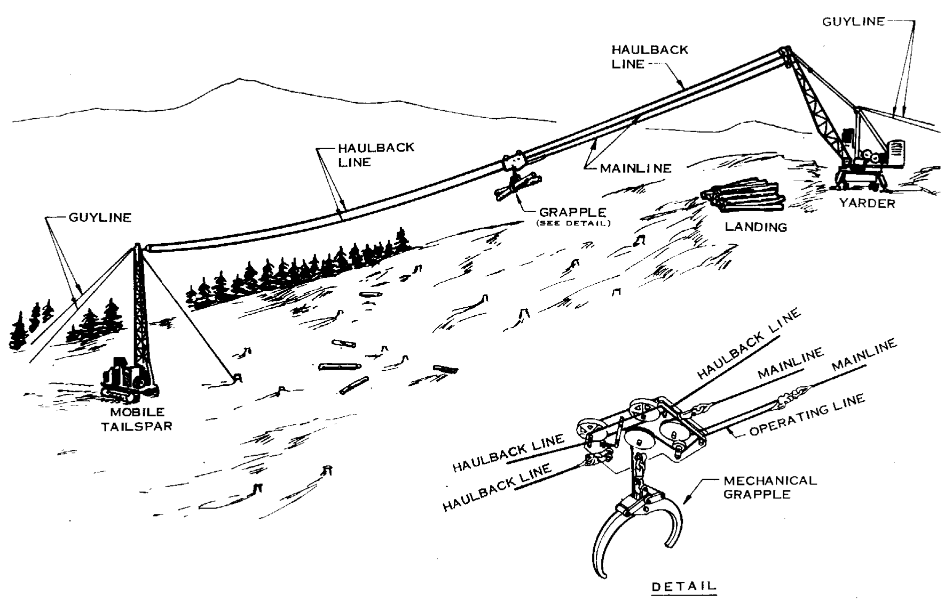


[82]A dropline is a skidding line that can be pulled out (dropped) from below the carriage to extend the lateral reach of the chokers. The dropline can be an extension of the mainline (Figure 4.4) or be wound on the drum in the carriage (Figure 4.6).

Grapple yarding is best suited to clearcuts with short yarding distances where roads are not constrained.

A running skyline can operate either with chokers or with a log grapple. The grapple yarder is a configuration of running skyline that uses a relatively short yarding crane (swing yarder) equipped with a log grapple (rather than chokers) to grasp and yard logs (Figure 4.5).[83] The grapple yarder has no lateral yarding capability. Grapple yarding corridors are parallel and narrowly spaced; logs are landed at the roadside, or on the road where slopes exceed about 45%. By incrementally moving the yarding equipment along the road, yarding corridors can be kept nearly perpendicular to the road and slope contours. Where a mobile backspar machine (e.g., a modified hydraulic excavator) is used to speed movement between corridors and to increase lift, backspar trails are required. Grapple yarders are normally used to yard logs across distances of less than 150–200 m. Grapple yarding is best suited to clearcuts with short yarding distances where roads are not constrained.

Figure 4.5 Grapple yarder.



When a running skyline is configured for chokers rather than a grapple, a lightweight carriage can be used (Figure 4.6). Depending on the type and capabilities of the carriage, lateral yarding of up to 30 m is feasible. This allows for retention cuts, where some or all of the retained trees are dispersed throughout the cutting unit.

[83]Grapple yarding refers to a cable-based method of yarding logs with a grapple (or grapple tongs) from where they are felled and bucked, to a roadside. This method employs a yarder with a 15- to 17-m crane built on a hydraulic excavator-like chassis. In British Columbia coastal operations, the chassis is commonly on tracks.

With true skyline yarding, both live and standing skylines use a stationary cable ("skyline") suspended between a yarding tower and a backspar. The mainline attaches to a carriage that travels along the skyline by gravity or by controlling mainline and haulback movement at the yarder.

Figure 4.6 **Live skyline with a radio-controlled slackpulling carriage showing full log suspension.**

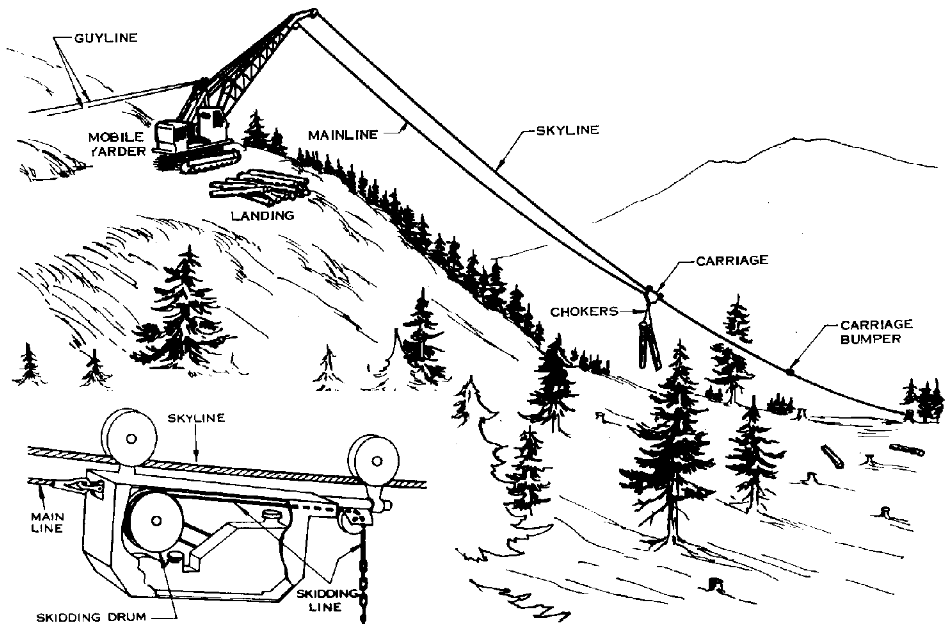


Photo 4.1

In this example, a live skyline with a tower is being used to yard logs over a forested riparian corridor.

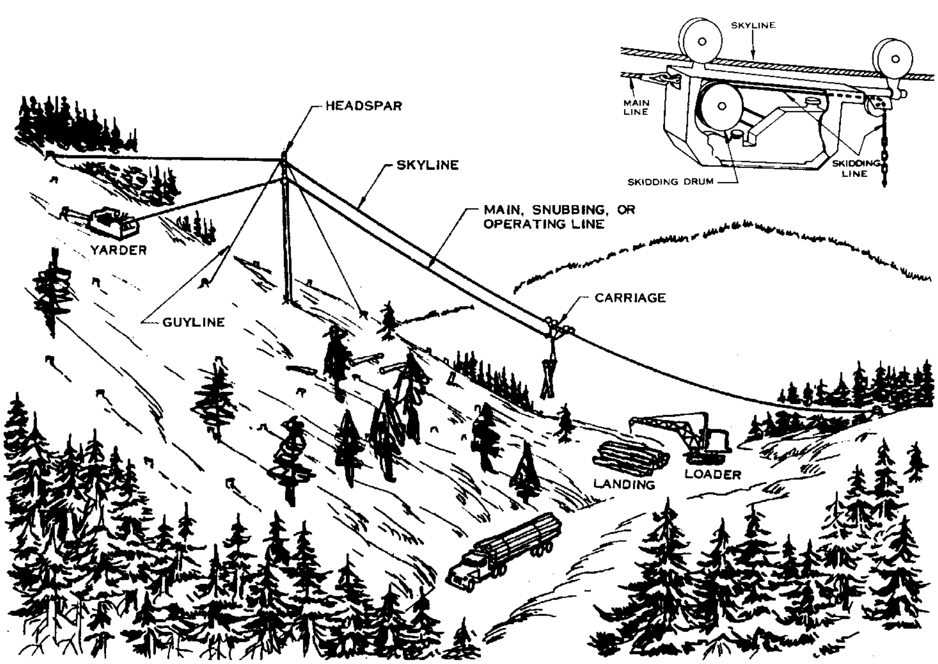
Live skylines are typically used where road access is constrained and long yarding distances (greater than 300 m) are required.

The "live skyline" is suspended between the yarder and a backspar (usually a tree), with one end of the cable anchored to tail-holds and the other wound on a drum so that the skyline can be lowered and raised during yarding (Figure 4.6). A carriage rides on the skyline with chokers attached directly to the carriage or to a dropline. In the latter case, chokers can be pulled laterally into the stand. Logs are commonly yarded with partial suspension, although full suspension is possible in suitable topography. Live skylines are typically used where road access is constrained and long yarding distances (greater than 300 m) are required.

Standing skylines are used where full suspension of logs is desired or for yarding long distances— of up to 1500 m.

In the "standing skyline," both ends of the skyline cable are secured and the skyline cannot be raised or lowered during yarding (Figure 4.7). Chokers are attached to a dropline which can be lowered to the ground; logs are attached and pulled up to the carriage. Standing skylines are used where full suspension of logs is desired (e.g., to move logs from one side of a stream to the other, where roads are not possible or permitted, or for yarding long distances—up to 1500 m). With appropriate topography the system can carry logs over standing trees or regeneration; otherwise, narrow yarding corridors must be cut through standing timber. Multi-span configurations are sometimes feasible with standing skylines.[84]

Figure 4.7 Standing skyline with a radio-controlled carriage.



[84]Multi-span configurations involve two or more spans of the skyline by using intermediate supports.

Balloon Yarding

Balloon yarding overcomes some of the limitations of cable systems (e.g., yarding distance, payload, and lift) in unfavourable topography. Balloon yarding uses cables to move logs to a stationary yarder at the landing, in much the same way as traditional cable systems. However, lift is provided by the balloon rather than as a consequence of topography and tower height.

Balloons are inappropriate for retention silvicultural systems.

Balloons can yard up to 1500 m, thus reducing road access requirements. Their vertical lift capability (15 000–18 000 kg) enables full suspension of logs. Balloons are best suited to larger clearcut operations because of the high log volumes needed to offset high set-up costs. Balloons are inappropriate for retention silvicultural systems because imprecise manoeuvring and positioning of the balloon reduces control of the operating lines (cables).

Helicopter Yarding

Helicopters are typically used to yard logs in sensitive or otherwise inaccessible terrain.

Helicopters are typically used to yard logs in sensitive or otherwise inaccessible terrain. Optimal flight distance is typically 600–1000 m although maximum yarding distances can extend to 2000 m, with high value timber. Level to downhill flight paths are preferred to take advantage of gravity. Widened roadsides or water, rather than constructed landings, can be used as unloading sites (drop sites) for logs.

Compared to ground-based and cable yarding methods, helicopter logging has both higher operating costs ($45–60/m^3) and higher yarding production rates (500–1500 m^3/shift). Because of high production rates, safe, efficient movement of workers and equipment requires careful planning. If central landings are used, they must be relatively large to accommodate log storage and segregate work activities for adequate worker safety. For such reasons, pre-harvest planning and organization are critical to the success of helicopter logging operations. Because helicopters have specific, limited payload lifting capacity,[85] and very high operating costs, logs—especially large logs—must be bucked precisely so that helicopters carry near to maximum payload and log value on each trip. Helicopters with heavy-lift payload capacity (e.g., Sikorsky S-64 and Boeing Vertol) are more suitable for higher levels of retention than medium-lift machines (e.g., Sikorsky S-61), because of their greater ability to lift logs almost vertically through remaining forest canopy.

Helicopter yarding is more sensitive to weather than cable yarding. Winds and landing location need to be considered. Fog, low cloud, and wind speeds above 50 km/hr usually suspend helicopter operations.

[85]"Payload lifting capacity" refers to the weight that a helicopter can safely lift and transport. Helicopters can be classified as "low-lift" (up to 5000 lbs), "medium-lift" (5000–10 000 lbs), and "heavy-lift" (greater than 10 000 lbs).

Table 4.1 summarizes the basic characteristics and capabilities of each yarding method.

Table 4.1 Characteristics of common yarding methods.

Yarding method		Yarding distance	Limiting slope %	Applicability to different silvicultural systems	Yarding corridor arrangement	Potential for detrimental soil disturbance	Comments
Ground-based	Skidders (rubber-tired or tracked)	Uphill 120 m; downhill and flat 60–600 m	30–40%	Flexible; clearcuts, partial and retention cuts	Flexible	Moderate to high	Best suited to drier and/or cold climates, and strong soils (coarse-textured, dry, or frozen); potential for root damage
	Hoe forwarder	Uphill 20–70 m; downhill 20–120 m	Uphill 15–30%; downhill 35%	Flexible; clearcuts, partial and retention cuts, and thinning	Flexible	Low (<5%) if measures taken to protect soils	Allows full separation of yarding and loading; low labour requirement
	Scandinavian-style forwarders	150–600 m	15–20 %	Flexible; clearcuts, retention cuts, thinning	Flexible	Low to moderate	Potential for future use in managed stand harvest
Cable	Highlead	Uphill 100–300 m; downhill 30–100 m (recommended), 30–200 m (typical); no lateral yarding	Determined by falling and bucking safety	Clearcuts, apart from strips or wedges in the outer half of setting	Radiating	Low to moderate, depends on lift; locally high in ground-lead situations or in broken or gullied terrain	Lift is limited by tower height and slope configuration; partial suspension in favourable topography
	Grapple yarder	Uphill 100–200 m; downhill 50–150 m; no lateral yarding	Determined by falling and bucking safety	Most effective for clearcuts or strip cuts due to lack of lateral yarding capability	Parallel; at right angle or slightly angled to road (downhill yarding)	Low with adequate log suspension	15–17 m crane; uses road as landing; mobile backspar improves efficiency; only 2–4 guylines; fast yarding corridor changes
	Yarding crane (swing yarder) with dropline carriage	Uphill 100–700 m; downhill 100–400 m; 10–30 m lateral yarding	Determined by falling and bucking safety	Flexible; clearcuts, partial and retention cuts	Parallel; at right angle or angled to road; and radiating	Low with adequate suspension	15–17 m crane; uses road as landing; mobile backspar improves efficiency; only 2–4 guylines, fast yarding corridor changes
	Live skyline (tower)	Uphill, up to 1000 m; downhill, up to 700 m; lateral yarding to 30 m	Determined by falling and bucking safety	Flexible; clearcuts, partial and retention cuts, thinning	Radiating	Minimal with adequate suspension	6–8 guylines; accesses large area, may stay in place for one to several weeks; large volume accumulates at the landing; requires sound anchors for guylines and tail-holds; usually for single-span operations
	Standing skyline (tower)	Uphill or downhill up to 1500 m; lateral yarding to 30–60 m	Determined by falling and bucking safety	Flexible; clearcuts, partial and retention cuts, thinning	Radiating	Minimal; full suspension system in suitable topography	Used where full suspension is required (e.g., moving logs over a stream); requires sound anchors for guylines and tail-holds; has multi-span potential
Balloon		Up to 1500 m	Determined by falling and bucking safety	Limited to large clearcuts due to lack of line control	Radiating	Minimal; full suspension system	Requires large volumes to be economical; very sensitive to wind /heavy rain
Helicopter		Up to 2000 m where timber value allows	Determined by falling and bucking safety	Very flexible; clearcuts, partial, and retention cuts	No corridors	None	Road as landing or water drop; snags and other danger trees must be removed above and around hook-up areas; high operating costs; must run at near capacity; weather sensitive

4.1.2 Factors Affecting Choice of Harvesting System

As previously noted, harvesting systems are selected based on site variables and management objectives. Specific factors affecting the choice of harvesting system include:

- topography (slope steepness and variability);
- soil (composition, sensitivity to disturbance);
- silvicultural system (level of retention, number of harvest entries);
- timber characteristics (log size and volume per hectare);
- potential road access and roading constraints (Chapter 5); and
- yarding distance and direction; if cable yarding, desired log suspension (full or partial) is based on risk of detrimental soil disturbance, damage to retained trees, and protection of other resource values.

The selection of harvesting system follows a decision matrix (Figure 4.8).

Topography and soil characteristics are the key factors in determining if ground-based yarding methods are appropriate.

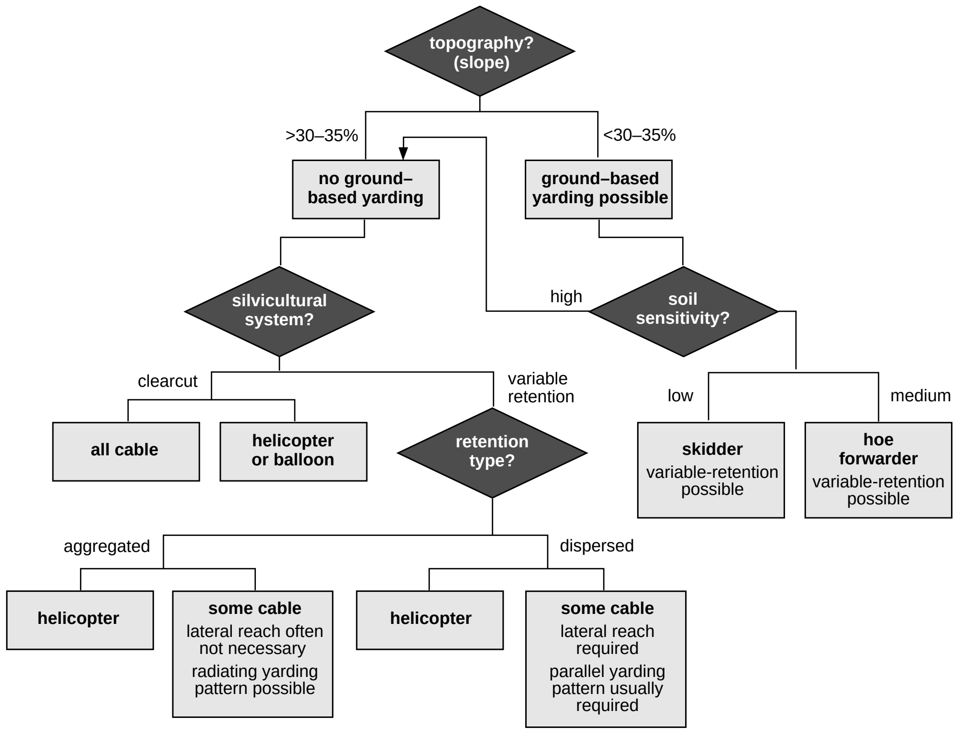
Topography and soil characteristics are the key factors in determining if ground-based yarding methods are appropriate. Ground-based yarding equipment is limited to slopes of less than about 35%, and is further constrained by soil type in relation to weather (i.e., rain, soil water content, soil-bearing strength).

For all yarding methods, stand and timber characteristics, such as volume per hectare and log size, influence choice of machine size and power, production rates, and operating costs. In general, an inverse relationship exists between harvest unit costs ($\$/m^3$), and log size and timber volume per hectare. Indirect costs such as minimizing damage to soil or aesthetic values also influence profitability of harvesting operations. Capital, operating, and labour costs are significantly higher for cable yarding and heli-logging than for ground-based systems. The feasibility of locating and constructing roads determines how close yarding equipment can get to the timber and may be an overriding determinant.

Yarding distance and direction also affect harvesting options.

Yarding distance and direction also affect harvesting options. Tower skyline yarding requires central landings with radiating yarding corridors. These corridors tend to accumulate large volumes of timber in the landing and, because of corridor overlap close to the landing (Figure 4.3), cannot retain trees near the landing. Radiating corridors may also require cross-slope yarding with attendant difficulty in controlling logs, and consequent potential for increased ground disturbance and damage to the residual stand. In such situations, full suspension may be required to keep corridor width, ground disturbance, and residual tree damage within acceptable levels (Figure 4.9).

Figure 4.8 **Harvesting systems decision matrix.**



Summary

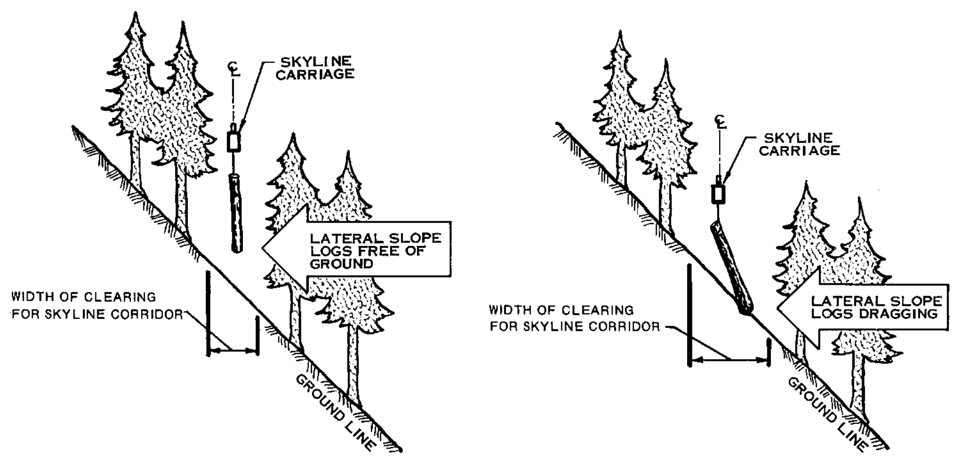
silvicultural system	slope < 30–35%	low soil sensitivity	medium soil sensitivity	high soil sensitivity
yarding method		**skidder** variable-retention possible	**hoe forwarder** variable-retention possible	avoid ground-based yarding

silvicultural system	slope > 30–35%	clearcut	variable-retention system: aggregated retention	variable-retention system: dispersed retention
yarding method		**all cable** **helicopter** **balloon**	**some cable** lateral reach often not necessary; radiating yarding pattern possible **helicopter**	**some cable** lateral reach required; parallel yarding pattern usually required **helicopter**

Highlead and grapple yarding are best suited to clearcutting where logs do not need to manoeuvre around standing trees.

In thinning and partial cuttings, including retention, the degree to which logs can be controlled during yarding affects residual tree damage, ground disturbance, and yarding productivity. Silvicultural systems that retain a significant number of trees will favour yarding methods with partial or full suspension and lateral yarding capabilities. Highlead and grapple yarding are best suited to clearcutting where logs do not need to be manoeuvred around standing trees, and lateral yarding is unnecessary. Running or live skyline methods using yarding cranes with dropline carriages are suited to retention cuts on steep slopes if yarding distances are less than 250–300 m. For longer yarding distances, tower skylines (standing or live) or helicopters are possibilities.

Figure 4.9 The effect of log suspension on corridor width when cross-slope yarding.



The final considerations in selecting a harvesting system are operational, such as specific features of timber and terrain, accessibility, and costs.

4.2 Harvesting in Clayoquot Sound

4.2.1 Historical Overview

Early logging in Clayoquot Sound concentrated on the gentle to moderate topography.

Early logging in Clayoquot Sound generally concentrated on the gentle to moderate topography of the Estevan Coastal Plain near Ucluelet and Tofino, and on steeper slopes close to tidewater.

Past harvesting activity in Clayoquot Sound was shaped by an even-aged management regime (clearcutting) and the operating constraints of the west coast environment (steep slopes, high precipitation, and sensitive soils). Like much of British Columbia's west coast, a clearcutting silvicultural system based on large old trees favoured handfelling and bucking, and highlead yarding to a central tower and landing. This changed with the advent of grapple yarding in the late 1970s.

Rising wages in B.C. encouraged a move to mechanized yarding operations as a means of reducing costs.

In the mid- to late 1970s, rising wages in British Columbia encouraged a move to mechanized yarding operations as a means of reducing costs. Highlead yarding operations, with crew sizes of five to six, were increasingly replaced by grapple yarding operations which required a crew of only two to three people. In 1985, about 90% of the 165 highlead towers operating in coastal British Columbia were 11 years or older; few new highlead machines were being purchased (two highlead towers in two years). By comparison, about two-thirds of the 125 operating running skylines were less than 11 years old (Sauder 1988). Yarding cranes, most of which were being used as grapple yarders, had become the machine of choice.

Past logging in Clayoquot Sound can be summarized as follows:

- The most readily accessible higher-value timber was harvested first. The current merchantable timber distribution is skewed to more difficult topography and more sensitive terrain. Immature timber is found on more moderate topography at lower elevations.
- Harvesting systems were designed for the prevailing silvicultural system—clearcutting.

The popularity of grapple yarding in the 1980s resulted in a denser road network.

- The popularity of grapple yarding in the 1980s resulted in a denser road network in the logged portion of the landscape. The bare cutslopes and fillslopes associated with these and earlier roads, plus any subsequent road-related slides, increased the visual impact of clearcuts, reduced forest productivity, and damaged aquatic ecosystems.
- Prior to the advent of grapple yarding, cutblocks typically involved multiple highlead settings. This, in combination with little control on cutblock adjacency, except for a short period of logging guidelines in the early to mid-1970s (*Coast Logging Guidelines* 1972), produced large clearcut landscapes. Many of the cutblocks deferred (left unlogged, between logged blocks) under the 1972 guidelines were logged when rules were relaxed in response to the economic recession of the early 1980s. At this time, a short-lived operation using a standing skyline (European Wyssen system) was employed to avoid roads on steep slopes; it produced a very large, highly visible clearcut opening.

The rate of harvesting, and policies regulating cutblock size, shape, and sequence have changed recently (Section 3.2.2). In the 1980s, more than 1000 ha was logged annually in Clayoquot Sound; by the early 1990s this had declined to less than 600 ha.

The *Clayoquot Sound Land Use Decision* (April 1993), identified 117 400 ha (45%) of Clayoquot Sound for general integrated resource management, with timber harvesting as a major use, and estimated the long-term harvest level from this area at 600 000 m^3/yr. The decision also stated:

> Throughout Clayoquot Sound, timber harvesting plans will be required to incorporate smaller dispersed cutblocks…Lower road densities and a corresponding increase in skyline and helicopter harvesting systems will be a key principle of future forest development plans. (British Columbia 1993a:13)

Smaller, dispersed cutblocks will likely result in a higher density of active roads.

This statement is an apparent contradiction in that "smaller dispersed cutblocks" will likely result in a higher density of *active* roads, the roads that produce the highest level of suspended sediment, often at rates of the same order as sedimentation resulting from landslides (e.g., Cederholm and Reid 1981; Haydon *et al.* 1991).

The area and means by which timber is extracted from Clayoquot Sound will continue to change as public values further influence decisions related to harvesting on Crown land.

4.2.2 Standards for Harvesting

The choice of harvesting system is recognized as an operational decision.

Existing standards applied in most of the Vancouver Forest Region and the proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* do not specify harvesting systems. The choice of harvesting system is recognized as an operational decision based on topography, ground conditions, timber type, machine availability, and economics. The harvesting system must be specified in the Pre-harvest Silviculture Prescription (PHSP). Where two or more systems are planned, they must be indicated on PHSP maps along with operating details such as season of logging and the location of planned backspar trails. This prescription is reviewed by government agencies and, upon approval, becomes a contractual obligation of the licensee to the province.

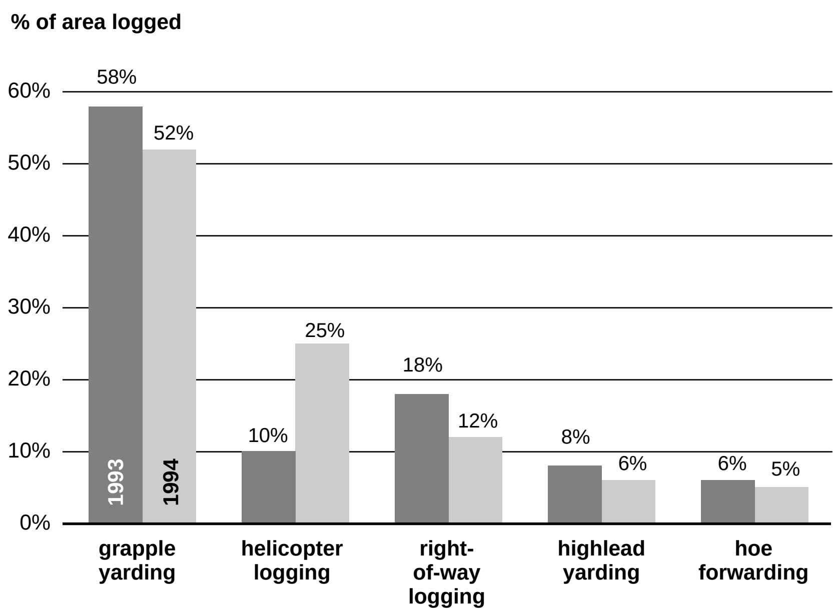
The *Clayoquot Sound Forest Practices Standards* (June 1993), and the *Interim Measures Agreement* (IMA) (March 1994) refer to specific harvesting systems. The *Clayoquot Sound Forest Practices Standards* state that "emphasis will be placed on the use of skyline and helicopter yarding methods to reduce road densities and eliminate the need for midslope roads on steep or unstable slopes," specifically in the upper Sydney and upper Clayoquot rivers (B.C. Ministry of Forests 1993a:6). The IMA restricts harvesting systems to "longline and full suspension aerial cable yarders and/or helicopter/balloon type systems" for areas covered by Total Resource Plans within part of the Clayoquot River Valley and on Flores Island, with provision for exceptions by the Central Region Board (British Columbia and the HawiiH 1994:12).

4.2.3 Recent Harvesting in Clayoquot Sound

Four main yarding methods have been used recently in Clayoquot Sound.

Four main yarding methods have been used recently in Clayoquot Sound (see Figure 4.10). Grapple yarding represented 58% of the volume harvested in 1993, followed by helicopter logging (10%), highlead yarding (8%), and hoe forwarding (6%).[86] Right-of-way logging, which involves clearcutting of linear strips prior to road construction, accounted for the remaining 18% of the logged volume. The width of right-of-way logging is often increased to more than that required for the construction of roads; the increase permits efficient yarding by modified line loaders or "long snorkels" operating from the road running surface. The volume of right-of-way logging is a direct function of the length of road built. Consequently, the proportion of right-of-way logging can be expected to drop as road densities are reduced.

Figure 4.10 Yarding methods used in Clayoquot Sound in 1993 and 1994.



Grapple yarding has dominated harvest operations in Clayoquot Sound since the 1980s.

Grapple yarding has dominated harvest operations in Clayoquot Sound since the 1980s for two reasons:

- it was, and is, more cost-effective than highlead or skyline yarding because of its relatively small crew size, short yarding cycle, and ability to change yarding corridors rapidly; and
- it could be widely applied to the topography of Clayoquot Sound provided road development was little constrained by policy and road costs could be recovered through stumpage allowances.

[86]Data supplied by B.C. Ministry of Forests, Port Alberni Forest District. "Highlead yarding" for 1994 apparently includes a tower skyline operation in Cypre River. Data for 1994 are preliminary.

Grapple yarding will be less suited to near-future harvesting conditions in Clayoquot Sound where topography and slope stability constrain road development, thereby requiring longer yarding distances and partial or full suspension of logs; and the variable-retention silvicultural system requires flexibility to move around retained trees.

Most remaining merchantable timber in Clayoquot Sound is located on the steep slopes of the Vancouver Island Mountains. In general, these areas require greater retention of trees (Section 3.4, R3.6), and midslope roads are undesirable (Section 5.1.3, R5.1). Slopes in the western, outer portions of the Vancouver Island Mountains tend to be relatively long and uniform, with some potential for ridge road locations. In appropriate terrain, ridge road location can be coupled with single- or multi-span skyline yarding. Ridgetop roads, however, are not always desirable. Montgomery (1994) has documented cases of surface drainage from ridgetop roads initiating debris slides in gullies below the ridge. To the east, well within the Vancouver Island Mountains, relatively uniform slopes are found primarily at lower to midslope positions; these, however, are commonly dissected by V-notch gullies which hinder some yarding methods. Upper slopes tend to be characterized by irregular, broken slopes with considerable bedrock outcrop.

Proposed operations presented a significant increase in non-conventional harvesting systems.

Of the anticipated 450 000 m^3 harvest in Clayoquot Sound during 1994, approximately 100 000 m^3 was expected to be yarded by helicopter and tower skyline operations. A skyline operation of about 20 000 m^3 was approved in Cypre River using a tower skyline rigged with a carriage and chokers to reach across the valley. Helicopter operations were planned for areas in Stewardson Inlet (about 30 000 m^3), Kennedy Lake Division (about 10 000 m^3), and Tranquil Creek (about 30 000 m^3). The proposed and/or approved operations represented a significant increase in non-conventional harvesting systems. In addition, permits are pending for non-clearcut silvicultural systems using grapple yarding, alone or in combination with hoe forwarding, on the Kennedy Flats and near Fortune Channel.

Application of harvesting systems must continue to change to meet the requirements of a variable-retention silvicultural system.

4.2.4 Yarding Methods Appropriate to a Variable-Retention Silvicultural System

Current cable yarding can be successfully applied to silvicultural systems other than clearcutting.

The selection of silvicultural system greatly influences the selection of yarding methods. Of the existing yarding methods, only balloon yarding cannot be used in anything but clearcut operations. Most cable yarding methods, as well as ground-based equipment and helicopters, can be used in non-clearcut silvicultural systems. Their effectiveness, however, depends largely on careful matching of specific yarding methods with the prescribed silvicultural systems and thorough cutblock design. Experience in the U.S. Pacific Northwest and in British Columbia shows that current cable yarding can be successfully applied to silvicultural systems other than clearcutting. For example, the Plum Creek Timber Company has successfully applied current harvesting equipment and methods in aggregated retention (patch and wedge) silvicultural systems (B.C. Ministry of Forests 1993e).

A variable-retention system requires harvesting methods that are:

- efficient and safe;
- flexible to accommodate different levels and distributions of retention; and
- appropriate to steep slopes and require low road densities.

Ground-based systems are flexible and can be readily adapted to various silvicultural systems, provided their impact on the soil and damage to the residual stand is not excessive.

For example, on the Montane Alternative Silvicultural Systems (MASS) trial site near Courtenay, B.C., a hoe forwarder and tracked skidder were used in old growth on gentle slopes (15–20% or less) to implement three silvicultural systems retaining forest cover: patch cutting (1.5 ha clearcuts), clearcutting-with-reserves (25 trees/ha retained),[87] and shelterwood (30% of the basal area of the stand, or about 150 stems greater than 17.5 cm dbh,[88] retained) (Beese 1994). Most unlogged slopes in Clayoquot Sound are greater than 20%, but ground-based systems have been used elsewhere on Vancouver Island where alternatives to clearcutting have been implemented (Moore 1994).

Highlead yarding is poorly suited to a variable-retention silvicultural system.

Highlead yarding is poorly suited to a variable-retention silvicultural system and totally unsuited to dispersed retention. Some pie-shaped aggregates could be retained between the far ends of yarding corridors. This initially would produce a more ragged edge rather than an isolated aggregate but could become an isolated aggregate when the adjacent area is logged. These aggregates could be oriented to improve windfirmness.

Grapple yarding can be used with aggregated retention where the aggregates are linear strips.

Grapple yarding also is poorly suited to a retention silvicultural system, especially if the trees to be retained are dispersed. Grapple yarding can be used with aggregated retention where the aggregates are linear strips between logged yarding corridors. This approach has been combined with some dispersed retention (25 trees/ha) in a recent cutblock at McTush Creek. Higher levels of aggregated retention may be feasible with grapple yarding if narrow cut strips are interspersed with linear retained aggregates.

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[87]The Panel would term these trials “dispersed retention”; if the 30% basal area is retained in the “shelterwood” cutting, the Panel would term that an “intermediate“ level of retention (Chapter 3, Figures 3.1 and 3.2).

[88]Dbh refers to “diameter breast height,” the stem diameter of a tree measured at “breast height,” about 1.3 m above the point of germination.

Skyline yarding is the cable yarding method best suited for retention.

Maintaining log control during yarding is critical in variable-retention silvicultural systems to minimize soil disturbance and damage to residual trees, and to maximize yarding productivity. Because of this, skyline yarding is the cable yarding method best suited for retention, particularly with dispersed retention.

With skyline yarding, log control is determined by:

- height of skyline above the ground;
- lateral yarding distance;
- ability to reposition the carriage during lateral yarding; and
- log lengths.

Where lateral yarding into a yarding corridor is involved (e.g., with dispersed tree retention), falling patterns must be integrated with the planned yarding. "Herringbone" patterns, which allow easier movement of logs into the main yarding corridor, require precise location of the skyline corridors, the spine of the pattern. Because of the importance of yarding corridor location in relation to the felled trees, fallers must be aware of corridor locations. As a result, corridor locations cannot be changed once falling has started.

Medium to large yarders will continue to be required for the variable-retention system.

Horsepower ratings for yarder engine sizes commonly used in Clayoquot Sound range from 350 hp to over 600 hp. Table 4.2 shows yarder sizes (in hp requirements) for typical combinations of log sizes and yarding distances in clearcut operations. Medium to large yarders will continue to be required to maintain line speed and yarding productivity for the variable-retention system and anticipated log sizes, particularly with longer yarding distances.

Table 4.2 The effect of yarding distance and log size on yarder engine size.

Yarding distance	**150 m**	**250 m**	**300 m**
Average log size (m^3/log)		**Equipment size**[1]	
0.4	small	medium	medium-large
0.8	small	medium	medium-large
1.5	medium	medium-large	large
3.0	medium-large	large	large

[1]Small refers to yarders less than 350 hp, medium from 350 to 550 hp, and large to greater than 550 hp.

Source: Conway (1982).

Some helicopters can be used efficiently in cutting systems that retain tree cover.

Although helicopter yarding has been used predominantly with clearcut operations to date, a helicopter yarding trial with a selection system was undertaken at Cat's Ears Creek in 1992. Trial results emphasized the importance of layout, planning, and payload capacity of the helicopter for successful helicopter operations. Despite high costs and manoeuvrability limitations, some helicopters can be used efficiently in cutting systems that retain tree cover.

The conditions under which helicopter yarding is practicable are significantly limited for the proposed variable-retention silvicultural system. The pilot must be able to see personnel on the ground to safely lower the load line[89] and must be able to lift the load without hanging up in the remaining trees. These concerns preclude logging of single trees but allow the logging of small patches or groups of trees. Retention or partial cutting systems require a significantly longer load line than is required in clearcut systems. Total load line length is the sum of the dominant tree height plus clearance between helicopter and canopy. As a rule, a minimum clearance of about 15 m between tree crowns and helicopter is required. For production and safety, a load line length of about 75 m should not be exceeded. Table 4.3 summarizes the potential of current yarding methods under a variable-retention silvicultural system.

[89]Load line is the line or cable that hangs from the helicopter to which the chokers are attached.

Table 4.3 Yarding methods – potential application with a variable-retention silvicultural system.

Yarding method		**Limiting factors** for application with a retention silvicultural system	**Future applicability**
Ground-based		Limited by the extent of suitable topography and soil conditions	In the short-term, limited by lack of merchantable timber on moderate slopes; expect increased application as managed stands become viable for commercial thinning and harvest
Cable	Highlead	Limited by lack of lateral yarding capability	Limited future use in small clearcuts and in aggregated (pie-shaped) retention cuts
	Grapple yarder	Limited by lack of lateral yarding capability, and short yarding distances	Some potential for narrow strip cuts interspersed with linear retained strips
	Yarding crane (swing yarder) with slackpulling carriage	Limited to medium yarding distances; rarely capable of full suspension because of machine and line wear	Considerable potential future use, especially on relatively uniform valleysides
	Tower skylines (live and standing)	Limited somewhat by specific requirements for topography, yarding distance, landings and solid anchors (for both guylines and tail-holds)	Most suited to demanding topographic conditions, including long yarding where roads are constrained, and cross-stream yarding while retaining riparian reserves
Balloon		Limited to clearcutting because of lack of control over moving lines	None
Helicopter		High levels of retention will be limited to cutting of small groups of trees rather than single trees because of safety concerns (visibility, rotor wash); limited on steep slopes because of the need to safely permit precise bucking	Considerable future potential, particularly on sensitive sites (stability, riparian, visual) requiring high levels of retention

4.3 Findings Regarding Harvesting Systems

Because of the inherent relations among silvicultural, harvesting, and transportation systems, many findings presented in this section are implications deriving from recommendations concerning silvicultural systems (Section 3.4) or roads (Section 5.1.3).

Implications of Past Harvesting in Clayoquot Sound

Past harvesting focused predominantly on low-elevation areas with moderate topography.

F4.1 Past harvesting in Clayoquot Sound focused predominantly on low-elevation areas with moderate topography. Much of the remaining, unlogged forest in Clayoquot Sound is on steeper, more difficult terrain.

F4.2 More than 80% of the older forests in the General Integrated Management Area of Clayoquot Sound is located on slopes steeper than 30° (approximately 60% slope). Yarding methods on these areas will be largely determined by the degree of retention prescribed and constraints on roads.

F4.3 Harvesting systems appropriate for future commercial thinning or harvesting in currently immature, managed stands will be determined by slope and soil sensitivity, in combination with log sizes. Because much of the earliest harvest was on gentle to moderate slopes, constraints of slope, as on ground-based equipment, will be less than for most presently mature stands.

Current Yarding Methods

Grapple yarding requires the greatest road density of all yarding systems currently used in Clayoquot Sound.

F4.4 Grapple yarding, because of its short yarding distances and lack of lateral reach, requires the greatest road density of all yarding systems currently used in Clayoquot Sound (Table 4.4). The high percentage of forest land converted to roads to support grapple yarding results in significant disruption to surface and subsurface drainage patterns. Ground disturbance can be even greater in situations where backspar trails are constructed.

Table 4.4 Area occupied by haul roads, landings, and backspar trails with various yarding methods.

Yarding method	% area occupied by:[1]			Total area (%)
	Haul roads	Landings	Backspar trails	
Grapple	9.5	0.5	1.8	11.8
Highlead	7.4	1.6	0.2	9.3
Skyline	3.5	0.9	0.1	4.5

[1]Area occupied is not equivalent to area of site degradation as defined by the Vancouver Forest Region (B.C. Ministry of Forests 1991b, 1992c, 1992d).

Source: Krag *et al.* (1993).

Skyline and helicopter yarding require lower road densities and result in less soil disturbance during yarding, thereby reducing the environmental impact of harvesting. Helicopter yarding requires no on-block roads, landings, or backspar trails. However, if logs will be dropped on land (rather than water), existing landings may be enlarged or new landings constructed to handle the high volume of logs produced by helicopter logging operations.

F4.5 Recent and currently planned alternatives to clearcutting involve low levels of retention, the so-called “clearcut-with-reserves.” This system uses mostly well-established yarding methods—hoe forwarding, grapple yarding, and heli-logging. Very little experience has yet been gained in coastal British Columbia with retention cuts using cable yarding with lateral yarding capability, particularly at high levels of retention.

Harvesting Implications of a Variable-Retention Silvicultural System

F4.6 The variable-retention silvicultural system proposed for Clayoquot Sound (Section 3.4) will continue to produce logs with dimensions comparable to those currently produced (typically more than one cubic metre). Medium to large yarding equipment will continue to be needed to handle such logs (Table 4.2). Depending on the age at which thinning takes place, thinning operations may use smaller equipment.

The variable-retention silvicultural system requires flexible yarding methods that can efficiently and safely remove timber.

F4.7 The variable-retention silvicultural system requires flexible yarding methods that can efficiently and safely remove timber from a stand without damaging either the trees retained or the soil.

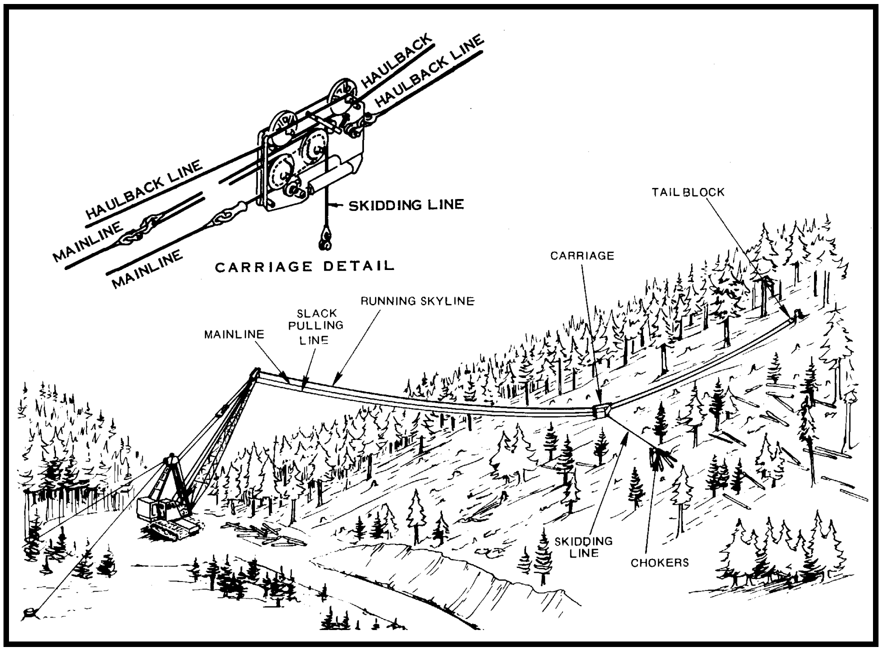
F4.8 Where topography and soil conditions permit (Figure 4.8), ground-based yarding methods provide the greatest flexibility for both the amount and distribution of retention.

F4.9 The wet climate, steep slopes, and silty to loamy surface soils that are susceptible to damage limit the areas in Clayoquot Sound that are appropriate for ground-based yarding methods.

Most of the cable yarding equipment currently used in Clayoquot Sound can be adapted to a variable-retention silvicultural system.

F4.10 Most of the cable yarding equipment currently used in Clayoquot Sound can be adapted to a variable-retention silvicultural system. For example, by replacing the log grapple with a slackpulling carriage with chokers, a grapple yarder becomes a yarding crane with lateral yarding capability (Figure 4.11). The mobility of yarding cranes makes them well suited to situations that require parallel corridors, such as along valley sides with uniform slopes. They can be used in both running skyline and live skyline configurations.

Figure 4.11 Retention with a yarding crane (swing yarder) equipped with a slackpulling carriage.[1]



[1]The slackpulling carriage provides increased lateral yarding capability, typically up to 30 m.

Lateral reach and partial to full suspension capabilities are often required.

F4.11 Lateral reach and partial to full suspension capabilities are often required for yarding in a variable-retention silvicultural system to maintain the required log control along the full length of the yarding corridor.

- Where retention is aggregated (e.g., in small patches, wedges, or strips), lateral reach may not be required, then highlead or grapple yarding can be used.
- Where retention is dispersed, lateral yarding capabilities are required; grapple yarding and highlead yarding are unsuitable. Yarding cranes with slackpulling carriages suit this situation.
- At high levels of retention, yarding corridors must be narrow and both line and log movement must be well controlled. With favourable topography, partial suspension (e.g., with a yarding crane) may be adequate. Where combinations of topography, long yarding distance, and high levels of retention preclude the use of yarding cranes, tower skylines or helicopters must be used.
- Parallel corridors are better suited to high retention levels than are radiating corridors which, because of corridor overlap, result in almost complete tree removal close to the landing (Figure 4.3).

- Where cross-slope yarding must occur, full log suspension is necessary to prevent damage to retained trees on the down side of yarding corridors. This requires the use of live or standing tower skylines.

The variable-retention silvicultural system will reduce the extent of grapple yarding in Clayoquot Sound.

F4.12 The variable-retention silvicultural system will reduce the extent of grapple yarding in Clayoquot Sound. Longer reach cable yarding methods (e.g., tower skyline) and helicopter yarding will increase as the length of roads on steep mid- to upper-slopes that are potentially unstable or sensitive to changes in drainage patterns (both surface and sub-surface) are minimized. Slope configurations will restrict the use of ridge roads and opportunities for uphill skyline yarding.

F4.13 High retention levels and/or slopes that are too steep to safely permit the precise bucking that helicopter yarding requires will constrain helicopter yarding. For high retention levels, removing trees in small patches (less than or equal to 0.3 ha) will permit helicopter yarding.

F4.14 Balloon yarding, which is characterized by poor control of the operating cables as the balloon moves, is not suited to a variable-retention silvicultural system.

F4.15 Yarding methods appropriate to a variable-retention silvicultural system (e.g., longer skyline spans, lateral reach capability) are more complex than past yarding methods in Clayoquot Sound.

F4.16 The variable-retention silvicultural system requires greater planning and more detailed layout of falling to meet retention objectives, yarding efficiency requirements, and worker safety.

Rigging skills have declined over the last decade.

F4.17 Rigging skills have declined over the last decade because grapple yarding does not require a high level of rigging skill, especially where mobile backspar machines are used. Retention cuts employing live or standing skylines, backspar trees, intermediate supports, or lateral yarding will require more advanced yarding and rigging skills.

F4.18 In general, falling and yarding efficiency will decrease as levels of retention increase. Findings from other areas with timber size and topography similar to Clayoquot Sound (e.g., Pacific Northwest Douglas-fir region) indicate a 1–41% decrease in production on areas that are partially cut or thinned (Daigle 1992). While falling and yarding costs generally increase with increasing levels of retention, there are also indications that where the extracted timber volume exceeds 350 m^3/ha, unit production costs ($\$/m^3$) are not significantly higher than those of clearcut operations (B.C. Ministry of Forests 1993e).

F4.19 In a variable-retention silvicultural system, the selection of leave trees and the falling and yarding of harvested trees profoundly affect faller safety and yarding productivity. Persons knowledgeable in the variable-retention silvicultural system, tree hazard assessment, and operational constraints in harvesting must select the trees in such situations.

F4.20 A past trend in harvesting operations has been to increase mechanization as a means of decreasing manpower requirements and increasing productivity. Harvesting methods appropriate to the variable-retention silvicultural system will counter this trend by requiring more labour. Although overall system productivity may be comparable, production rates per person-hour will decrease because of the larger crew.

Forest engineers, technicians, and forest workers will require greater knowledge and higher skill levels than have been required in the past. Labour requirements may double or triple.

F4.21 Because adoption of a variable-retention silvicultural system will require more planning, design, and engineering of harvesting operations (e.g., locating yarding corridors, ensuring adequate suspension), forest engineers, technicians, and forest workers will require greater knowledge and higher skill levels than have been required in Clayoquot Sound in the past. Information from various sources (e.g., B.C. Ministry of Forests 1993e) suggest that the labour requirement for engineering and field layout of harvesting operations may double or triple under a variable-retention silvicultural system.

4.4 Recommendations Regarding Harvesting Systems

The Panel's recommendations focus on harvest system planning, implementation, and worker training.

Harvesting systems are largely dictated by stand and site characteristics, in conjunction with management objectives as expressed in the Pre-harvest Silviculture Prescription. Panel recommendations, therefore, focus on harvest system planning, implementation, and worker training, rather than on specific criteria for selecting harvesting systems.

R4.1 Select a harvesting system that meets safety and other specified objectives (e.g., minimal ground disturbance) consistent with variable-retention silvicultural prescriptions.

R4.2 Plan and implement yarding to minimize soil disturbance, site degradation, and damage to retained trees. Restrict ground-based logging to hoe forwarding or similar low-impact yarding methods appropriate to the prevailing weather and soil conditions in Clayoquot Sound. Use partial or full suspension cable yarding and helicopter logging as required to minimize detrimental soil disturbance and damage to retained trees.

Undertake operational trials of harvesting with the variable-retention silvicultural system.

R4.3 Undertake operational trials of harvesting with the variable-retention silvicultural system at a range of levels and distributions of retention to establish design parameters and procedures for cutblock layout, falling, and yarding, particularly for skyline methods involving lateral yarding. Because this information is needed to support the recommended phase-in of a variable-retention silvicultural system, a cooperative effort (e.g., B.C. Ministry of Forests Engineering Branch, Forest Engineering Research Institute of Canada, and members of the forest industry) is warranted, including consultation with experienced operators in the Pacific Northwest.

Provide continuing education opportunities to encourage development of a skilled, motivated, and stable workforce.

R4.4 Develop education and training programs to provide forest engineers, technicians, and forest workers with the knowledge and skills required to plan and implement harvesting operations appropriate to a variable-retention silvicultural system in Clayoquot Sound. Provide continuing education opportunities to encourage development of a skilled, motivated, and stable workforce.

Training must address silvicultural objectives (e.g., habitat, biological diversity, regeneration) and operational constraints (e.g., harvesting system requirements, windfirmness, yarding patterns, falling patterns) at all levels, including:

- professional foresters who prescribe the level, type, and distribution of retention in the Pre-harvest Silviculture Prescription;
- forest engineers who formulate logging plans, and technicians who lay out retention cutting units; and
- fallers who make on-site decisions about safe and efficient falling, bucking, and yarding, and other forest workers involved in harvesting.

This education and training is urgent in view of the recommended phase-in schedule (Section 3.4.2, R3.21).

A university-level program of study in forest engineering is needed.

R4.5 A university-level program of study in forest engineering that would qualify its graduates for professional registration in both forestry (registered professional forester) and engineering (professional engineer) is needed to fulfil the greater demands for complex forest engineering and planning that the Panel's recommendations require.

R4.6 Government, forest companies, and labour, through discussion, must address issues of increased manpower requirements, reduced productivity (i.e., cubic metres per shift), and increased costs involved with the variable-retention silvicultural system.

5.0 Transportation Systems

Logs in Clayoquot Sound are transported by both roads and water.

Logs and other partly manufactured forest products (e.g., cedar shake blocks and cypress cants[90]) in Clayoquot Sound are transported by both roads and water. The road network is used for hauling logs, access by logging and silvicultural workers, movement of equipment (including heavy equipment), and access by recreational users and residents. Water transport is used to move most logs in Clayoquot Sound to processing facilities. After unloading the logs from logging trucks, the log handling system typically includes sorting and bundling logs in dryland sorts, watering log bundles, temporarily storing bundles in bag booms, and transporting via log barges. Water transport is also used extensively by residents and for recreational pursuits.

5.1 Road Transportation

Roads carrying low traffic volumes are often wider to serve both transportation and yarding.

The existing road system is the result of past requirements to accommodate off-highway trucks[91] and more recent requirements related to harvesting with grapple yarders. Roads often serve not only as transportation links but also as landings for grapple yarders. As a result, roads carrying low traffic volumes are often wider than 5 m, to serve both transportation and yarding functions.[92]

Photo 5.1

In Clayoquot Sound, road construction has tended to exceed guidelines for both running surface width and amount of productive forest area committed to permanent road.

[90]Cants are partly manufactured logs that are roughly squared, usually for export. Cypress (yellow-cedar) cants may be manufactured in the woods using chainsaws, and are generally from lower grade logs that were not loaded out during earlier logging.

[91]Off-highway trucks are logging trucks of a size (width and/or weight) that exceeds legal highway specifications.

[92]In this report, references to road width refer to the width of the road running surface, unless otherwise noted. In other documents, the running surface may be referred to as “stabilized road width.” See Figure 5.1.

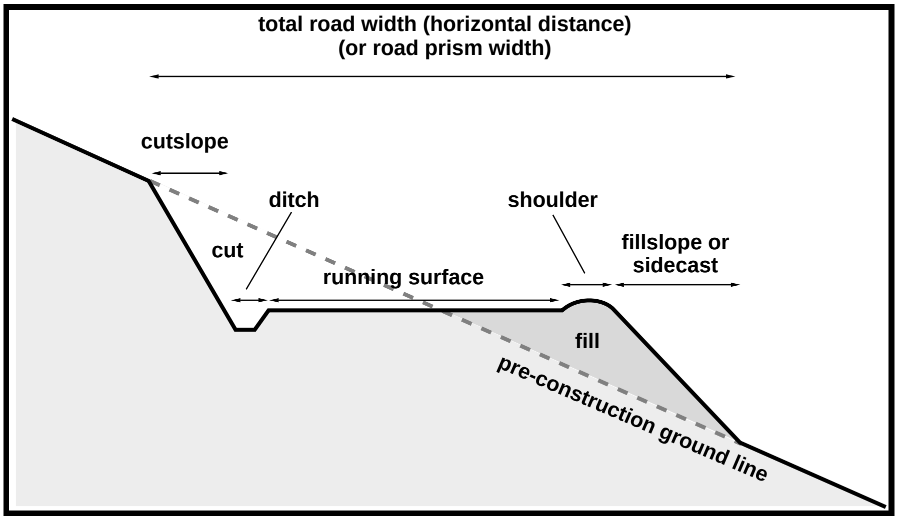
Determining the location of roads is complex.

Determining the location of roads is complex, and must consider many factors and objectives, including:

- operational and physical considerations:
  - existing road system;
  - transportation efficiency (including intended uses, road standard);
  - planned silvicultural and harvesting systems, and resulting layout;
  - engineering control points (physical, legal); and
  - topography.
- environmental considerations:
  - terrain, slope stability, and surface erosion hazard;
  - potential damage to growing sites (site degradation);
  - avoidance of riparian areas;
  - avoidance of special habitats (including habitats of rare, threatened, or endangered species) and ecologically sensitive sites (including karst[93]);
  - avoidance of heritage and cultural sites, and areas of special significance to First Nations;
  - potential visual impacts;
  - potential impact on recreational sites;
  - potential impact on reserves; and
  - rehabilitation potential.
- economic considerations:
  - road construction costs in relation to value of timber accessed as these differ among harvesting systems; and
  - operating and maintenance costs.

[93] Karst refers to the distinctive landforms, topography, and subsurface features, including caves, associated with limestone or other soluble bedrock.

Figure 5.1 Cross-section of forest road.



Road construction techniques changed significantly with the introduction of backhoes in the late 1970s.

Road construction techniques changed significantly with the introduction of backhoes (hydraulic excavators) in the late 1970s. Prior to that time, roads were built by bulldozers, so that the typical, fully benched roads[94] of steeper slopes involved sidecasting of waste excavated material. Most of the observed road-related landslides from older roads are associated with failures within or at the base of the sidecast material, and do not involve the actual road running surface. The Panel observed that roads constructed more recently by backhoes had fewer road-related failures. Better use and placement of excavated material, and better sorting of material (weathered soils and organics separated from unweathered materials and broken rock) all appear to have contributed to improved stability of the road prism.[95]

Most failures do not involve the actual road running surface.

During the last five years, a road deactivation program has been underway.

During the last five years, a road deactivation program has been underway on Vancouver Island. Currently the deactivation program appears to focus on restoring natural drainage patterns to the extent possible, and reducing failures in fill and sidecast materials.

[94]In a fully benched road the entire running surface is supported by a cut into the hillslope. In a partially benched road part of the running surface is supported by a cut into the hillslope and part is supported by fill material excavated from the cut (see Figure 5.1).

[95]Road prism refers to the geometric shape formed by the road from the top of the cut to the toe of the fillslope. The road prism width, the horizontal distance from the top of the cut to the toe of the fillslope, is several metres less than the clearing width, the width in which all trees are cut prior to road construction.

Photo 5.2

To create a road surface on steeper slopes, slopes were filled with sidecast material during construction (Figure 5.1). Most road-related landslides from older roads are associated with sidecast material.

5.1.1 Standards for Roads

Existing road standards have recently been collated in *Forest Road and Logging Trail Engineering Practices (Interim)* (July 1993). In addition, the *Clayoquot Sound Forest Practices Standards* require that:

- Road densities will be reduced from present practice. [No present or future density is specified.]
- Road layout will follow the overall access management plan. [That is, road permits would be issued only when an access development plan is in place.]
- Road width will be reduced to minimum requirements for off-highway hauling and equipment movement. In those instances where highway trucks are used, road widths may be reduced further. Road widths will be specified in approval documents. [This statement appears to recognize that grapple yarding has contributed to greater road widths in the past.] (B.C. Ministry of Forests 1993a:5)

Since 1991, efforts to reduce the amount of forest land converted to permanent access have increased.

Road widths in recent years average 5.4 m.

Since 1991, efforts to reduce the amount of forest land converted to permanent access (roads and landings) have been increased (B.C. Ministry of Forests 1991b, 1992c, 1992d). These guidelines were intended to limit permanent access to less than 7% of the productive forest area of a cutblock; and haul road running surface widths to 5 m. A recent review of haul roads reveals that the 5 m specification is not being met (Table 5.1). The review shows that road widths in recent years average 5.4 m. It also shows that total road width on steep slopes (i.e., greater than 55%) ranges from 21–24 m; 9–12 m of this total horizontal width is comprised of highly visible sidecast material, part of which is not capable of tree growth (Table 5.1).

Table 5.1 Average width of haul roads, by slope class.

		Weighted average width (m)					
Slope class (%)	**Number of samples**	**Cutslope**	**Ditch**	**Running surface**	**Shoulder**	**Fillslope or sidecast**	**Total**
< 25	118	0.8	3.4	5.2	1.4	4.7	**15.5**
26–55	176	1.9	2.7	5.4	1.8	7.0	**18.8**
56–65	27	3.9	1.7	5.7	0.7	8.8	**20.8**
> 65	16	4.8	1.0	5.8	0.9	11.8	**24.3**
All	**337**	**1.8**	**2.8**	**5.4**	**1.5**	**6.5**	**18.1**

Source: Adapted from Krag *et al.* (1993)

The November 18, 1992 letter from the regional manager, Vancouver Forest Region, requires licensees to evaluate terrain and stability conditions: where proposed cutblocks and roads are located *either* within terrain stability classes IV and V,[96] *or* Es1 and Es2 units;[97] in areas exhibiting natural instability, extensive gullying or slopes steeper than 60%; and in other specific areas designated by the district manager. Roads should not be approved on terrain with a moderate to high potential for road-induced landslides, unless such roads reach extensive areas of stable terrain *and* special road construction techniques are used to limit any potential road failure.

A recent, notable change is the requirement to apply erosion control by seeding all exposed soils associated with road construction.

The *Forest Practices Code of British Columbia Act* (July 1994) and proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* largely embody the provisions of the *Forest Road and Logging Trail Engineering Practices (Interim)* (July 1993). The most notable change is the requirement to apply erosion control by seeding all exposed soils associated with road construction (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:93).

In contrast to the interim practices, the proposed Forest Practices Code requires that "full bench cuts and end haul must be used on short-term roads built on areas identified as having terrain stability class IV or V slopes, unless other measures are designed by a professional engineer or professional geoscientist" (ibid.:87). This requirement follows from the more general requirement that "excavated material must not be sidecast on slopes identified as being stability class IV or V, unless the sidecasting has been prescribed by a professional engineer or a professional geoscientist" (ibid.:88).

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[96] A classification of terrain stability is described in *Coastal Terrain Stability Classification,* attached to the November 18, 1992 letter from the regional manager, Vancouver Forest Region (B.C. Ministry of Forests 1992b). (This attachment will be replaced in 1995 by a Forest Practices Code guidebook on mapping and assessing terrain stability. It is not anticipated that the five-class terrain stability classification will change.)

[97] "Es1" areas are "environmentally sensitive" areas of land mapped during forest inventory (1:20 000 scale) where the sensitivity of soils is high. Most (90% of the volume) of the timber growing on these sites is assumed to be unavailable and is not included in allowable cut calculations. "Es2" areas are also sensitive but the area may either be partly logged or logged under various constraints.

Terms describing the degree of slope stability in the proposed Forest Practices Code standards and regulations are ambiguous (but still undergoing revision), and include: “stability class IV or V slopes,” “areas prone to mass wasting,” “very unstable terrain,” “potentially unstable terrain,” and “unstable terrain.” Panel recommendations are phrased in terms of stability classes, particularly stability classes IV and V.[98]

5.1.2 Findings Regarding Roads

Existing road standards encompass two potentially competing objectives.

F5.1 Existing road standards encompass two potentially competing objectives: to reduce impact on terrestrial and aquatic ecosystems, and to provide cost-effective log hauling. For example:

- Forest roads, logging trails, and drainage structures are located and designed to minimize the combined costs of construction, log hauling, maintenance, safety requirements, site degradation, remedial works, and deactivation (B.C. Ministry of Forests 1993f:1); and

- Forest road networks should be planned to optimize industrial efficiency and minimize environmental impact while providing for user safety. (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:79)

Because various road construction considerations can conflict, clear road location priorities are needed.

F5.2 Because various road construction considerations can conflict, clear road location priorities are needed.

F5.3 Some existing road standards are unclear or insufficient to ensure adequate protection of terrestrial and aquatic ecosystems. Improvements are required with regard to road construction in difficult terrain, road dimensions, area converted to roads, and erosion and sediment control. Existing standards for road drainage structures (ditches, culverts, and bridges), road maintenance, and road deactivation are adequate (with minor revisions) to maintain roads in a usable condition without excessive erosion. However, existing standards are inadequate to avoid changes in slope hydrology.

Even when roads are located, built, and maintained according to the standards, roads alter slope hydrology.

F5.4 Even when roads are located, built, and maintained according to the standards, roads alter slope hydrology by intercepting subsurface flows in road cuts, accumulating it in ditches, and conveying the water and any entrained sediment directly to the surface drainage network or to localized areas of slopes. This alteration short-circuits the natural routing of runoff and changes stream water regimes; it can also change water quality, and lead to decreased slope stability.

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[98] See footnote 96.

F5.5 Past road construction on steep slopes has commonly resulted in long fillslopes (e.g., Table 5.1)[99] that are highly visible, degrade growing sites, lead to fillslope and sidecast instability, and increase sediment production.

F5.6 Current standards do not require consistent application of erosion control measures to exposed soil materials along roads. Exposed soils associated with roads, landings, borrow areas,[100] and waste disposal sites commonly remain unvegetated and susceptible to erosion for extended periods.[101]

F5.7 For the last decade or so, road width (i.e., width of running surface or "stabilized road width") has accommodated landing of logs along the road during grapple yarding and long snorkelling[102] as well as transportation functions. Resulting road widths commonly exceed 5 m.

Photo 5.3

The most convenient places for road construction are valley bottoms, which are also occupied by streams and rivers. The Panel recommends reserve areas on both sides of a stream to avoid negative impacts of roads (Figure 7.4).

[99]Fillslopes are slopes created by fill material that is excavated from adjacent cutslopes when building roads, or trucked in from elsewhere (see Figure 5.1).

[100]Borrow areas or borrow pits are areas of land from which materials such as sand and gravel are extracted for use elsewhere for road surfacing purposes.

[101]Adoption of proposed *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* (Section 9.7.6) will remedy this failing.

[102]Long snorkelling is short yarding from roads using modified (extended booms) line loaders.

Standards allowing conversion of 7% of the forest land to permanent access are too rigid and too high.

F5.8 Current regional standards allow for up to 7% of the productive forest landbase to be converted to a non-productive condition for permanent access (i.e., roads and landings) on a cutblock-by-cutblock basis.[103] This standard is too rigid for cutblock-by-cutblock consideration. The overall road system pattern is determined as much by the pattern of topography and terrain within a watershed as by the road requirements of individual cutblocks. Individual cutblocks can reasonably have more or less road depending on topography and the harvesting systems used. Site degradation limits should be set over larger, more integrated units, allowing flexibility within individual cutting units.

Seven percent is too high a proportion for site degradation in the Clayoquot Sound area when using a mix of yarding methods, including skyline and helicopter yarding, which require considerably less road than highlead or grapple yarding (Table 4.4). It is also inconsistent with the *Clayoquot Sound Forest Practices Standards* (June 1993), which require reduced road density and width.

F5.9 The stumpage appraisal system does not encourage any reduction in extent of road construction because cost allowances are credited based on the length of constructed road.

5.1.3 Recommendations Regarding Roads

Recommendations seek to minimize impacts of roads on terrestrial and aquatic ecosystems while providing for safety of users.

The following recommendations seek to minimize impacts of roads on terrestrial and aquatic ecosystems while providing for safety of users. Road standards must establish a basic level of engineering practice (including location, design, construction, maintenance, and deactivation phases) that protects terrestrial and aquatic ecosystems. Operational decisions (e.g., hauling efficiency, road class, and associated costs) should not be embodied in standards.

Respect recommended priorities related to road location.

R5.1 Respect the following priorities in resolving conflicts related to road location:

- Where irreplaceable values or highly sensitive features are on or near a proposed road location, select another road location or do not build a road. Such features and values include special or rare habitats (including habitats known to be occupied by endangered, rare, and vulnerable species), heritage and cultural features, active floodplain areas and channels,[104] areas mapped as stability class V or Es1, and all but highly localized areas of marginally stable terrain.

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[103]This is referred to as site degradation and includes the full width of disturbance no longer capable of tree growth (i.e., the non-productive portion of cutslopes, shoulders, and fill/sidecast slopes as well as the road running surfaces and ditch).

[104]See Section 7.4.1 for definition of active floodplain and Section 7.4.5 for discussion of roads in hydroriparian zones.

- Where damage to watershed integrity and ecosystem function is possible, construct roads only if: no alternative route is available; the road is required to access a substantial harvestable area; *and* mitigating measures (e.g., special construction, rehabilitation) are biologically and physically feasible. Seek professional advice from appropriate specialists approved by the B.C. Ministry of Forests (e.g., professional agronomists (soil scientists), professional biologists, professional engineers, professional geoscientists) whenever road construction is contemplated in areas including: mapped stability class IV terrain; highly erodible soils; mapped Es2 areas; localized areas of marginally stable terrain; or areas where significant impact on growing sites, riparian zones, or aquatic ecosystems can be anticipated.

- Where significant damage to visual or recreational values is possible, use the proposed location only where mitigating measures are feasible according to appropriate specialists.

R5.2 Improve on-the-ground performance in construction and maintenance of road drainage structures (ditches, culverts, bridges) to meet the demands of the wet climate. Reduce the impact of roads on hydrological regimes by constructing roads that allow the passage of shallow subsurface groundwater. Achievement of this recommendation will require research.

Require an overall road deactivation plan.

R5.3 Require an overall road deactivation plan that addresses and effectively integrates the needs for long-term access for stand tending, protection, and recreation. The plan should reflect the fact that roads are a long-term investment, often needed to facilitate future land management.

R5.4 For main or branch roads on slopes consistently greater than 55%, use full bench cuts and endhaul construction, or seek professional advice to ensure that slope stability is maintained and potentially affected resource values are not diminished. In rock cuts, use controlled blasting techniques and follow manufacturers’ specifications to: avoid damage to standing timber, retain shot-rock on the right-of-way, maximize the utility of the rock for subgrade or rip-rap, minimize over-breakage, and prevent blast-triggered slides.

R5.5 Revegetate all disturbed areas associated with roads. Promptly apply erosion control, grass-legume (or equivalent) seed mixes to all denuded mineral soil surfaces (i.e., surfaces other than clean shot-rock or bedrock associated with road construction), including cutslopes, fillslopes, borrow pits, and waste disposal areas. Use indigenous, non-invasive species for revegetation wherever possible to avoid deleterious effects on non-forest communities (e.g., white clover, *Trifolium repens,* can invade saltmarsh communities and replace the native springbank clover, *Trifolium wormskjoldii*). Research is anticipated to increase the number of indigenous species available for rehabilitation.

R5.6 With the increased skyline yarding to central landings, and helicopter yarding that are expected to accompany the variable-retention silvicultural system (Section 4.3, F4.12), many roads will serve only transportation requirements (i.e., will not be used as a landing). Therefore, determine required road widths based on anticipated vehicles (i.e., vehicles that will use the road) and traffic volumes. Road widths should not exceed 4.25 m except as required on curves for sidetracking of trailer units and for turnouts. Wider or higher standard roads may be justified by special needs or safety, such as heavy industrial or recreational use, or regular use by local communities.

The maximum percentage of the harvestable area designated for permanent access should normally be less than 5%.

R5.7 Determine the percentage of the productive forest landbase to be converted to permanent access (roads and landings) on a watershed-specific basis during watershed-level planning. The maximum percentage of the *harvestable* area designated for permanent access should normally be less than 5%. All other temporary roads and access trails must be rehabilitated to a productive state.

5.2 Water Transportation

Most log sorting is now done on land.

British Columbia's coastal forest industry uses near-shore marine waters to transport logs from woodlands to mills. Historically, logs were dumped into water at the end of relatively short coastal road systems, water-sorted by species and grade, usually bundled into booms, and towed to a mill. Now, most sorting is done on land, with sorted bundles of logs dumped into the water for storage before transportation to manufacturing centres on log barges.

Photo 5.4

After sorting, logs are temporarily stored in large booms before being transported by barge to processing facilities.

Sheltered waters are used for dumping, limited water-sorting, and booming of logs. These three activities have several impacts on the foreshore and its resources:

Greatest bark accumulation occurs at the foot of skids where logs or log bundles enter the water.

- *Dumping:* Yarding of logs directly into the water with A-frames is seldom used today. At short-term dumping sites where logs are not sorted, logs may be pushed down skids either loose or in bundles, and bark may be lost in the process. These logs may then be moved to a main dump where they are removed from the water (dewatered), sorted on land, bundled, and replaced in the water. At all log dumping sites, greatest bark accumulation occurs at the foot of skids where logs or log bundles enter the water.

  Log bundling has reduced bark loss during dumping. Heli-logging has also reduced debris accumulation on the foreshore because logs are bucked and limbed in the woods. Dump sites for heli-logging must be deep enough to accommodate the plunge of dropped logs to avoid bottom damage and sediment production.

- *Water-sorting:* Bark loss and bottom churning occur if logs are sorted by dozer boats. These impacts are reduced if logs are sorted, graded, and bundled on land before being put into the water.

- *Boom storage:* In the past, booms were often held in estuaries where the influence of fresh water reduced damage by marine borers. Efforts are now made to locate log storage areas at sheltered, non-estuarine sites with deeper waters.

Estuarine ecosystems have especially high biological and cultural values.

Estuarine ecosystems have especially high biological and cultural values (see Section 2.2.5). They are important contributors to regional biological diversity, and because of their importance for fish, shellfish, and waterfowl, have traditionally been camping, fishing, or hunting sites. Several important traditional root vegetables were dug from estuarine saltmarshes by the Nuu-Chah-Nulth, including springbank clover, Pacific silverweed (*Potentilla anserina pacifica*), and missionbells (*Fritillaria camschatcensis*). Using estuarine waters for log dumping, water-sorting, and storage has damaged these environments. Bark deposition at dump sites, ocean floor compaction at shallow, tidal sites where booms are grounded, and accumulation of woody debris that escapes from booms during storms have all had negative effects.

During the last two decades, major log handling improvements have reduced the impacts of log dumping.

During the last two decades, major log handling improvements have reduced the impacts of log dumping on coastal waters, foreshore habitats, and near-shore resources. Because most logs are now sorted at dryland sorts, the input of bark and woody debris into the near-shore environment has decreased considerably. After being sorted on land, logs are usually bundled before dumping into the water, moved to temporary storage by dozer boats, and subsequently transported on barges. Log bundling and the use of barges has greatly reduced log loss during water transport.

Dryland sorts, which have replaced water-sorting, require the following features:

- proximity to logging operations and road systems;

- sufficient size to accommodate the required number of bunks[105] and to either permit truck access and turning on the dump or allow trucks to cross the dump and turn around off-site;
- protection for adjacent booming grounds from storm waves, because waves greater than 1 m make operating dozer boats and holding booms together difficult; and
- sufficient water depth that bundles do not hit bottom and break when put into the water.

5.2.1 Standards for Log Handling and Water Transportation

Protection of the environment during log sorting, water storage, and water transport is currently addressed in diverse guidelines, policies, and legislation.

Little explicit attention is paid to non-commercial species.

The *British Columbia Coastal Fisheries/Forestry Guidelines* protects Marine Sensitive Zones[106] through guidelines dealing with helicopter and balloon systems, A-frame and handlogging systems, and streamside areas. The *Fisheries Act* contains measures to prevent damage to fish and fish habitat. Federal Department of Fisheries and Oceans (DFO) policies, such as the "Policy for the Management of Fish Habitat" and the "No Net Loss Policy," prescribe measures to protect habitat, and require mitigative or compensatory measures in cases where damage occurs (e.g., with log dump construction and operation). Little explicit attention is paid to non-commercial species.

The format for site assessments is not standardized.

Current regulations require that applications for any proposed development with potential impact on foreshore, intertidal, or subtidal zones be submitted to BC Lands and the Coast Guard. BC Lands, as the lead agency in this process, refers such applications for review and comment to interested agencies and groups such as the DFO, First Nations, and upland landowners. The format for site assessments is not standardized, although DFO does have a system of classifying habitats according to fisheries value and sensitivity (Canada. Department of Fisheries and Oceans 1994). DFO may accept a proposal outright, accept it with compensation and/or a compensation bond, or reject it, depending upon the assessed value of the site to fisheries. The effectiveness of compensation projects is generally not known because of inadequate follow-up evaluation (i.e., cursory observation but not detailed data collection). The Coast Guard reviews the application only in relation to the *Navigable Waters Act*.

No special regulations apply to booms; the Coast Guard's primary concern is with safety of larger vessels (e.g., log barges).

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[105]Bunks are cradle-like structures in which logs of various species and grades are accumulated until the desired log bundle size—usually about 50 m^3—is attained.

[106]Marine Sensitive Zones include herring spawning areas, shellfish beds, marsh areas, juvenile salmonid rearing areas and adult salmon holding areas (B.C. Ministry of Forests, B.C. Ministry of Environment, Lands and Parks *et al.* 1993:184).

Roadbuilding standards, to the extent that they apply to construction adjacent to log dumping sites, are collected in *Forest Road and Logging Trail Engineering Practices (Interim)* (1993).

The *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* (1994) require that aquatic (marine and freshwater) drop sites for helicopter and balloon logging be located beyond the littoral zone[107] (or beyond the 10 m depth contour). In addition "'A' frame and handlogging operations must not be conducted adjacent to or within marine-sensitive zones" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:112).

5.2.2 Findings Regarding Water Transportation

Comprehensive standards for log dump development, operation, or maintenance have not been compiled.

F5.10 Comprehensive standards for log dump development, operation, or maintenance have not been compiled.

F5.11 Bottom accumulation of bark and woody debris is the most significant physical effect of log handling. Other problems include runoff of suspended material and leachates from dryland sorts, the release of leachates from logs and bark, bottom shading, and some escape of deleterious substances such as fuels, oils and anti-fouling compounds. Where logs are sorted or bundles are moved by dozer boats, scouring by propeller-wash may also occur. Compaction of bottom substrates by the grounding of logs or booms is a problem at shallow log dump and storage sites.

F5.12 Biological impacts of log handling include:

- crushing of organisms where booms ground in estuaries;
- poisoning of benthic organisms by toxic leachates;
- reduction of both species richness and productivity due to habitat alteration; and
- disturbance to spawning herring which may lead to abandonment of spawning sites.

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[107] The littoral zone is, strictly speaking, the intertidal zone, and customarily, the zone between the upper limit of wave action (the back of the storm beach or cliff base), and the seaward limit of significant wave action on the sea bed (approximately the 10 m depth contour).

5.2.3 Recommendations Regarding Water Transportation

Water handling and transport standards must protect estuarine and marine environments, and their associated biota.

Water handling and transport standards must protect estuarine and marine environments, and their associated biota, by minimizing the impacts of log dumping, log sorting, booming, and transportation.

R5.8 Standards are required for dryland sort and log dump construction, operation and maintenance. Construct and operate dryland sorts to ensure that:

- the surface of the dryland sort slopes landward, rather than seaward; and
- surface runoff is intercepted by a ditch on the landward side of the dump. The ditch should direct runoff to a collecting basin from which solids are filtered and regularly removed.

R5.9 On all proposed log dump sites, undertake an ecological assessment that permits DFO to evaluate productivity and sensitivity of the system (including non-commercial species); a physical assessment to determine site exposure to waves and storms, anticipated wave velocities and direction, and near-shore terrain conditions; and an assessment of probable impacts (including noise) on heritage, scenic, wildlife, and recreational values.

R5.10 Minimize time logs are in the water, especially shallow water, by sorting on land and storing log bundles in deep water.

R5.11 Locate log dumps at sufficient distances from sensitive areas such as herring spawning sites, shellfish beds, estuaries, or eelgrass beds, to preclude physical disturbance or deposition of deleterious organic materials.

R5.12 Ensure log dump sites are deep enough to avoid problems with the propeller wash of dozer boats and grounding of booms or bundles.

R5.13 Restore sites that have been damaged by excessive accumulations of bark, woody material, or fine organic material.

6.0 Scenic, Recreational, and Tourism Values and Resources

The forests of Clayoquot Sound are important to people in several ways: for cultural, spiritual, and historical reasons; as a setting for current activities; and as a source of life-sustaining products and economic well-being.

The Panel has not considered all human values.

The Scientific Panel has been unable to do comprehensive work on systems intended to recognize and protect human values. First Nations' values are addressed in some detail in the Panel report, *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b). Economic and community values are briefly described in Section 2.3.2 of this report. The overall approach of the Scientific Panel is based on ensuring long-term economic and community benefits by recommending forest practices that sustain ecosystem integrity.

Its overall approach has been to ensure long-term economic and community benefits by recommending forest practices that sustain ecosystem integrity.

Two specific aspects of human values were included in the Panel's mandate and are addressed here. Scenic values and resources are addressed because of their importance in Clayoquot Sound to all recreation, tourist, and resident groups, and because of concern over the way past forest practices have affected scenic values. Recreational and tourism values and resources are addressed because they present significant economic opportunities that can be compatible with the forest practices recommended by the Panel.

Restriction to these values acknowledges the Panel's mandate, but ignores many values of the non-indigenous culture—especially those values that might be termed reverential or spiritual. There is a distinction between identifying *places* with intrinsic cultural value and identifying *types* of landscapes and landscape features that facilitate pleasurable, relaxing, or rejuvenating *experiences* (the particular place of the experience is not paramount). Respect for place develops with time and is naturally best developed within the indigenous culture, but not restricted to it (e.g., Leopold 1949; Tuan 1974).

While consistent with its mandate, the Panel's restriction to the values in this chapter bears three important limitations:

1 it is indirect in its consideration of reverential or spiritual values of the non-indigenous culture;

2 by focusing on types of activity (e.g., kayaking, hiking), it emphasizes landscape type instead of place (particular places are important to some); and

3 by restricting consideration to perceptions (e.g., scenic values) and experiences (recreational and tourism), planning is limited by current perceptions and opportunities.

These limitations do not reduce the significance of values addressed under the Panel's mandate.

6.1 Scenic Resources

6.1.1 Standards for Managing Scenic Resources

Past Standards and Practices

In many areas of the province, forest practices are conducted with limited regard for scenic values.

Managing forests for their scenic values has a short history in British Columbia. Scenic landscape management activity was minimal before 1981 when the *Forest Landscape Handbook* (B.C. Ministry of Forests 1981) was produced. That work was only a guideline. In the late 1980s, the B.C. Ministry of Forests was authorized to manage scenic values, but visual resource management was not mandatory. Only with the passing of the *Forest Practices Code of British Columbia Act* (July 1994) has visual landscape management become a requirement. In many areas of the province, forest practices are conducted with limited regard for scenic values.

The first approach to forest landscape management in North America was developed in the late 1960s in the United States (Litton 1968). Experts conducted an inventory and analysis of physical landscape features (such as form, line, colour, and texture) and assessed public sensitivity to the landscape by analyzing use. That method was refined in the early 1970s to include visual quality objectives,[108] ranging from preservation to maximum modification (Bacon and Twombly 1973). A derivation of that method of forest landscape management was adopted in B.C. in 1981 and is still in use (B.C. Ministry of Forests 1981).

In Clayoquot Sound, more recent cutblocks better conform to landscape design principles.

With the implementation of the provincial program for forest landscape management, significant efforts were made to conduct landscape inventories and analyses. Standards for that work have been continually refined. The landscape foresters also work with the forest industry on an ad hoc basis to incorporate landscape design principles into forest plans. The result has been a gradual increase in awareness about scenic values and sporadic improvements in cutblock design. In Clayoquot Sound, many of the harvested areas reflect past forest practices: cutblocks are very large, dominate the landscape, do not conform with the terrain, and have obtrusive features such as straight edges, rectilinear corners, and severe road scars. Some more recent cutblocks (e.g., the small cutblocks above Warn Bay at the north end of Fortune Channel) better conform to landscape design principles.

[108] See footnote 38.

Photo 6.1

Visual impressions strongly influence people's impressions of forest health and management effectiveness. Past practices have created negative impressions.

Existing Standards

The primary components of the visual forest landscape management system are the landscape inventory and analysis, which are usually conducted concurrently. They both involve fieldwork by a landscape expert, who travels along scenic corridors mapping visible landforms as landscape units, then applying the following four attributes to each landscape unit:[109]

- landscape sensitivity rating (LSR) – the visual importance based on biophysical characteristics, and viewing and viewer-related factors;
- visual absorption capability (VAC) – the ability of the landscape to absorb human changes without a reduction in visual qualities or integrity;
- existing visual condition (EVC) – the level of human alteration in the landscape; and
- recommended visual quality objective (VQO) – the limit of acceptable visual change in a landscape.

Landscape inventory requires interpretation and judgement.

The first three attributes constitute the landscape inventory in that they describe characteristics of the landscape. Determining the VQO is the landscape analysis phase of the process in which the inventory is analyzed and a VQO is recommended. Both LSR and VAC are rated high, medium, or low based on a combination of factors; both approaches require significant interpretation and judgement by the fieldworker. The scale for EVC and VQOs ranges from no alteration to a very high level of removal or alteration of the existing forest cover. The VQO is recommended by the landscape expert conducting the inventory. This proposed rating is subsequently considered with all other forest values, and the B.C. Ministry of Forests district manager applies an approved VQO.

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[109] Definitions are those used by the B.C. Ministry of Forests.

Recreation and public groups are sometimes consulted during landscape inventories to identify high-use areas and to determine public preferences for different landscapes. The B.C. Ministry of Forests *Recreation Manual* guidelines recommend public involvement throughout all phases of the forest landscape management process (B.C. Ministry of Forests 1991c:Chapter 11).

Photo 6.2

People move through and experience Clayoquot Sound in a variety of ways. Scenic resources management must consider a range of scales.

Forest landscape management techniques for inventory and analysis focus on mapping landscape units at a scale of 1:20 000 or 1:50 000. Sometimes, corridors are divided into much larger landscape management units (LMU), usually at 1:50 000, and each LMU is assigned a VQO based on use characteristics and the overall character and quality of the scenery. This subregional-level analysis is considered optional, and is not consistently conducted. No other requirements or methods for landscape inventory or analysis consider large areas.

Guidelines for incorporating visual considerations into detailed forest planning have developed significantly in recent years. Nelson Forest Region approved forest landscape management guidelines in 1992, which have been refined and expanded in the draft document *Visual Landscape Management Guidelines for Visually Sensitive Areas within Provincial Forests* (1993), applicable province-wide. Guidelines cover topics such as timber harvesting, roads, silvicultural practices, recreation management practices, and range management practices.

A trend in recent guidelines is to quantify the area that can be harvested under each VQO category.

A trend in recent guidelines is to quantify the area that can be harvested under each VQO category. Different guidelines specify that the percentage of a landscape unit to be harvested should be measured in plan view (i.e., on a map), in perspective (e.g., on a photograph), or either way. The *Visual Landscape Management Guidelines for Visually Sensitive Areas within Provincial Forests* state that these percentages are not meant to replace landscape design of harvest units and careful forest practices on a site-specific basis. However, they also state that the guidelines are meant to direct strategic planning and timber supply analysis at the subregional level for visually sensitive areas and to ensure that the percentage alteration within a landscape unit logged by clearcutting falls within the ranges shown (B.C. Ministry of Forests 1993g:14–15).

Because of the predominance of clearcutting in the past, most guidelines for landscape design relate to clearcutting only.

Because of the predominance of clearcutting in the past, most guidelines for landscape design relate to clearcutting only. The draft *Visual Landscape Management Guidelines for Visually Sensitive Areas within Provincial Forests* addresses partial cutting in addition to clearcutting.[110] A significant amount of field experience is required to establish firm visual guidelines for selection systems.

Cutblock design has extremely important effects on scenic values. The primary method to influence cutblock design is visual impact assessment of proposed cutblocks. If a proposed cutblock fails to meet the approved VQO, its design is modified until it conforms. Visual impact assessment has not been required in most forest areas in the past, but has been requested in specific situations by the B.C. Ministry of Forests regional landscape foresters or district ministry staff. The Port Alberni Forest District generated a *Visual Impact Assessment Handbook* in 1991 to provide guidance to forest companies. Standards are evolving towards more widely applied requirements for visual impact assessment.

Photo 6.3

Cutblocks can be designed to be less obtrusive, thereby minimizing the reduction of scenic values.

New approaches to scenic resource management have been occurring in Clayoquot Sound as part of the Scenic Corridors Planning Process.

New approaches to scenic resource management—some state-of-the-art— have been occurring in Clayoquot Sound as part of the Scenic Corridors Planning Process. Jointly administered by the B.C. Ministry of Forests and B.C. Ministry of Small Business, Tourism and Culture, the project involves development of a management plan for the scenic corridors identified in the *Clayoquot Sound Land Use Decision* (1993). Project participants include an Interagency Planning Team of regional, provincial, and federal government representatives with technical experts, and an advisory group made up of industry, local government, user groups, and the public. In January 1995, the group produced a draft report, *Clayoquot Sound Scenic Corridors Landscape Management Plan* (B.C. Ministry of Forests and B.C. Ministry of Small Business, Tourism and Culture 1995).

110 Partial cutting is an ill-defined term commonly encompassing both genuine silvicultural systems (e.g., selection cutting) and selective harvest (not a silvicultural system).

6.1.2 Findings Regarding Scenic Values[111]

General

Most existing forest plans do not adhere to landscape design principles.

F6.1 The integration of visual landscape values into forest planning and management has been sporadic due to two primary factors: it has not been a requirement, and few people have visual landscape planning skills. Integration of visual considerations has been best when landscape foresters have been involved with other resource experts and the public in the planning of controversial areas. Most existing forest plans do not adhere to landscape design principles.

With current knowledge and tools, a more objective and flexible system is possible.

F6.2 Existing standards have evolved from a system developed over 20 years ago in the United States, before computers were readily available to facilitate landscape analysis and when the understanding of visual resources was at an earlier stage of development. With current knowledge and tools, a more objective and flexible system is possible. Fieldworkers can collect standardized information, then use a computer to analyze the information in several alternative ways and to derive factors such as scenic quality, scenery preferred by specific user groups, or visual absorption capability. Computers are also extremely useful for visual impact assessment of proposed cutblocks. They can accurately plot proposed cutblock locations in perspective, and realistically simulate how cutblocks will look from different vantage points.

Forest practices documents are vague in their references to visual landscape management.

F6.3 Forest practices documents are vague in their references to visual landscape management. For example, *Clayoquot Sound Forest Practices Standards* (1993) state that a "Total Resource Plan will contain…a forest landscape management plan" (B.C. Ministry of Forests 1993a:2). However, a "landscape management plan" is never defined and is not used in visual landscape management documents. *Development Plan Guidelines for the Vancouver Forest Region* (1993) state that the Development Plan should include a landscape inventory and VQO, but provides no direction about what to do with that inventory (B.C. Ministry of Forests 1993d:3). The *Coast Planning Guidelines Vancouver Forest Region* (1992) state that integrated resource management planning should "incorporate identification of aesthetic resources," "net down the landbase addressing concerns such as landscape issues," and "use landscape management requirements to determine harvest pattern" (B.C. Ministry of Forests 1992a:3, 5). Specific methods for these processes are not provided.

F6.4 In the *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* (1994) and in the B.C. Ministry of Forests organizational structure, visual landscape management is a subset of

[111] The discussion of findings in this section is based primarily on standards and practices in place before the Clayoquot Sound Scenic Corridors Planning Process occurred. At the time of writing, the Scenic Corridors work has not been finished.

recreation planning. While the placement itself is not necessarily a problem, it is essential that those working on landscape management recognize the importance of scenery to First Nations, other residents, and tourists—not solely to recreationists.

The current visual landscape management system applies only to visually sensitive areas but these are not defined.

F6.5 The determination of areas subject to landscape inventory and analysis and visual landscape guidelines has been highly variable and inconsistent in the province. Selection of areas has been evolving and was not resolved at the time the *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* (1994) was published. The current visual landscape management system applies only to visually sensitive areas but these are not defined. Inventories in the past were conducted only from highways and primary water transportation corridors, whereas some visual landscape inventories are now conducted from logging roads and trails. The need to follow guidelines and conduct visual impact assessment has been at the discretion of the B.C. Ministry of Forests.

Inventory and Analysis

The current system of landscape inventory is subjective and inflexible.

F6.6 The current system of landscape inventory is subjective and inflexible. It is subjective because of the interpretation required. It is inflexible because only three values are provided: landscape sensitivity rating (LSR), visual absorption capability (VAC), and existing visual condition (EVC), of which two are interpreted.

LSR is intended to account for so many factors that it becomes a subjective rating, and therefore inconsistent. It is intended to include a measure of public perceptions, but often the recreational and environmental sectors provide different responses than the forestry sector; no mechanism exists for resolving such differences. VAC, also based on a combination of factors, is determined subjectively because assessing all of the factors consistently is difficult. Because the landscape inventory requires a significant level of field interpretation, its use is limited. With a more detailed and comprehensive inventory, it would be possible to understand the more basic elements of the scenery and to analyze the landscape from the perspectives of different user groups; this would make the inventory more flexible. Current standards for landscape inventory and analysis have not been updated substantially since computer technology became available and since understanding about how people perceive the landscape has increased.

VQOs have several limitations.

F6.7 Recent standards, such as those contained in the proposed Forest Practices Code, rely almost exclusively on visual quality objectives (VQOs) to manage scenic resources. This approach has several problems:

- The definitions of alteration in VQOs previously included only timber production and did not account sufficiently for other existing or potential uses, such as mining, aquaculture, or communities. Modest reference to other uses is included in the most current documents.
- Landscape analysis, which sets VQOs, is based solely on determining the maximum amount of logging that can occur, rather than an evaluation of the opportunities and constraints related to scenic resources (e.g., such as fit with topography and cutblock shape).
- The terminology used to define VQOs is not readily understandable to the public. It also could be easily confused with the Panel's proposed terminology for describing silvicultural systems (e.g., variable-retention silvicultural systems).

Planning

Currently, no plans are developed for scenic resources; Clayoquot Sound is an exception.

F6.8 Forest visual landscape management as currently practised falls short of actual planning for scenic resources. There are three important stages in planning: inventory, analysis, and plan development. The current system:

- includes inventory and analysis, but no plan for scenic resources; and
- involves little consideration of larger areas where the most important decisions are required.

The Clayoquot Sound Scenic Corridors Planning Process is an exception.

Generally, the application of VQOs to landscape management units more closely resembles a landscape prescription than a landscape plan. Planning for scenic resources should consider patterns of existing and potential use over large areas, overall characteristics of the scenery, public perceptions, and broader issues such as maintaining in a relatively unaltered form characteristic landscapes which may not be protected adequately through the Protected Areas Strategy. Specifying VQOs is only one part of planning for scenic values.

The Scenic Corridors Planning Process in Clayoquot Sound is the first initiative in B.C. to involve the public in planning for scenic values specifically.

F6.9 Although current guidelines state that there should be public input during all phases of forest landscape management, this has not occurred in practice. The primary exception is where agency and public interest committees are established for specific planning processes (e.g., Local Resource Use Plans). The Scenic Corridors Planning Process in Clayoquot Sound is the first initiative in British Columbia to involve the public in a process to address scenic values specifically. Otherwise, landscape work was conducted most often by experts using methods not conducive to public input. Information on inventory and analysis was sometimes presented at public open houses for tree farm licence (TFL) plans, but the public has difficulty understanding the information or providing input at that stage. Landscape design options have been shown to the public only in isolated situations at the discretion of the B.C. Ministry of Forests regional landscape foresters or staff in the forest districts.

F6.10 Landscape experts recommend VQOs for specific areas. These recommended scenic values are considered along with other forest values, and approved VQOs are established by the B.C. Ministry of Forests district manager. In the past, the approved VQOs have inconsistently reflected the recommended VQOs, and the process for integrating the various concerns (e.g., scenery, timber, wildlife) has not been well established.

Visual considerations are incorporated into timber supply analysis by determining the area that can be "denuded."

F6.11 The document *Procedures for Factoring Recreation Resources into Timber Supply Analysis* (December 1993) represents a first step towards incorporating visual landscape considerations into forest planning but has some drawbacks. The procedures are a highly quantified approach to determining the amount of area which can be "denuded" within each landscape unit. While the procedures enable detailed information to be readily passed on to the person developing forest plans, they have been developed within a timber-oriented approach to forest management, which is incompatible with the ecosystem-based approach recommended by the Panel. Furthermore, there are limits to the utility of quantification with respect to scenic values.

F6.12 The trend towards quantifying VQOs by stating a percentage range of forest cover that can be removed (e.g., 6–15%) fits well with the current system of forestry management that establishes an allowable annual cut (AAC) before detailed planning occurs. There are, however, several problems with quantification of VQOs:

- There is confusion over whether measurements should be taken in plan or perspective. Some forest companies can measure accurately only in plan, and these measurements do not effectively indicate the visual impact of proposed cutblocks.

The percentage of a landscape unit from which timber is removed depends on how the landscape unit is defined.

- The percentage of a landscape unit that is actually altered (i.e., timber is removed) depends on how the landscape unit is defined and measured; but the delineation and measurement of landscape units can be highly variable. Simply specifying a percentage range could lead to large landscape units being identified during inventory which, while providing the forester with greater flexibility, would mean less detailed inventory—and potentially more timber removed. For example, a 10 ha cutblock would be a small percentage in a landscape unit defined as an entire slope adjacent to a fjord, but a much larger percentage if the landscape unit was smaller and delineated by two major gullies. Methods for measurement in perspective during visual impact assessment have not resolved issues such as the effects of foreground screening on measurements or whether trees exposed behind a cut area should be measured. These issues can significantly affect the percentage of a landscape unit occupied by a cutblock.

- Unless the range of allowable alteration or timber removal is very large within a VQO, some cutblocks will necessarily fall outside the specified range. This challenges the utility of numerically based VQOs.

- Quantified VQOs (i.e., amount of timber removed) detract from design considerations such as the way the cutblock fits within the landscape.

- A further effect of establishing quantities for VQOs is to encourage harvest at the upper level of a specified range, ignoring important local variations.

F6.13 The recent development of the draft *Visual Landscape Management Guidelines for Visually Sensitive Areas within Provincial Forests* (1993) is a positive step. Unfortunately, these guidelines do not define "visually sensitive areas," and include many site-specific guidelines for landscape management that are difficult to interpret and enforce. They at times conflict with other guidelines; for example, draft biodiversity guidelines recommend leaving slash in place, and visual landscape guidelines recommend removing slash. Little effort has been made to integrate the concerns or guidelines of various disciplines. Whereas past guidelines considered clearcutting as the only silvicultural system, recent guidelines consider alternative silvicultural systems.

The Clayoquot Sound Scenic Corridors Planning Process has addressed many important concerns.

F6.14 The Clayoquot Sound Scenic Corridors Planning Process has addressed many of the concerns noted in this section. The Panel has not critiqued that work because it is being refined as this report is being produced.

6.1.3 Recommendations Regarding Scenic Values

To effectively incorporate human values into forest practices will require different ways of planning and managing for scenic values, including new ways of involving people in the process. The Panel proposes a new approach to visual landscape management with the following objectives:

- to be as objective as possible, given that there will always be some level of interpretation in documenting scenic values;
- to undertake planning for scenic resources over large areas;
- to provide opportunities for meaningful public involvement; and
- to be integrated into the forest planning process.

Many of the Panel's suggestions have already been implemented in the Clayoquot Sound Scenic Corridors Planning Process.

Many of the suggestions for inventory and analysis of scenic resources have already been implemented in the Clayoquot Sound Scenic Corridors Planning Process.[112] This has occurred partly through informal consultation with members of the Scientific Panel.

R6.1 Involve the provincial government, First Nations, regional and local governments, recreation and tourism groups, industry, and other public interest groups in the inventory, analysis, and planning of scenic resources. Provide opportunities for meaningful involvement by the public at large.

R6.2 Develop an inventory system for scenic resources with the following characteristics (see Appendix III for more detail):

- Map scenic resources for all of Clayoquot Sound at a scale of 1:250 000 which considers overall landscape patterns and the role of the landscape in relation to existing and potential use.
- Develop a new inventory system for visual landscape units[113] which would be used during subregional and watershed planning. During this inventory, divide the study area into landscape units based on similarities in landscape characteristics (e.g., physiography and level of alteration), the degree and type of human activity, and viewer-related factors (see Appendix III).[114] For each landscape unit, describe the landscape characteristics, including the degree of alteration or development and major land and water uses.

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[112]See, for example: Juan de Fuca Environmental Consultants *et al.* (1994); Juan de Fuca Environmental Consultants, and Viewpoint Recreation and Landscape Consulting (1994); and B.C. Ministry of Forests, and B.C. Ministry of Small Business, Tourism and Culture (1995).

[113]Landscape unit is the term used by the B.C. Ministry of Forests. This departs from the Panel's use of the term "working unit" throughout this document.

[114]This type of inventory, already conducted by the Scenic Corridors Planning Process for Clayoquot Sound, is suitable for the subregional and watershed levels of planning (see Chapter 7).

Develop a new scale to describe visual quality objectives based on less technical terminology.

- Develop a new scale to describe visual quality objectives which: describes alteration by less technical terminology, is easier for the public to understand, is unrelated to silvicultural system terminology, and accounts for uses other than forestry. The following terms could be used: unaltered/undeveloped, natural-appearing, minimal alteration/development, moderate alteration/development, highly altered/developed, intensively altered/developed.

- Clearly summarize the landscape inventory information on maps (e.g., landscape characteristics, degree of alteration/development) so that participants in the planning process can understand and provide input to the inventory.

R6.3 Use the information from the landscape inventory, existing and potential use patterns, and public preferences in the area to analyze scenic resources. Determine the patterns in the landscape, levels of scenic quality, and opportunities and constraints for use related to future scenic resources. Conduct this analysis at the subregional and watershed levels. Computer modelling is an effective way to analyze the landscape inventory information. Involve the planning group in the analysis.

Develop a long-term management plan for scenic resources.

R6.4 Based on the analysis in R6.3, develop a long-term management plan (e.g., 100 years with review every five years) for scenic resources. This plan should identify visual landscape management units for all of Clayoquot Sound. For each management unit, include:

- a description of the essential characteristics of the scenery;

- existing and potential resource values and human uses;

- the relative value of scenic resources in the unit; and

- visual landscape management objectives, including the desired character of the area, the proposed level of alteration or development, needs and methods of rehabilitation, acceptable land and water uses, and any specific measures that may be required to protect scenic values.

Quantification of alteration should be avoided. Examples are a better way of showing intent. The plan should be developed in consultation with the planning group identified in R6.1.

R6.5 Integrate the recommendations of the visual landscape management plan into all other forest plans during subregional-level, watershed-level, and site-level planning (see Chapter 7). Where visual concerns must be reconciled with those of other resource values, do so in a collaborative manner with all disciplines represented, recognizing that the primary goal is to maintain ecosystem integrity.[115]

Require visual impact assessment on all of the most important scenic areas.

R6.6 Use landscape design principles in the development of detailed silvicultural plans and development plans for other uses. Having someone with visual landscape skills involved in the initial layout of cutting units facilitates the design process. Require visual impact assessment and subsequent refinement of proposed alterations to meet visual landscape objectives on all of the most important scenic areas. Involve the public in the review of proposed harvest areas, providing illustrations that can be easily understood.[116]

R6.7 Continue the development of visual landscape guidelines in consultation with interdisciplinary teams, using monitoring and research results to refine the guidelines so that all resource values are appropriately addressed.

6.2 Recreational and Tourism Resources

Planning for recreation and tourism in Clayoquot Sound must be integrated into forest planning and management.

The Scientific Panel recognizes the importance of recreation and tourism in Clayoquot Sound, and believes that planning for them must be integrated into forest planning and management.

6.2.1 Standards for Recreation and Tourism

The B.C. Ministry of Forests has been involved in recreation planning for Crown lands outside parks since 1971. In 1978, the *Ministry of Forests Act* and the *Forest Act* established recreation as one of the resource mandates of the ministry. Before that, planning for forest recreation involved the development of recreation inventories as part of the Canada Land Inventory initiative in the late 1960s. This work was conducted primarily from aerial photographs at a scale of 1:50 000, and resulted in highly interpreted maps that estimated capability for specific recreation activities.

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[115]In its deliberations about appropriate forestry practices in the General Integrated Management Area, the Panel invoked constraints in the order: safety, ecosystem integrity, operational effectiveness, and visual appearance.

[116]For example, using three-dimensional techniques such as computer simulations.

The current system for recreation inventory was developed in the early 1980s.

In the early 1980s, the current system for recreation inventory was developed (B.C. Ministry of Forests 1990). It involves identifying features that can support recreation (including existing and potential activities); evaluating the significance of an area and level of management needs; and mapping the existing recreation opportunity spectrum (ROS), which classifies areas ranging from primitive to urban.[117] Recreation inventory usually involves fieldwork and contacts with user groups; these latter activities have increased in recent inventory efforts.

The B.C. Ministry of Forests Recreation Program has emphasized preparing recreation inventories. It has protected numerous sites for recreation, although in some cases the values of those sites have been compromised by adjacent activities. Not all sites have been protected; at some sites values have been reduced because of nearby resource uses such as forestry and aquaculture. Effects of high levels of alteration (e.g., clearcutting) on recreation in adjacent areas are difficult to assess. There is, however, some indication that recreational use patterns are negatively affected by past and present logging because recreational users do not generally spend time in areas that are highly altered, especially along the coast where roads are not required for access (ARA Consulting Group 1992).

Photo 6.4

The B.C. MInistry of Forests has been involved in recreation planning outside parks since 1971.

The B.C. Ministry of Small Business, Tourism and Culture was given the responsibility of planning for tourism resources in 1990. Because integrated resource and land-use planning have been occurring on a regional basis, the ministry decided to inventory and map tourism resources at a scale of 1:250 000. These inventories consist of numerous layers of information representing all

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117 The recreation opportunity spectrum (ROS) is a classification of areas based on remoteness, size, and evidence of humans. The classes are primitive, semi-primitive non-motorized, semi-primitive motorized, roaded resource, rural, and urban.

resources that are important for tourism, including physiography, scenery, fish, and wildlife. Because the information is not interpreted, it can be used for many types of analysis related to tourism. The level of detail and use of the information, however, are limited by the scale. The primary planning for tourism has occurred through integrated resource and land-use planning processes such as the Commission on Resources and Environment (C.O.R.E.).

6.2.2 Findings Regarding Recreational and Tourism Resources

The following are the primary areas where existing standards and practices have been lacking and where future efforts are required to ensure that recreational and tourism resources and opportunities are adequately protected and sustained.

Overlapping Jurisdictions

Inefficiencies have resulted from separate ministries being responsible for recreation and tourism.

F6.15 The B.C. Ministry of Forests has responsibility for recreation, whereas the B.C. Ministry of Small Business, Tourism and Culture has the mandate to plan for tourism. More and more, the mandates of these two ministries are overlapping when addressing outdoor pursuits. The biggest difference at this time is that tourism is represented by industry groups and commercial operators, while recreational interests are represented by outdoor recreation groups such as kayaking, canoeing, or mountaineering associations. The separate programs for recreation and tourism planning have created inefficiencies.

Inventory, Analysis, and Planning

Recreation inventory methods have focused primarily on site-specific resources.

F6.16 Recreation inventory methods have focused primarily on site-specific resources with only informal and inconsistent consideration of overall patterns of recreation experiences which may extend over large areas. For example, in Clayoquot Sound, several areas offer potential for multi-day kayak and sailboat trips. Consideration of these opportunities requires planning for the staging area, all routes travelled, and the overnight anchorages or campsites.

F6.17 Recreation analysis focuses primarily on determining the significance of recreational resources and assigning each recreational resource to a management class. No indication is provided on how to manage important resources. The recreation opportunity spectrum (ROS) (see Section 6.2.1), which could be used as a management tool, is currently used as an inventory tool only (designation of management objectives for wilderness areas are an exception).

The recreation program includes inventory and analysis of recreational resources, but no development of a plan.

F6.18 The recreation program includes inventory and analysis of recreational resources, but no development of a plan for those resources. Therefore, topics such as the following are not considered: planning for a range of recreational and tourism opportunities, from wilderness-based expeditions to high-end excursions that are sensitive to the area's natural resources; or analysis of future opportunities that might include new routes and/or rehabilitation of logged areas. Such planning is difficult without involving recreation and tourism groups.

F6.19 Recreation experts conduct recreation inventory and analysis, usually with input from user groups. Inventory and analysis mapping is then completed in a highly technical way. Opportunity for meaningful public or tourism operator involvement is limited once documents have been drafted. Completion of the analysis by experts and the lack of public review can pose problems in consistency especially because the analysis of recreational significance is subjective.

F6.20 Recreation inventory and analysis have been inconsistent in their consideration of tourism needs. Recently, tourism operators have been included in contact lists for recreation inventory projects, but their involvement is limited.

F6.21 Forest planning and management, as currently practised, are inconsistent in their incorporation of recreational values into decision-making. This inconsistency derives from the lack of recreation plans or measures required to protect recreational resources. Recreation experts have usually been involved in forest planning on an ad hoc basis. More recently, integrated resource planning processes—such as Land and Resource Management Planning (LRMP) and Local Resource Use Planning (LRUP)—have included recreation as one of the resources represented on study teams.

Tourism resource inventories are extremely useful tools for tourism planning at a regional scale.

F6.22 Tourism resource inventories are extremely useful tools for tourism planning at a regional scale. Similar inventories may be required at finer scales for more detailed planning.

Current Standards

F6.23 Many forest practice documents make vague references to incorporating recreational concerns or make recommendations that would be difficult to fulfil with available information. For example, the *Clayoquot Sound Forest Practices Standards* states that a "Total Resource Plan will contain…location of protected areas and deferred areas and linkages needed to maintain…recreational values" (B.C. Ministry of Forests 1993a:2). Because recreation plans do not exist, the information needed to meet that requirement is available only through direct contact with a recreation officer. That contact may or may not occur. *Development Plan Guidelines for the Vancouver Forest Region* state that the Development Plan should include a recreation inventory, but provide no direction about what to do with that inventory (B.C. Ministry of Forests 1993d:3).

F6.24 At the analysis level, the document *An Interim Guide for Completing a Recreation Analysis Report in the Vancouver Forest Region* (1994) addresses many of the concerns and existing drawbacks noted in F6.17 through F6.20, and F6.23. The recommended procedure in that guide needs to be tested, refined, and monitored.

F6.25 To address the need to incorporate recreational considerations into forest planning (e.g., F6.8), the document *Procedures for Factoring Recreation Resources into Timber Supply Analysis* was prepared in December 1993. This document incorporates recreational considerations within the Environmentally Sensitive Area (ESA) system.[118] Some observations are:

The appropriateness of using the ESA system for incorporating recreational values must be evaluated.

- The appropriateness of using the ESA system for incorporating recreational values must be evaluated over time. ESAs are used to protect specific values (e.g., soils, wildlife, recreation) but this information is formally used only to "net down" the timber supply and does not relate to future use of areas. Areas identified as ESAs must be specified within an appropriate planning process.
- The recreation inventory, and especially the recreation capability information, may not be well adapted to the ESA system because they were not developed for this use.

6.2.3 Recommendations Regarding Recreational and Tourism Values

Integrate planning for recreational and tourism resources.

R6.8 Integrate planning for recreational and tourism resources. Because of their strong interrelationships, plan recreation and tourism in concert with planning for scenic resources.

R6.9 Ensure that the First Nations, provincial, regional, and local governments, and recreation and tourism groups are the principals involved in the inventory, analysis, and planning of tourism and recreational resources. Create opportunities for meaningful involvement by other public and industry groups.

[118] See footnote 53. Environmentally sensitive areas include potentially fragile, unstable soils that may deteriorate unacceptably after forest harvesting, and areas of high value non-timber resources such as fisheries and wildlife, including rare and endangered species, water, and recreation.

Photo 6.5

Recreation planning must involve government, First Nations, and recreation and tourism groups.

Display inventory information in a form easy for the public to understand.

R6.10 Ensure that recreation inventories are conducted at subregional scales (e.g., 1:250 000) and watershed scales (e.g., 1:50 000 or 1:20 000). Display inventory information in a form that is easy for the public to understand.

R6.11 Analyze recreational and tourism opportunities, and develop plans for recreation and tourism at the subregional, watershed, and site levels (Chapter 7). At the subregional level, these plans should include recreation opportunity spectrum (ROS), scenic, and other management objectives for all areas, including identification of acceptable activities and uses. At the watershed level, plans should include potential uses and facilities for specific sites, and management objectives for protecting the resources at those sites. Management objectives should include the level of protection required, from complete protection to protection of key features. At the site level, plans should ensure that key characteristics of the site are retained and that alteration or development is sensitive to the value of the resources to the public.

R6.12 Ensure that forest planning includes maintaining the recreational and tourism capability of resources.

7.0 Planning for Sustainable Ecosystem Management In Clayoquot Sound

Attaining the objectives of ecosystem management requires a new approach to planning.

The leading principle of the Scientific Panel is that an ecosystem-based approach be used to manage the forest resources of Clayoquot Sound. To achieve the objective of sustainable ecosystem management, the Panel recommends a new approach to forest management activities. According to the primary themes of the Panel's second report (Scientific Panel 1994a), the approach seeks to:

- maintain watershed integrity
  - maintain the stability and productivity of forest soils;
  - maintain waterflows and critical elements of water quality within the range of natural variability and within natural waterways;
- maintain biological diversity
  - create managed forests that retain near-natural levels of biological diversity, structural diversity, and ecological function;
  - maintain viable populations of all indigenous species;
  - sustain the species, populations, and the processes associated with late-successional forest stands and structures;
  - maintain the quality and productivity of aquatic environments;
- maintain cultural values
  - protect areas and sites significant to First Nations people;
- maintain scenic, recreational, and tourism values
  - protect areas of significant scenic, recreational, and tourism values; and
- be sustainable
  - provide for a sustainable flow of products from the managed forests of Clayoquot Sound.

Attaining these objectives requires a new approach to planning. Effective ecosystem management requires more than a commitment to the principles and recommendations found elsewhere in this report. Even with a thorough understanding of practices to maintain ecosystem integrity, those practices carried out in isolation from prior, concurrent, or future activities will not provide effective management. Planning at a variety of spatial and temporal scales is critical at all stages of forest ecosystem management.

The planning framework is necessary for Panel recommendations to achieve their intended effect.

The Scientific Panel recommends a new, comprehensive planning framework within which the proposed operational forest practices are to be applied. Without this framework, many of the Panel's recommendations would be out of context, would not achieve their intended effect, and in some cases could be applied in an ecologically inappropriate way. Planning must be supported by appropriate inventory, analysis, and monitoring. The planning framework is outlined in this chapter (Figure 7.1).

7.1 Current Approach to Planning

"Non-timber" values are considered to the extent they constrain the maximum utilization of the timber resource.

The Panel reviewed the current approaches to forest planning and existing planning standards in its second report (Scientific Panel 1994a:56–57). At present, forest planning at management unit and operational levels is initiated largely by forest companies holding licences to cut timber. Existing standards for preparing and submitting these plans, such as the *Development Plan Guidelines for the Vancouver Forest Region*, require that the plan consider the harvest of all operable timber, subject to the constraints imposed by principles of integrated resource management. The Panel has described this approach to planning as a "constrained maximization approach"—"non-timber" values are considered only to the extent that they constrain the maximum utilization of the timber resource.

Information on so-called non-timber values, such as aquatic, soil, and cultural resources, forms the basis for determining the level of constraint on the timber resource. This information is often inadequate, yet there are few requirements to collect better information. Assessment of cumulative effects of forest management and the integration of planning on a regional basis are hampered because administrative boundaries (e.g., forest land tenures), rather than ecological or physiographic boundaries, usually delimit planning units. Time scales for planning are based on an operational time frame (usually five years), whereas the time of a timber crop rotation falls between 60 and 100 years.

Once plans are complete or nearly complete, they are submitted to government agencies for approval through the "referral process." Interested parties other than the forest company and government agencies usually become involved at this stage. Through advertisements, the public is invited to review plans that have been submitted. Unfortunately, the process has proceeded so far by that point that there is often a high degree of reluctance to change plans.

The Panel recognizes local initiatives to change the current approach to planning. The Tofino Creek Watershed planning process, which included interested parties at an earlier stage of plan development, was based on a physiographic (watershed) unit, and collected baseline information beyond that normally acquired. The referral process in Clayoquot Sound also now involves an Interagency Review Team, which includes representatives from three government ministries. The team reviews plans collectively, rather than the single lead-agency approach used previously. The Central Region Board, through the *Interim Measures Agreement*, is also responsible for reviewing planning initiatives. Relatively more information about non-timber values is collected now than in the past.

A constrained maximization approach makes timber values paramount.

Despite these positive developments, the general approach to forest planning is still characterized by five elements:

- a constrained maximization approach which makes timber values paramount;
- the use of available (often inadequate) information about non-timber values such as environmental and cultural resources;
- the use of administrative rather than ecological boundaries for planning;
- a referral process in which most planning is completed before interested third parties are consulted; and
- lack of adequate monitoring as an integral part of the planning process.

Planning based on the principles of ecosystem management outlined in the Panel's second report (Scientific Panel 1994a:14–17) will require major changes in these five elements of planning.

7.2 New Planning Framework

7.2.1 Planning Principles

The Panel's first report (Scientific Panel 1994b:8–9) included several guiding principles for ecosystem management. The following are proposed principles for planning in Clayoquot Sound, with references to the original guiding principles noted in parentheses:

The primary planning objective is to sustain the productivity and natural diversity of the Clayoquot Sound region.

R7.1 Adopt an ecosystem approach to planning, in which the primary planning objective is to sustain the productivity and natural diversity of the Clayoquot Sound region. The flow of forest products must be determined in a manner consistent with objectives for ecosystem sustainability. This entails abandoning the specification of AAC as an input to local planning (general principle #1; guiding principle #7).

Use the watershed as the basic unit for planning and management.

R7.2 Adopt physiographic or ecological land units, rather than administrative units, as the basis for planning. Use the watershed as the basic unit for planning and management, recognizing that more than one watershed may be required to plan for values such as biodiversity, scenery, and cultural features (guiding principle #6).

R7.3 Use practices that represent the best application of scientific and traditional knowledge and local experience in the Clayoquot region (guiding principle #12). To accomplish this, collect appropriate baseline information about the full range of biophysical and cultural forest resources and values, and use this information and knowledge to assess ecological responses to change.

Engage local people in all phases of planning.

R7.4 Engage the Nuu-Chah-Nulth and other local people in all phases of planning and managing the land, freshwater, and marine resources of Clayoquot Sound (guiding principle #14).

R7.5 Develop plans at subregional, watershed, and site levels, and establish internal consistency among these plans, so that plans developed for smaller areas and shorter time periods are consistent with plans for larger areas and longer time periods (see Figure 7.2).

R7.6 Ensure that plans are consistent with land-use objectives for adjacent Protected Areas and special management zones.

R7.7 Base planning on a long-term perspective, at least in the order of 100 years when considering large areas, and 10 years for operational planning of smaller areas. These time frames are required to incorporate the cycles of many natural processes, and to ensure that operational plans address post-harvest management.

R7.8 Inventory, analyze, and plan for a full range of forest resources, forest uses, and forest management activities. Undertake new inventory as needed at an early stage of planning, prior to analysis.

Conduct monitoring to understand the effects of plans and to guide future adjustments.

R7.9 Monitor the effects of plans and check against management objectives to facilitate adjustments to better achieve intended goals; that is, employ adaptive management procedures.

R7.10 Recognize that the rate (percentage of area cut per unit time) and geographical distribution of timber harvesting are more important determinants than is the volume removed when wood harvest is planned (guiding principle #8). *After* analysis of resources and development of area-based plans, determine the anticipated annual volumes of timber to be cut for watershed-level planning units.

Planning is area-based rather than volume-based.

Area-based harvest levels functionally replace the AAC.

This last principle is fundamental. The planning process recommended by the Panel results in calculation of the *area* in the watershed available for commodity production, specifies a rate at which the watershed can be harvested (percentage of area per year), and identifies the locations where harvesting may occur. Thus, planning is *area-based* rather than *volume-based.* The timber volume available each year from a watershed planning unit is determined by the outcome of the planning process and depends on the characteristics of the area available for harvesting. These harvest levels functionally replace the AAC in defining expectations for harvestable wood volume from planning areas.

The Panel's recommendations for area-based planning must be reconciled with existing legislation that requires setting an AAC as an input that drives much of the forest planning process. Related legislation that stipulates penalties for licensees if a pre-set AAC is not within specified limits must also be reconciled with this new approach.

7.2.2 Participation in Planning

The principles of ecosystem management proposed by the Scientific Panel in its previous reports and reiterated in Section 7.2.1 must guide the planning process. Central to this process is a protocol that respects participants and their values and concerns, and a commitment to combine traditional ecological knowledge and scientific knowledge to achieve ecosystem management.

Decisions based on ecosystem management principles should be the responsibility of those most closely affected by the decisions made.

Decisions based on ecosystem management principles should be the responsibility of those most closely affected by the decisions made. The Nuu-Chah-Nulth, the original owners and residents of Clayoquot Sound, must be major participants in planning and decision-making; they have long been the stewards of their lands, waters, and resources (Scientific Panel 1995b). Other principal participants must include the local non-aboriginal communities; the provincial government, industries, and businesses operating or having land tenures in the area; and public groups with interests (such as conservation or recreation) in the area.

Appoint a planning committee of highly motivated people who are knowledge-able about resources.

R7.11 Appoint a planning committee, which includes stakeholders and other interested parties and experts at all levels of planning, to coordinate the planning process in Clayoquot Sound. Committee members must be highly motivated, knowledgeable about resources, and willing to adopt the protocol described in R7.14.

R7.12 Open planning committee meetings to public observation and participation. Interested members of the public should be able to request time on meeting agendas for making presentations. All papers, reports, and documents used by the planning committee should be available for public review.

Several models for participation in planning are useful to consider.[119] The U.S. Forest Service is currently using one such model in the implementation of the President's Forest Plan.[120] In that process, and in similar approaches used in Washington State,[121] the representation and number of participants from each organization (government, government agencies, and other groups) is determined before the actual participants are selected. Individuals are then invited to apply for those positions, indicating why they should serve. Selection of the actual participants is based on their knowledge of local and regional

[119]Geisler *et al.* (1994) review approaches to citizen participation in natural resource management within the Pacific Northwest that are not discussed here.

[120]J. Vandenheydon to P. Schiess, letter, October 27, 1994.

[121]Reid and Ziemer (1994); P. Schiess, pers. comm., 1995.

issues; understanding of public land uses and activities; knowledge and understanding
of cultures involved; ability to communicate; willingness to work towards ecologically sound, mutually beneficial solutions to complex issues; respect and credibility in local communities; and commitment to attend meetings and undertake supportive work as needed. In this U.S. Forest Service model, the regional forester, following approval by the Secretary of Agriculture (the federal department responsible for the U.S. Forest Service), ultimately makes the decisions of representation (both by balance and selection).

Individuals are invited to apply to participate in planning, indicating why they should serve.

British Columbia's Commission on Resources and Environment (C.O.R.E.) provides another model in its consensus-based planning process involving stakeholders and other participants. Participants were considered to have equal authority in the planning process. Although disagreements among participants did not permit consensus to be achieved, the C.O.R.E. approach offers helpful ideas for forest planning processes including a less hierarchical, more inclusive decision-making procedure, and encouragement of sharing of concerns and ideas among participants (British Columbia Commission on Resources and Environment 1995).

Usually, the process of individuals presenting their perspectives and others trying to understand these views results in consensus.

Nuu-Chah-Nulth cultural traditions are also relevant in considering planning and decision-making principles for ecosystem management. First, the underlying principle for Nuu-Chah-Nulth decision-making is respect for all life and all individuals (Scientific Panel 1995b). Directly following from this principle is the recognition that everyone has a view, or perspective, and has a right to express this view. Others, because of their respect, are obliged to try to understand views that are presented, whether or not they agree with them. Usually, this process—of individuals presenting their perspectives and others trying to understand these views—results in consensus-based decisions. If a consensus is not forthcoming, a collective or majority decision is made, with full disclosure of the outcomes and of the conflicting views. Respect for the majority view by those in dissent allows them to accept the decision and to work productively within it.

Second, individuals inherited responsibility for stewardship of lands and resources through the institution of *h̲ah̲uulhi.* A young person inheriting a particular role in this system was trained and educated under the guidance of an older, experienced specialist and practitioner. On gaining the necessary experience, the younger individual made a commitment to be responsible for specific lands and resources. Decisions, however, were not made in isolation. Leaders, elders, and community members were consulted on an ongoing basis. As well, adaptive strategies were used. Observation and monitoring were continuous; observers reported to the individual responsible for a place or a resource, who developed and directed activities based on those observations. The Nuu-Chah-Nulth "apprenticeship" approach, characterized by experiential training and education, detailed long-term observation, ongoing consultation, and commitment to sustaining ecosystems and resources, illustrates elements important in developing effective planning processes.

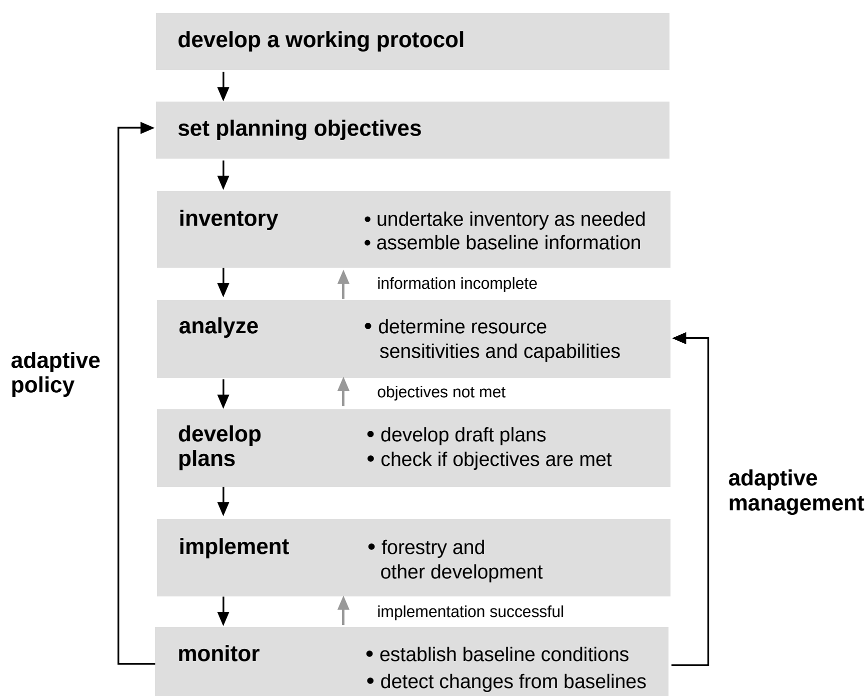
7.2.3 The Planning Process

The Panel recommends three levels of planning: subregional, watershed, and site (R7.5, and described in Section 7.3). Some planning committees (e.g., for the Ursus Creek Local Resource Use Plan) already exist. Groups planning at different levels must communicate.

At the site level, planning should be undertaken by the forest manager in accordance with higher level plans.

R7.13 Notify subregional- and watershed-level planning committees about site-level plans. These committees do not need to be involved in site-level plans, although they should monitor the implementation of these plans to ensure that they are in accordance with watershed and subregional plans (e.g., Tsitika Follow-up Committee adopted a similar role). At the site level, the forest manager involved (i.e., tenure holder, licensee, or government agency) should undertake planning in accordance with higher level plans, and with appropriate expert assistance.

Figure 7.1 The planning process.



R7.14 Planning should include the following steps (Figure 7.1):

- Develop and agree on a working protocol, based on mutual respect, that will guide the planning process. The protocol must clarify how the group will work together, how disputes will be settled, how decisions (consensus or other) will be reached, and how the process (including meeting and work schedules) will proceed.

The Scientific Panel incorporated the Nuu-Chah-Nulth decision-making process and found it to be extremely successful.[122] A high level of respect characterized Panel deliberations and facilitated progress and decision-making.

- Establish planning objectives in terms appropriate for each planning level. Identify the types of environmental and cultural resources that are to be protected.
- Based on these objectives, determine the methods and scope of the inventory required. (Section 7.3 describes the type of information to be collected at the three levels; Appendix III provides more detail.)
- Analyze data to determine status of resources, rates of biological processes, and consequent land and resource sensitivities and capabilities. Support planning as needed with technical analysis by experts from appropriate resource management agencies, forest companies, First Nations, and other parties. Identify areas to be reserved and areas where resource extraction or development may occur, including constraints that may limit the amount and type of activity.
- Develop plans for specific management activities based on input from members of the planning team and the public. Evaluate various plan options to determine which best meets planning objectives.

  Recently, the rapid production, comparison, and evaluation of alternative plans has become technologically feasible through computer-assisted, spatially explicit decision-support tools. These tools can consider large areas and long time periods, and display probable ecological, visual, and economic consequences of alternative plans (Bunnell and Kremsater 1994; Daust and Bunnell 1994). This has reduced barriers to detailed planning over large areas or long periods.
- Implement plans primarily at the site level (i.e., confirm boundaries of harvestable areas and specific locations of resource extraction and development activities). As noted in the Panel's second report (Scientific Panel 1994a:16), workers with education and training in ecosystem management must conduct this step; worker skills should be upgraded as required. Effects of implementation extend beyond the site. Monitoring should be instituted at site and watershed levels to track effects.
- Monitor ecosystem processes and components to assess the extent to which objectives are being met.

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[122] The approach is not exclusive to the Nuu-Chah-Nulth and differs little from that of Quakers (The Religious Society of Friends).

Although monitoring generally occurs at site and stream reach levels, it must be analyzed and interpreted at the watershed and subregional levels of the planning hierarchy. The arrows linking monitoring to the setting of objectives and analysis represent adaptive policy and adaptive management, respectively. As a result of experience gained in implementation and monitoring, the planning team may modify or refine the planning objectives or specific practices. More baseline inventory may be required to modify practices effectively. Changes in objectives or inventory, or information from monitoring, can lead to further analysis and planning. Because the planning process is cyclical, new knowledge will be effectively and continually incorporated.

7.2.4 Time Frames

Planning must consider both the natural time frame of organisms and ecosystems, and the organizational time frame of human activities.

Planning must consider both the natural time frame of organisms and ecosystems, and the organizational time frame of human activities and infrastructures. The natural time frame is determined by the life cycles of a myriad species, and the longer successional cycles of complex ecosystems such as forests. Upon these, are superimposed still longer-term changes in basic elements of the environment, notably climate, soil, and geology.

Human institutions determine the organizational time frame. These institutions are also subject to change in response to the accumulation of knowledge and evolution of social values.

For the forests of Clayoquot Sound, natural time frames include:

- a millennium—the time for an old-growth forest to reorganize substantially its entire mass and structure;
- several centuries—the time to establish old-growth characteristics from a regenerating forest;
- many decades—the time to detect definitive trends in most macrofauna or macroflora in response to other than catastrophic events and for an initially immature forest to reach maturity; and
- a few decades—the time frame for significant changes in response to climate and hydrological fluctuations on the coast.[123]

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[123] A pattern of alternating dry and wet periods of 20–30 years in length is present in runoff records in British Columbia (Barrett 1979, and subsequent work by M. Church (unpublished)). It is reasonable that hydrological records should reveal environmental sensitivity: runoff is the residual of precipitation and evaporation, the driving processes in hydroclimate. The pattern observed in British Columbia is widespread in western North America (Karl and Riebsame 1989) and reasons for it are beginning to emerge from climate modelling exercises (Latif and Barnett 1994).

Organizational time scales include:

- many decades—the rotation time for forests that are continuously exploited for fibre;[124]
- a few decades—the time for major changes in technology and social attitudes (i.e., approximately a human generation);
- 10 years—the time frame for the cycle of operational planning activity and post-harvest management on a harvest unit; and
- one year—the fiscal and operations year.

R7.15 Implement the following time frames for planning:

- 100 years for subregional-level planning with major revisions every 10 years, or more frequently if required;
- 100 years for watershed-level planning, showing projected activities in 10-year increments, with revisions every five years, or more frequently if required; and
- 10 years for site-level planning, starting five or more years ahead of the work, with revisions every year during active operations.

Resource planning should be conducted within a 100-year horizon, and operational planning should occur within a 10-year horizon. Planners and managers must realize, however, that factors operating on the longer time scales of the ecosystem may affect plans and activities within the 10- to 100-year scales. A very significant effect may be associated with the changing resiliency of animal populations in the face of clearing and fragmentation of formerly continuous forest habitat.[125]

[124]In the variable-retention silvicultural system recommended by the Panel, rotation length does not consistently have the same meaning as when applied to conventional clearcutting. Although specific areas may be subject to long-term even-aged management, both reserves and trees retained during logging may differ during subsequent harvest; that is, time between harvest at any one location can be highly variable (see Chapter 3).

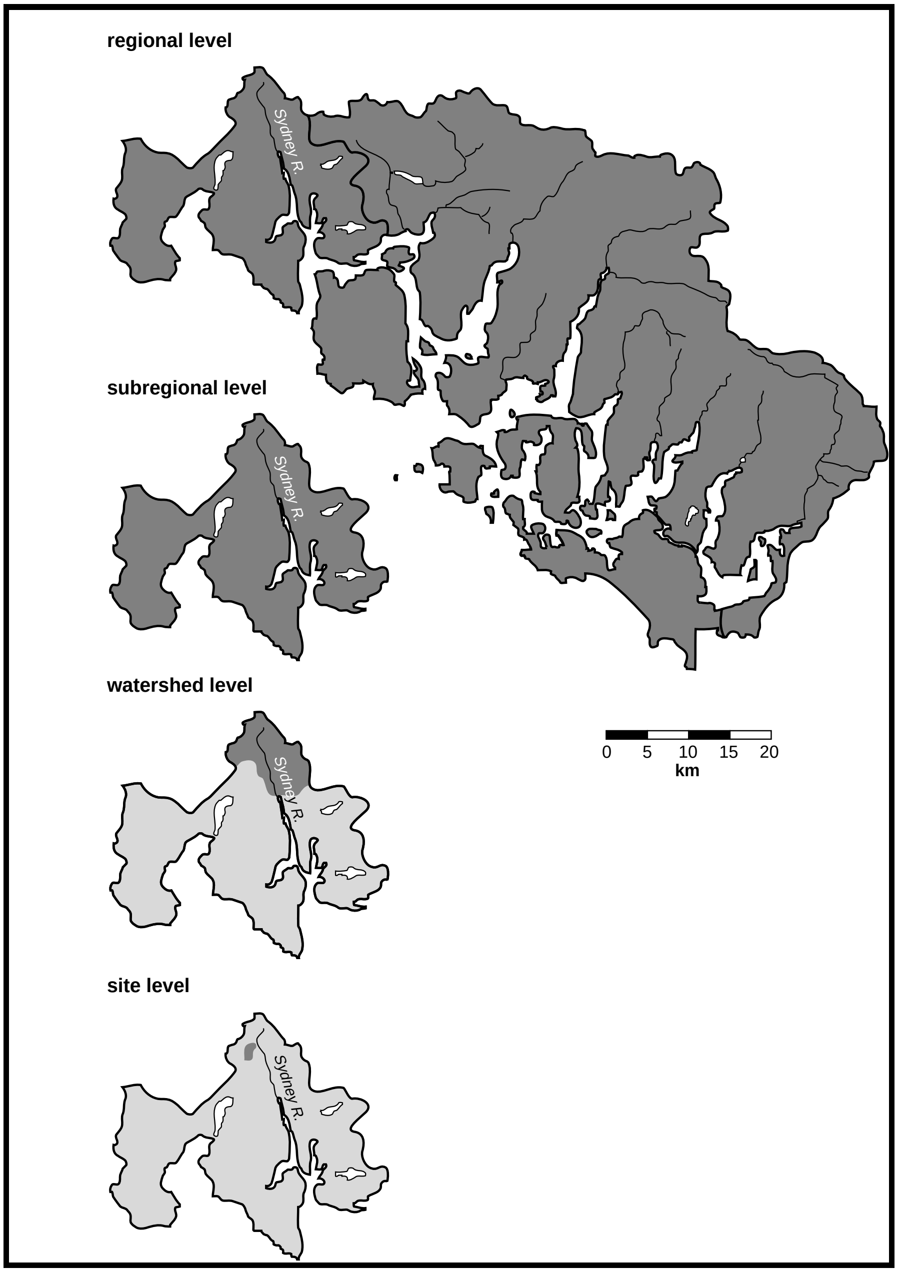
[125]See McNay and Bunnell (1994) for an example in which animals may require several generations to adapt to habitat changes because behavioural patterns are learned from the mother. The result is years to decades of potential population stress as old habits persist and animals continue using what has become suboptimal habitat.

7.3 The Levels of Planning

The hierarchical approach to planning is critical.

The Panel recommends three levels of planning: subregional, watershed, and site (Section 7.2.1, R7.5 and Figure 7.2). The hierarchical approach to planning is critical. Each level of planning defines the level beneath it; watershed-level planning, for example, determines harvestable areas in which site-level planning for cutting units can proceed. Conversely, planning and monitoring at lower levels provide details for interpretation and analysis at higher levels, thus refining and implementing objectives of higher level plans.

Figure 7.2 Recommended planning hierarchy for Clayoquot Sound.



The following sections describe the areas, objectives, and activities pertaining to these three planning levels.

7.3.1 Subregional-Level Planning

The C.O.R.E. process recognizes both subregional and regional planning efforts (British Columbia Commission on Resources and Environment 1994:53). Because both regional and subregional plans address broad land-use allocation and objectives, they are potentially interchangeable. Presently, two major distinctions exist between regional and subregional planning:

- the size of area considered (regional plans have been produced for significantly larger areas than most land and resource management planning areas or subregions); and
- who initiates and facilitates the process (in regional planning, C.O.R.E. has provided overall direction, while in subregional land and resource management planning, provincial ministries lead the process).

Recognizing these distinctions, the Panel has termed this upper level of planning "subregional." Within Clayoquot Sound, the Panel considers such subregional planning to apply to large areas consisting of aggregations of watersheds. Although it may be appropriate to consider all of Clayoquot Sound as a subregion, the challenge of gathering information or differentiating social structures suggest that smaller areas will serve better as the largest planning unit. For upper level planning, the Panel proposes three subregions (Figure 7.3):

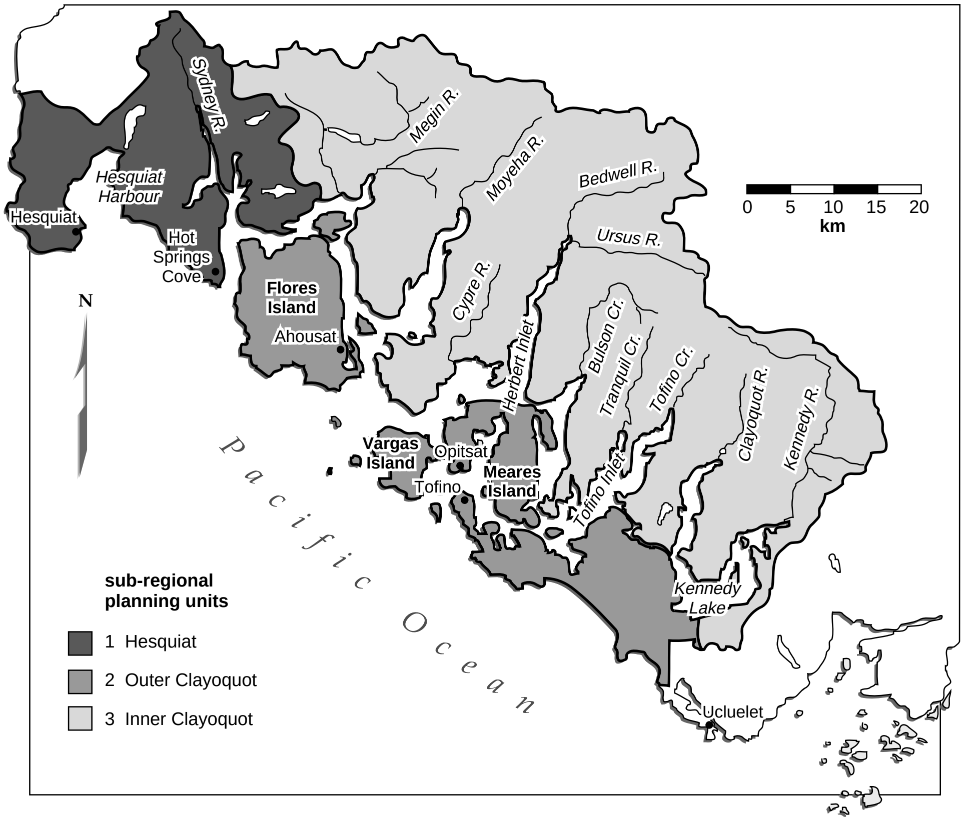
1 "Hesquiat" (Upper Sydney and Hesquiat);

2 "Outer Clayoquot" (Meares, Vargas, and Flores islands, and Esowista Peninsula); and

3 "Inner Clayoquot" (the remaining area of the Clayoquot Sound Decision Area).

These three subregions aggregate the 60 watershed units and subunits used in the Clayoquot Sound Sustainable Development Strategy (1994); the smallest (Hesquiat) is about 42 000 ha. Final definition of subregions is best done by a planning committee created for Clayoquot Sound, but the three proposed are physiographically, ecologically, and operationally appropriate and appear to accommodate the social diversity within Clayoquot Sound. Appropriate mapping scales for subregional-level planning range from 1:50 000 to 1:250 000.

Figure 7.3 Proposed subregions for planning in Clayoquot Sound.



Subregional-Level Planning Objectives

Subregional planning considers issues and resources that span large areas, and provides a context and guidance for watershed-level plans.

Subregional planning considers issues and resources that span large areas, provides a context and guidance for watershed-level plans, and addresses issues that cross watershed boundaries. Specific objectives of subregional-level planning are:

1 to identify watershed-level planning units;

2 to integrate reserves established during watershed-level planning with land-use zones (e.g., Protected Areas) to ensure the establishment of an adequate network of reserves;

3 to assess and plan for resources, such as scenery and recreation features and habitats for wide-ranging wildlife populations, that cannot be addressed adequately at only the watershed-level of planning;

4 to plan linkages (e.g., corridors for recreational uses, for biological diversity, and for road and water transportation) among watershed-level planning units;

5 to estimate the anticipated harvest level from area-based, watershed-level planning to develop estimates of harvestable timber volume over time; and

6 to coordinate and plan monitoring activities for subregional, watershed, and site levels (see Chapter 8).

Items 2–5 demonstrate that planning activities must operate iteratively between the different levels of planning. In particular, subregional objectives can be achieved only after some watershed-level planning is complete.

Subregional-Level Planning Activities

This section outlines important inventory, analysis, plan development, and monitoring activities in subregional planning. The section is structured within four primary themes identified in the Panel's second report (Scientific Panel 1994a): watershed integrity; biological diversity; cultural values; and scenic, recreational, and tourism values. Estimates of sustainable regional productivity are believed to be dependent on these themes and are discussed under monitoring (Section 8.4.3).

Basic information is required to support subregional planning.

Basic information required to support subregional planning includes watershed geography; descriptions of major ecosystems (e.g., variant boundaries, general successional patterns); summary information of the current forest condition (e.g., harvest and disease history); identification of First Nations' cultural areas; existing and proposed transportation corridors, recreation and scenic areas; important areas for wildlife including migration routes; and centres of human activity (see Appendix III for details).

Watershed Integrity

Information from watershed- and site-level studies will be useful at the subregional level.

Most planning to maintain watershed integrity occurs at the watershed and site levels. During subregional planning watershed-level planning units must be identified. Inventory and monitoring systems must be developed to ensure that the information obtained from watershed- and site-level studies will also produce useful summary information about the distribution and complementarity of reserves and land-use zones, and insight into whether these reserves and zones are fulfilling subregional objectives.

Biological Diversity

Practices that maintain watershed integrity and biological diversity will also maintain the integrity of terrestrial ecosystems.

The Panel believes that practices that maintain watershed integrity and biological diversity will also maintain the integrity of terrestrial ecosystems. Subregional concerns related to biological diversity focus on maintaining adequate habitats to allow migration of animals, and connectivity among plant and animal populations across watershed boundaries. The Panel has assumed that: standards recommended for ecosystem management, when applied at the watershed level, will provide sufficient habitat diversity and connectivity for dispersal of most organisms; and ensuring movement among watershed-level units is a sufficient objective for subregional-level planning for biological diversity. The following steps are to be followed during subregional planning to ensure the movement of organisms among watersheds:

1 Consult species lists and knowledgeable local people. Identify any species undertaking migrations or other movements across watershed boundaries.

2 Species-specific fieldwork may be required to identify the areas that particular species use for cross-watershed movements (e.g., for Roosevelt elk, fieldwork could include radio-tracking animals).

3 Describe the habitat characteristics required to allow movement of these species, and provide management prescriptions to maintain those characteristics in the movement "corridors." Habitat requirements for wide-ranging species are reasonably well documented and will usually be available from local biologists and the traditional knowledge of First Nations peoples.

4 Ensure that movement corridors are maintained over time by designating those areas on all maps used during planning.

Cultural Values

During subregional planning, Nuu-Chah-Nulth ***haḫuulhi*** areas should be mapped (by the Nuu-Chah-Nulth) and the role of ***haḫuulhi*** in planning identified. At this planning level, make decisions regarding appropriate levels of protection for culturally important areas[126] that extend across watershed boundaries. Identify such areas and initiate preliminary planning to outline watershed-level management actions to sustain values in these areas. Include participation of Nuu-Chah-Nulth Nations in all planning activities.

Scenic, Recreational, and Tourism Values

Planning to maintain scenic, recreational, and tourism values is to be conducted largely at the subregional level.

Planning to maintain scenic, recreational, and tourism values should be conducted largely at the subregional level. Supporting inventory must be conducted at two scales as described in Appendix III, with more general information mapped at 1:250 000 and more detailed information at 1:20 000. Based on analysis of the inventory, develop plans. These plans should include visual and recreation management objectives for all areas, including the desired character of the area, the proposed level of alteration or development, needs and methods of rehabilitation, acceptable land and water uses, and recreation opportunity spectrum (ROS) objectives.[127]

[126] Culturally important areas are discussed in detail in *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b).

[127] A draft plan for scenic resources in Clayoquot Sound has been prepared as part of the Scenic Corridors Planning Process. For kinds of recreation opportunity spectrum objectives see footnote 117.

Summary

During subregional planning, maps should be compiled that integrate all resource information, land-use zones (including Protected Areas), and locations of corridors for recreation and biological diversity. Transportation corridors for extraction activities that cross watershed boundaries, and locations of cultural, scenic, and recreational resource areas should also be identified.

Subregional maps should identify planning units for watershed-level planning, and subregional plans must guide watershed-level planning. Watershed-level information should be synthesized to produce a summary assessment of all regional resources.

7.3.2 Watershed-Level Planning

Watershed-level planning applies to a single watershed or a group of contiguous watersheds.

Watershed-level planning applies to a single watershed or a group of contiguous watersheds. The planning unit will usually include one or more primary watersheds.[128] In large primary watersheds (notably the Kennedy at greater than 50 000 ha), several watershed planning units would be formed comprising smaller secondary watersheds. The planning area is to be about 5 000–35 000 ha. Appropriate mapping scales for watershed-level planning range from 1:10 000 to 1:20 000.

Watershed-level planning is critical because it is within individual watersheds that the cumulative effects of land use impact ecosystems.

The watershed level is the key long-term planning level, because it is within individual watersheds constituting the watershed-level planning unit that the cumulative effects of all land-use activities create stress on ecosystems. Stress is created by changes in the flows and quality of water, and by changes in the access to water experienced by various animals. It also occurs through changes in the area and structure of various habitat units, and their potential fragmentation. To assure ecosystem integrity and protection of biological diversity, adequate reserves must be identified in the watershed planning unit.

Watershed-Level Planning Objectives

Objectives at the watershed-level focus on identifying reserves and harvestable areas within the watershed. Harvesting is permitted only outside reserve areas which are intended to maintain long-term ecosystem integrity in the watershed,

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[128]A primary watershed is one that drains directly to the sea. A secondary watershed is one in which the main stream drains to (is tributary to) a primary channel (main stream of a primary watershed); a tertiary watershed drains to a secondary channel, and so on. Readers should note that the "watershed-level" of planning encompasses a number of watersheds *sensu stricto* or "in the strict sense." This is inevitable because of the hierarchical nature of watersheds, whereby secondary and tertiary (tributary) watersheds are nested inside primary ones, and also because some primary watersheds are small. Analysis of individual watersheds occurs within the watershed-level planning units. The smallest watersheds for which the Panel makes any explicit recommendations are 200 ha (about 1% of the area of a watershed planning unit).

to protect First Nations' culturally important areas, and to protect recreational and scenic values.

The watershed level is the appropriate level at which to analyze and interpret information collected at the site level but pertinent to monitoring most effects of management actions on the watershed (see Chapter 8).

The primary objectives of watershed-level planning are:

Planning focuses on identifying reserves and harvestable areas.

Develop, within harvestable areas, management plans which respect the sensitivities of resources.

1. to identify and describe the environmental resources; natural processes; and cultural, scenic and recreational values in the planning unit;
2. to map and designate as "reserves" specific areas within the watershed that:
    - contribute significantly to maintaining watershed integrity and habitats of aquatic and terrestrial organisms. These areas include hydroriparian ecosystems;[129] unstable terrain; habitats of threatened, vulnerable, or rare species of plants and animals; and areas of other important forest habitats (e.g., forest-interior habitat and late successional forests) sufficient to ensure continuation of those ecosystems;
    - are of special significance for First Nations peoples; and
    - have high recreational or scenic significance;
3. to map and designate specific areas (termed "harvestable areas") within the watershed where forest harvesting or other resource uses will not compromise the long-term integrity of the forest ecosystem, its use by First Nations people, or its recreational or high scenic value;
4. to develop, within harvestable areas, management plans that respect the sensitivities of resources to harvesting and other development by:
    - checking that rate-of-cut constraints are observed within individual watersheds of the watershed-level planning unit, and determining an appropriate watershed-specific rate for forest harvesting within the harvestable areas;[130]
    - projecting an appropriate pattern and distribution of forest roads and cutting units within the harvestable area and other working units, and including, in a general way, proposed retention levels and harvesting methods (details are developed at the site level);
    - identifying post-harvesting management and restoration activities;

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[129] See Section 2.2.4.

[130] In setting watershed-specific harvest rates, variance may be accepted from the 1% per year rate-of-cut rule on a watershed-specific basis, allowing for the individual character of watersheds, subject to approval by the planning committee with professional advice. For specific examples, see Section 3.4.2, Rate-of-Cut, R3.1. The watershed-specific rate-of-cut allows calculation of a first approximation of the annual volume that can be harvested or AAC.

- developing watershed-level plans for resources other than timber; and
- checking that planning objectives for all resources are being met, and revising plans as necessary

5 to identify species especially sensitive to human disturbance (see Appendix III), map their required habitats, and avoid these habitats during construction of roads, trails, and recreation facilities;[131] and

6 to design and implement a monitoring program at the watershed level, and to plan monitoring activities that collect data at the site level.

Watershed-Level Planning Activities

Comments following summarize information and provide recommendations for primary activities that occur during watershed-level planning.

Collect and Analyze Information

Information required to support watershed-level planning is much more specific and extensive than that required at the subregional level.

Information collected at the watershed level includes detailed mapping of all surface waters (including seasonal and ephemeral streams), terrain, ecosystems (i.e., to site series or similar level), standard forest cover classes with age classes over 400 years[132] designated separately, and habitats for red- and blue-listed plant and animal species; locations of special ecosystems (e.g., spawning areas); locations of culturally important areas; and mapping and description of landscape units and recreation units. Features are described in greater detail than at the subregional level. Appendix III contains an expanded list of information requirements.

Identify Reserves

Identifying reserves (i.e., by rigorously applying recommendation 7.16), along with setting appropriate rates of cut and road development, will replace the application of current arbitrary cutting unit sizes, and adjacency and green-up rules (see Chapter 3).

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[131] For many species, such as nesting bald eagles, the timing of potential disturbance is most important. Appropriate guidelines to avoid sensitive periods are often available (e.g., Bunnell *et al.* 1992).

[132] Scattered anecdotal information indicates that forests support a unique biota after about 400–600 years of age. Available information is insufficient to delimit the age class; the Panel recommends that one objective of monitoring be to estimate further meaningful subdivisions of forest age class 9, the oldest age class (Section 8.3.4).

At the watershed level, map and designate reserves in which no harvesting occurs.

R7.16 At the watershed level, map and designate reserves in which no harvesting will occur to protect key hydroriparian ecosystems, unstable slopes and sensitive soils, red- and blue-listed species, late successional forest with forest-interior conditions, important cultural values, and areas with high value scenic and recreational resources. Integrate reserve establishment with the refinement and detailed mapping of various land-use zones (e.g., Protected Areas). Reserves include:

- Reserves to protect hydroriparian resources.

Identify reserves that include the drainage system and hydroriparian zone around streams, lakes, wetlands, and marine shores.

Identify reserves that include the drainage system and hydroriparian zone around streams, lakes, wetlands, and marine shores to ensure adequate protection for aquatic and riparian ecosystems. Drainage features and their hydroriparian zones are critical to protecting ecosystems, especially in Clayoquot Sound (see Chapter 2). The approach to maintaining their functional integrity proceeds from a classification system based on both physical and biological features (see Section 7.4 and Appendix II for details).

- Reserves to protect sensitive soils and unstable terrain.

Identify reserves for unstable slopes by the extent of stability class V terrain.

Identify reserves for unstable slopes by the extent of stability class V terrain as determined by the methodology outlined in the forthcoming *Mapping and Assessing Terrain Stability Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995b). Sensitive soils (e.g., blocky colluvium, very shallow folisols) which decline in productivity when disturbed must also be reserved. Only stable terrain and resilient soils should be available for forest harvesting operations.

- Reserves to protect red- and blue-listed plant and animal species.

Red- and blue-listed species are either threatened, endangered, vulnerable, or rare. Identify and reserve habitats for species on these lists,[133] recognizing that protection is often better implemented at the site level for widely ranging, rare species; and that planning their protection may occur at the subregional level.

[133]The proposed Forest Practices Code may allow designation of “species at risk,” which will provide legislative direction to protect species so designated. A “species at risk” is any wildlife species deemed to be threatened, endangered, sensitive, or vulnerable; or any threatened and endangered plants or plant communities identified by the B.C. Ministry of Environment, Lands and Parks as requiring protection.

- Reserves to protect forest-interior conditions in late successional forest.

It is important to maintain some patches of older forests that provide conditions similar to the interior of late successional forests.

Some species of plants and animals are closely associated with microclimatic conditions found inside older forests. It is important, therefore, to maintain some patches of older forests that provide conditions similar to the interior of historic forests. Assuming tree heights of 50 m, a reserve width of 300 m will provide at least some forest-interior conditions. The Panel recommends that 20% of the forests in age classes 8 and 9[134] of a watershed-level planning unit should constitute forest-interior conditions (e.g., Chen *et al.* 1995).[135]

Use 1:10 000 to 1:20 000 scale air photos and forest cover maps to identify forest-interior conditions. Providing no evidence is found that age class 9 requires further subdivision, the Panel assumes that this habitat information is readily available from forest cover maps. As noted in Chapter 8, monitoring should be designed to evaluate this assumption.

- Reserves to protect cultural values.

The Panel's report *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b) discusses a variety of culturally important areas, including sacred areas, historic areas, and current use areas. These areas must be determined by the Nuu-Chah-Nulth Nations and protected in ways consistent with traditional knowledge.

- Reserves to protect scenic and recreational values.

Areas with especially high scenic and recreational values are to be protected.

Protect areas with especially high scenic and recreational values from alteration. These areas include unprotected unaltered areas with the highest scenic values, unaltered scenic areas of high value which are important because of their location (e.g., visible from a community or an important recreation site), and important recreation sites such as beaches or bays with primitive use objectives.[136] Identify these areas through the scenic and recreational planning processes described in Chapter 6.

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[134]If research and monitoring reveal the importance of an older age class (see footnote 132), age class 8 may not meet the objective of this reserve.

[135]The Panel recommends that at least 40% of the forest in a watershed-level planning unit (i.e., all reserves plus forest retained in harvestable areas) be in age classes 8 and 9 (see following subsection, Plan Management Activities in the Harvestable Area).

[136]"Primitive use," as defined by the B.C. Ministry of Forests recreation opportunity spectrum, refers to areas of primarily unmodified natural environment, with non-motorized access, and no facilities except where required for safety and sanitation (B.C. Ministry of Forests 1991c:6–8).

- Reserves to represent all ecosystems.

Calculate areas of each biogeoclimatic site series contained within all designated reserve areas.

Calculate areas of each biogeoclimatic site series (or surrogate) contained within all designated reserve areas. Note that the previously mentioned reserves will commonly overlap. Add to these reserves, as necessary, to ensure that the entire variety of ecosystems is represented in the reserve system to maintain plants, animals, and other organisms that have specific habitat requirements. Reserve ecosystems that are rare in greater proportion than their representation in the area.

- Reserves to ensure linkages among watershed-level planning areas.

Based on information from the subregional planning level, add to the reserve as necessary to allow migrations of animals, to provide connectivity among plant and animal populations, or to accommodate recreational opportunities.

Plan Management Activities in the Harvestable Area

Identifying reserves to maintain ecosystem integrity also defines areas available for resource extraction or development.

The process of identifying reserves to maintain ecosystem integrity also defines areas within the watershed available for resource extraction or development. These areas may be used for forestry activities, collection or production of other resources (e.g., mushrooms, plants, animals), or development (e.g., resort, housing).

In the area identified for resource extraction or development, the Panel recommends silvicultural systems and harvesting systems that more closely approximate natural disturbances. Determine appropriate levels of retention and appropriate harvesting methods following recommendations in Chapters 3 and 4. Only conceptual plans can be developed at the watershed level; specific plans are developed at the site level.

In areas identified for resource extraction or development, determine appropriate levels of retention and appropriate harvesting methods.

When active logging is occurring in an individual watershed, check annually to ensure that the rate-of-cut for that watershed (as guided by Chapter 3, R3.1) is not exceeded. Check also that at least 40% of the forest in the watershed-level planning unit is in late successional forest (age classes 8 and 9). Because these wet coastal forests historically were comprised of 90–100% old growth over many hundreds of years, 40% is an estimated minimum to allow continued, natural ecosystem function.[137] The variable-retention silvicultural system that the Panel recommends will result in mixed age classes over small areas and retain more of the structural characteristics of older forests than would stands regenerated under an even-aged silvicultural system.

[137]This 40% can be comprised of both reserve areas and areas of late successional forest retained in harvestable areas.

The following plan components should be developed:

- layout of existing and projected cutting units (see Section 7.3.3) including projected levels of retention (e.g., low, moderate, or high);
- a roading plan that shows existing and projected roads; rate of road development; the maximum percentage of the harvestable areas that can be converted to roads and landings; other watershed-specific road constraints (e.g., avoiding floodplains or midslopes); and road maintenance and road deactivation plans, including erosion and sediment control measures;
- a contingency plan for rehabilitating any potential damage; in particular, erosion events (natural or induced erosion, mass wasting, or surface erosion) or escapes (spills) of deleterious substances; and
- a monitoring plan that assures compliance with standards and assesses the effectiveness of the standards. The monitoring plan must identify activities at the watershed level and sampling designs for collecting information at the site level.

The sum of several watershed-level plans will provide a Total Resource Plan for a larger forest management area such as a tenure or other administrative unit.

These plans must be integrated with relevant aspects of the plans for scenic, recreational, and tourism resources, and any other plans for specific resources. The sum of several watershed-level plans will provide a Total Resource Plan for a larger forest management area such as a tenure or other administrative unit.

7.3.3 Site-Level Planning

At the site level, planning pertains to one or more discrete units proposed for a specific management activity.

Site-level planning covers many types of “sites” and activities, including areas proposed for logging (i.e., cutting units), areas used for other activities such as recreation (e.g., recreation units), or specifically managed habitat for a species at risk[138] (wildlife unit). Thus, the area defined by various working units will vary with the type of use being planned. At the site level, planning pertains to one or more discrete units proposed for a specific management activity. These units, typically one hectare to several tens of hectares, may be larger if deemed appropriate to meet ecosystem management objectives. The appropriate mapping scale for site-level planning ranges from 1:2 000 to 1:5 000.

Site-Level Planning Objectives

The objectives of site-level planning are:

1 to identify smaller features requiring protection that were not identified during watershed-level planning, including ephemeral streams and small wetlands, wildlife trees, culturally important sites (including culturally

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[138]See footnote 133.

modified trees), recreation sites, and scenic features (see list of inventory items in Appendix III); and

2 to ensure that individual sites are well integrated with other existing and potential sites.

Where sites are proposed for logging (i.e., cutting units), further objectives include:

3 to identify precisely the location of all roads and cutting unit boundaries;

4 to determine the silviculture prescription, including the level(s) of retention (see Chapter 3);

5 to specify the harvesting method(s) and any seasonal constraints on cutting (see Chapter 4);

6 to identify any other specific constraints on road construction and cutting activities; and

Working units for timber extraction must be within an identified harvestable area in the watershed-level plan.

7 to refine the previous objectives by considering all resource values, including diversity of aquatic and terrestrial species, cultural concerns, and scenic and recreational values.

Working units for timber extraction (i.e., cutting units) and stand tending activities (e.g., fertilization units, thinning units) must be within an identified harvestable area in the watershed-level plan.

Site-Level Planning Activities

Collect Information

Requirements for information at the site level include *refinements* of information collected at the watershed level (e.g., validation and refinement of ecosystem boundaries, mapping of ephemeral streams); more detailed information about terrain features, forest stands (e.g., timber volume and levels of downed wood), and endangered, threatened, or vulnerable plant and animal species; detailed mapping of sites important to First Nations; and detailed landscape and recreation features.

Refine Inventory and Analysis

Before any management activities are initiated on the site:

1 Survey the site to identify hydroriparian types not mappable (i.e., too small), or not mapped (i.e., missed) at the watershed level of planning.[139]

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[139] See Figure 7.4 or Appendix II for more information on the hydroriparian classification system.

2 Check terrain and soils to ensure stability.

If logging activity is to occur in areas with stability class IV, a slope stability specialist must check these areas.

If logging activity (cutting or roadbuilding) is planned in areas with stability class IV, ensure that a slope stability specialist (i.e., professional geoscientist or professional engineer) checks these areas. Also, check potential stability problems related to previously constructed roads. Certain site features critical to planning are difficult to assess (e.g., terrain stability class IV when forest cover is intact; Section 3.3. F3.14). At the site level, there should be provision for reassessment or continuing professional oversight regarding such features.

3 Check for presence of red-listed, blue-listed, and old-growth associated species (see Appendix III), and inventory the habitats within the stand required by these species.

4 Check for special habitats (e.g., heron roosts, sites having rare plants).

5 Describe distributions of wildlife trees, large trees, downed wood, and shrub and tree species.

Original distributions of these features can provide baseline information for operational recommendations concerning the retention of live trees, wildlife trees, downed wood, and shrubs; and provide guidance for tree species regeneration and spacing.

6 Check for the presence of culturally important areas.

7 Check for important scenic, recreation, or tourism features.

8 Check adjacent sites for conditions that could affect planning for the current unit.

Plan Management Activities for Working Units

Each individual unit within the harvestable area must be planned in relation to other existing and potential units.

Each individual unit within the harvestable area where forest management or other development activities are proposed must be planned in relation to other existing and potential units.

Plans at the site level must show detailed features of the site and adjacent areas including: streams of all classes; lakes and wetlands; road access (if any) to the site; and all sensitive conditions (e.g., shallow or wet soils, unstable and marginally stable terrain, areas difficult to regenerate, floodplains, cultural features, important scenic and recreation areas and features). The boundaries of areas to be retained or subject to other constraints during harvest must be defined. Where sites involve logging, a plan must show the outer site boundaries; the detailed cutting unit layout; and road locations (if any) in relation to the features, reserves, and other limitations noted above.

Site-level planning includes development of silvicultural and logging plans.

Site-level planning includes development of silvicultural and logging plans. Silviculture prescriptions must include amount, distribution, and type of retention (see Chapter 3); planned methods of regeneration (natural or planting); preferred and acceptable tree species to be grown for timber; stocking levels; acceptable regeneration delay; any post-logging treatments (e.g., control of competing vegetation); windthrow management plans; and designation of retained areas or structures (e.g., wildlife trees, cultural sites) with their associated "no-work" zones. Logging plans must include method(s) and season of logging, and edge treatments along external boundaries and around internal reserves or special management zones (stream, stability, scenic, cultural, karst, or other exceptional topography; see Appendix III). Plans must also indicate site-specific road construction standards, road maintenance plans, and road deactivation measures.

The plans for silviculture, logging, and any other development must follow landscape design principles and indicate how scenic and recreational values will be protected. Visual impact assessment must be conducted at this level to ensure that proposed alterations will fall within visual landscape management objectives.

7.4 Hydroriparian Reserves

Waterbodies and their immediate vicinity represent special environments.

Waterbodies and their immediate vicinity represent special environments in the forest, both because they are the locus for water flowing through the system and because they include habitats with the greatest diversity and productivity. Because of the importance of the hydroriparian zone in an ecosystem-based approach, the Panel presents detailed recommendations for delineating and managing the zone.[140] Activities should be planned at the watershed level, and checked and monitored at watershed and site levels.

An appropriate system of stream classification recognizes the ecosystem units including the stream channel and the adjacent terrestrial surface.

Forest management in British Columbia and elsewhere has included some form of special management or protection for stream channels, streamside habitat, and the shore zone. In British Columbia, the principal basis for specifying management procedures has been a simple classification of the stream channel, and characteristics of fish populations in the streams (see, for example, the *British Columbia Coastal Fisheries/Forestry Guidelines* 1993). In an ecosystem-based approach to land management, these criteria are neither sufficient nor logical, as a basis for managing aquatic and riparian ecosystems, because they do not recognize the essential connectivity of the entire drainage system. A classification that recognizes the ecosystem units themselves, including the stream channel (or standing waterbody) and the adjacent terrestrial surface to the limit of riparian influence, is more appropriate (Gregory *et al.* 1991). The classification devised by the Panel is illustrated in Figure 7.4; details are presented in Appendix II.

[140] See Section 2.2.4 for a detailed discussion of the hydroriparian zone.

Figure 7.4 **Classification of the hydroriparian system.**

Stream Environment

- **A alluvial channels**
  - **1 gradient ≤8%**
    - channel width
    - i <3 m
    - ii 3–30 m
    - iii >30 m
  - **2 gradient >8%**
    - i <3 m
    - ii 3–30 m
    - iii >30 m
- **B non-alluvial channels**
  - **1 gradient ≤8%**
    - a not entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
    - b entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
  - **2 gradient 8–20%**
    - a not entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
    - b entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
  - **3 gradient >20%**
    - a not entrenched
      - i seasonal or perennial
      - ii ephemeral
    - b entrenched

Standing Waterbodies and Wetlands

- **A lakes**
  - **1 oligotrophic**
    - i sand or gravel beach
    - ii low, rocky shore
    - iii cliffed or bluff shore
    - iv wetland shore
  - **2 non-oligotrophic**
    - i sand or gravel beach
    - ii low, rocky shore
    - iii cliffed or bluff shore
    - iv wetland shore
- **B wetlands**
  - i marsh
  - ii fen
  - iii swamp
  - iv shrub-carr
  - v meadow
  - vi bog

Marine Shores

- **A adjacent to open waters**
  - **1 beach**
    - i sandy (incl. dunes)
    - ii gravelly shore
    - iii bouldery shore
  - **2 non-beach**
    - i low shore
    - ii shore bluffs
    - iii rock cliffs/ steep slope
- **B adjacent to protected waters**
  - **1 lagoon**
    - i sandy (incl. dunes)
    - ii gravelly shore
    - iii bouldery shore
    - iv saltmarsh
  - **2 estuarine**
    - i marsh
    - ii mudflat
    - iii sandflat
    - iv gravel or boulder flat
    - v low, rocky shore
    - vi bluffs, cliffs, or steep slopes

Appropriate protection for aquatic and riparian ecosystems must consider the entire drainage system and the entire hydroriparian zone.

Special forest management in the hydroriparian zone has in the past been restricted to land adjacent to waters with identified or expected fish habitat value, and to certain upstream waters that flow directly into waters with fish habitat value. Special management has been prescribed in zones of arbitrary distance from the shore (e.g., 10 m, 30 m) within which no forest harvest or restricted harvest will occur. Neither criterion is sufficient to ensure protection of the hydroriparian zone.

To assure appropriate protection for aquatic and riparian ecosystems, the entire drainage system and the entire hydroriparian zone must be considered. As well as maintaining the integrity of aquatic and riparian ecosystems, a protected zone that spans the entire drainage system forms the skeleton of a continuously connected forest environment that affords movement and dispersal of animals and plants through the landscape, including passage to ridgelines and into adjacent watersheds.

Environmental influences originating on adjacent land units may influence the hydroriparian zone.

Environmental influences originating on adjacent land units may influence the hydroriparian zone. These factors principally will be local climatic effects that extend into the forest from a forest edge, and effects upon soil stability and sedimentation that may be produced by activities on adjacent land. To eliminate the latter effect, the Panel's recommendations for special land management in some cases extend beyond the limit of the hydroriparian zone. In particular, in the following recommendations, reserve zones mean "no-work" zones: any prescribed edge feathering of the retained forest must occur outside the specified reserve limit.

Climatic effects around streams are significant.

The control of climatic effects is complex because some climate factors change more rapidly than others with distance into the forest from an edge (Figure 7.5a). Major parameters of interest are solar radiation and air temperature, both of which influence stream temperature, soil moisture, and soil temperature. Major adjustment occurs over a distance of 50 m (approximately one "site potential tree height"[141] in much of the Clayoquot Sound region). A substantial portion of the riparian forest effect on the stream channel derives from within about 30 m of the streambank (0.6 site potential tree height; Figure 7.5b). A hydroriparian reserve of twice these distances (that is, on both banks) affords a forest reserve of 60–100 m, which the Panel judges to be sufficient to withstand wind forces directed along the stream valleys, essentially parallel with the reserve. This reserve will also substantially attenuate ground-level humidity fluctuations, light levels, and wind immediately along the stream—all factors that may influence the welfare of riparian epiphytes, understory plants, and small animals (e.g., amphibians and arthropods). The reserve also will ensure the preservation of principal hydroriparian functions, including provision of litterfall and coarse woody debris to the stream, and root strengthening of streambanks (Figure 7.5b).

[141] The Panel has assumed that 50 m is the representative site potential tree height for stands growing on productive sites in Clayoquot Sound.

Figure 7.5a Riparian forest effects on microclimate as a function of distance from stand edge.

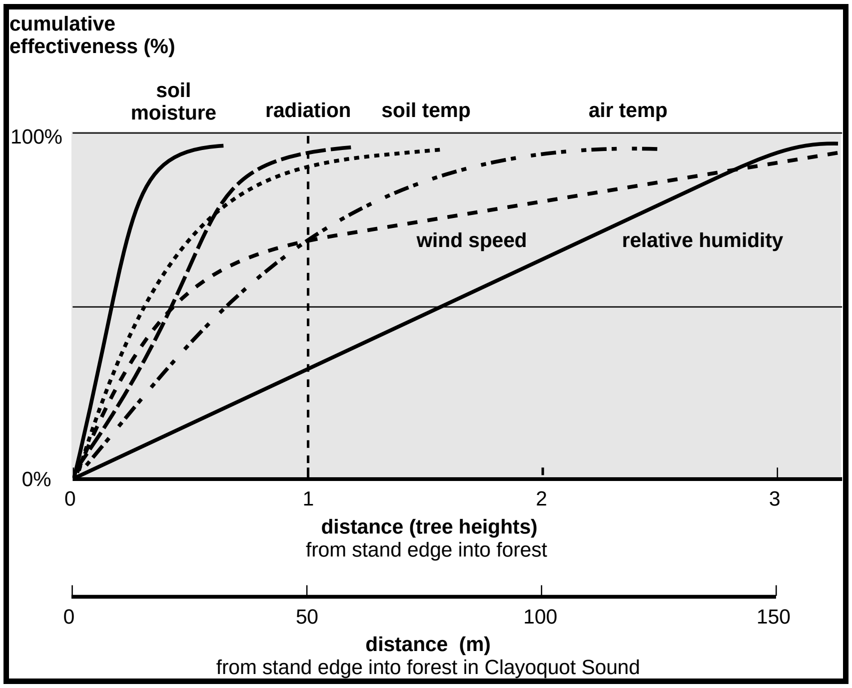
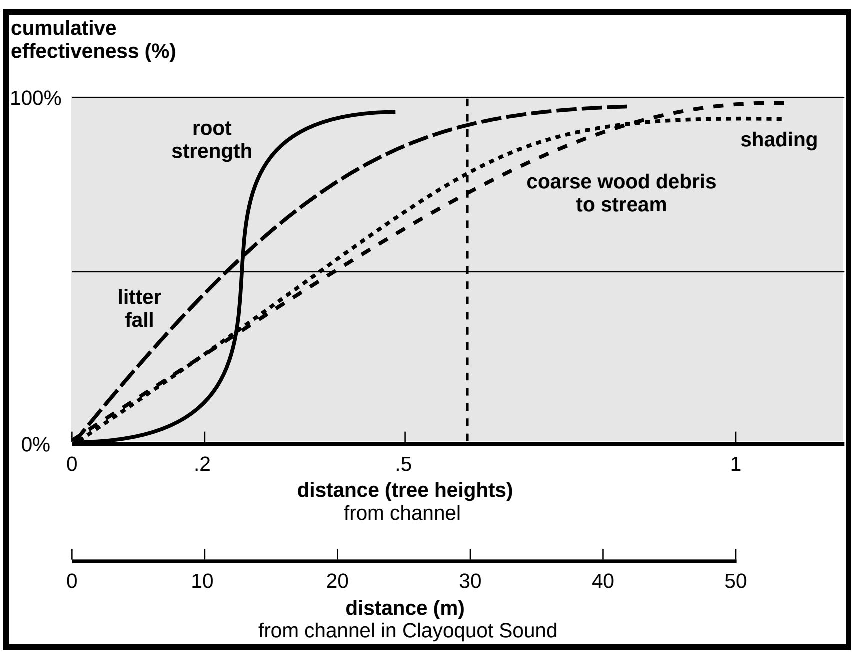


Figure 7.5b Riparian forest effects on streams as a function of distance from stream.



Source: Forest Ecosystem Management Assessment Team 1993:Figure V-13. Figures constructed from data in Chen (1991). Absolute distance scales added for this report. Dashed vertical lines represent distances used in recommendations for riparian reserves.

Recommendations for managing the hydroriparian zone are organized according to the type of waterbody and character of the adjacent riparian land.

Recommendations for managing the hydroriparian zone are organized according to the type of waterbody and character of the adjacent riparian land. Lotic (stream), lentic (standing fresh water), and marine waters form the most basic division. Streams are further classified according to whether the channel is alluvial, and according to gradient, confinement, and channel width. These criteria determine the nature of the hydroriparian zone. Lentic systems are classified according to shore morphology (lakes) and wetland type. Marine shores are classified according to shelter and shore morphology. The classification criteria can be determined during terrain mapping. In the recommendations that follow, waterbody classes are described only briefly. The complete classification of hydroriparian features is given in Appendix II. Distances given in the following recommendations, are horizontal (map) distances.

7.4.1 Streams

Designate the entire hydroriparian zone as a special management zone.

R7.17 Designate the entire hydroriparian zone as a special management zone.

A special management zone is an area to which particular land management rules or constraints apply. These rules are the direct consequence of the quality of the terrain or features found in the area. The hydroriparian zone consists of the entire floodplain of the stream, alluvial fan surfaces, and, where channels are entrenched, the entire slope that rises immediately from the channel. Hydroriparian zones delimited by none of these features are defined according to microclimate influences around the stream, as previously discussed (e.g., Figure 7.4). The floodplain is the flat valley floor (“valley flat”) constructed by the river, hence underlain by alluvial sediments.

R7.18 Reserve the entire “contemporary floodplain” of streams in Class A(1) (alluvial channels with gradient less than 8%), except areas of “dry floodplain” more than 50 m from a perennially or seasonally active channel or site of seasonal standing water. Dry floodplain may be a special management area harvested by a silvicultural system with high retention, provided that appropriate access can be arranged.

The “contemporary floodplain” is the valley flat adjacent to a stream channel that is subject to inundation in the contemporary streamflow regime and that, consequently, has soils composed of recently deposited stream sediments. “Active floodplain” denotes that part of the floodplain subject to frequent inundation; that is, occupation by standing or flowing water more often than once in five years. The five-year period is chosen because regional analyses of stream flooding in western North America show that nearly all streams with contemporary floodplains exceed "bankfull"[142] and occupy at least a part of the floodplain at least once in every five years. At a frequency of once in five years, the annual and partial duration flood sequences essentially coincide: that is, water levels are unlikely to be so high more than once within the same year.[143]

This one-in-five-year frequency definition of the active floodplain is operationally identical with that of "riparian woods" given in the *Proposed Wetland Classification System for British Columbia* (Kistritz and Porter 1993:15).[144]

"Dry floodplain" means floodplain areas subject only to occasional inundation (i.e., occupation by standing or flowing water at least once in 30 years), and not otherwise classified as "wetland" (see Appendix II). A period beyond 30 years is difficult to establish.[145]

Access in hydroriparian areas must not constrain ecosystem function.

In practice, frequency of inundation on many floodplains cannot be precisely determined: the presence of water-tolerant understory plants will be the best indicator of the extent of the active floodplain. Dry floodplain areas may be discriminated by the presence of overbank stream sediments deeper than in the active floodplain, on which a substantial litter layer (LFH soil horizon) has accumulated. "Appropriate access" in this recommendation (R7.18) means access that does not, in the opinion of a professional biologist with expertise in riparian ecology, constrain or threaten ecosystem function in any way (as by establishing a barrier to waterflows or to the movement of animals).

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[142]"Bankfull" denotes the water level when flow begins to escape the confines of the channel at some places within a reach. Where this stage is not evident by water overtopping a steep bank, it can be identified by water inundating soil in which perennial terrestrial plants are rooted.

[143]The frequency of recurrence of flood flows customarily is determined by selecting the highest flow occurring in each year to form the annual flood sequence (or "annual extreme value sequence"). This procedure ignores many high flows that are not the highest of their year. For ecological analysis, all such flows should be considered. For example, all flows above the bankfull stage of the stream are relevant to floodplain condition. Flows selected according to a threshold flow level are referred to as a partial duration sequence. Flows recurring less often than once in five years on average are very unlikely to occur more than once in a year, so the two sequences coincide at long return periods.

[144]Kistritz and Porter 1993:15. "Riparian woods are seasonal wetlands with mineral-rich moist soils that were formed by fluvial or lacustrine processes. These swampy wetlands are located within the active process zones or corridors of rivers and lakes. Inundation occurs during periods of flooding (return period of less than five years), induced by peak river flows, rising lake levels, or intense precipitation periods. Saturation or inundation is seasonal with occasional periods of severe flooding during years of extreme runoff. Soils are well-aerated mineral to organic in composition. The vegetation is characterized by a dense cover of flood-tolerant trees and shrubs which can be deciduous (e.g., cottonwood, willows, alders, red-osier dogwood) or coniferous (e.g., western redcedar, hemlock, various spruces)." Kistritz and Porter note that this definition is also identical with the "medium and low benches" of Banner *et al.* 1990.

[145]Refer to footnote 123.

R7.19 In Class A(2) (alluvial channels with gradient of 8–20%), reserve areas within 50 m of present channels (30 m for A(2)(i): channels less than 3 m wide), recently active channels, and any other routes that appear, in the opinion of a professional geoscientist or professional engineer with expertise in fluvial geomorphology or river engineering, to be subject to avulsion. Other portions of the hydroriparian zone of Class A(2) streams may be harvested by a high retention system. In the case of alluvial fans, the "contemporary fan surface"[146] shall be treated the same as the contemporary floodplain (R7.18) and reserved from logging.

In non-alluvial channels with gradient less than 8%, a larger portion of the valley flat will be available for high retention harvest.

R7.20 Treat streams in Class B(1)(a) (non-alluvial channels with gradient less than 8%, not entrenched) as Class A(1) (see R7.25 for exceptions).

It is probable that, in this class, a much larger portion of the valley flat will be dry floodplain, hence available for high retention harvest. In many cases, the "valley flat" will consist of a low terrace, but it will be difficult to obtain unequivocal evidence that the stream does not inundate the surface, or to obtain expert agreement on such a classification. This physiographic situation is common in British Columbia; in many situations, streams are very slightly degraded into early Holocene alluvium but have immediately armoured their bed with large rocks and have not formed trenches. In addition, the absence of hydrological measurements on most streams means that flood levels cannot be established with legal precision. This recommendation seeks to avoid the need for controversial decisions because frequent inundation is easy to demonstrate.

R7.21 For streams in Class B(1)(b) (non-alluvial channels with gradient less than 8%, entrenched), designate a reserve that extends to the top of the entrenchment slope or 50 m from the streambank (30 m for B(1)(b)(i), width less than 3 m), whichever is greater. Feathering for windfirmness may be permitted at the outer edge of the reserve (see also following comment). An additional reserve or "no machinery" zone of at least 30 m width will be designated beyond the top of slopes that are being actively undercut by the stream.

The additional special management zone above undercut slopes is to avoid aggravating potential instability by destroying the root network.

The top of the entrenchment slope coincides with the limit of the "inner gorge" as specified in the *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994a:14–15). The purpose of the additional reserve or special management zone above undercut slopes is to avoid aggravating potential instability by destroying the root network. Mature trees in this zone may be harvested

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[146] That portion of the fan where additional sedimentation resulting from flood or avulsion is likely to occur.

if they can be felled away from the stream within a high retention harvest plan. Streams confined by stable rock slopes constitute a special case (see R7.28).

R7.22 Treat streams in Class B(2)(a) (non-alluvial channels with gradient 8–20%, not entrenched) as Class A(2) (see R7.25 for exceptions).

Streams in this category will often be flowing on steep alluvial fans where it is difficult to decide whether the surface is “active” (subject to frequent inundation). They may be subject only to very rare (but major) debris-flow events. Defining any part of the fan surface that is not liable to experience avulsion will be more difficult than in the case of Class A.

R7.23 Treat streams in Class B(2)(b) (non-alluvial channels with gradient 8–20%, entrenched) as B(1)(b).

R7.24 For streams in Class B(3)(a)(i) (non-alluvial channels with gradient greater than 20%, not entrenched, seasonal or perennial flow), designate a reserve that extends 20 m from the channel.

Seasonal or perennial streams, unlike ephemeral streams, have regular base flow, derived either from springs or persistent seepage through the banks.

R7.25 Designate no general reserve for streams in Class B(3)(a)(ii) (non-alluvial channels with gradient greater than 20%, not entrenched, ephemeral flow), and those channels in classes B(1)(a)(i) and B(2)(a)(i) (non-alluvial channels with gradient less than 21%, not entrenched, less than 3 m wide) that carry only ephemeral flow. But, require evaluation by a professional biologist to determine whether special management prescriptions are warranted for ecological reasons, and employ special management where deemed necessary.

This recommendation seeks to avoid excessive division of the landscape around small ephemeral channels. Nearly all of these channels will be directly downslope from channels in Class B(3)(a)(ii), which are similarly treated.

Ephemeral streams carry storm runoff only, which is derived from bank seepage or from overland flow. Ephemeral streams should be classified during ground-based terrain checking. Most of these streams will be less than 1 m wide. Special management prescriptions might specify local reserves, and no machinery (falling and yarding away from the hydroriparian zone).

Channels classified as gullies shall be subject to gully management prescriptions.

R7.26 For streams in Class B(3)(b) (non-alluvial channels with gradient greater than 20%, entrenched), designate a reserve that extends to the top of the entrenchment slope or 20 m from the channel, whichever is greater. However, if the sidewalls adjacent to the channel (and including the channel zone) are classified as having low or no potential for instability, then apply criteria for Class B(3)(a). Apply gully assessment procedures to channels that are classified as gullies according to the *Gully Assessment Procedures for British Columbia Forests* (Hogan *et al.* 1995). Most streams in this category in Clayoquot Sound will be gullies.

R7.27 Apply the gully management prescription of Hogan *et al.* (1995). However, modify the pre-logging management strategies described in their procedure for use in Clayoquot Sound so that all channels assessed as having high or moderate potential for downstream impact, and high or moderate potential for debris flow, water flood, or fan destabilization shall have no logging within the gully.[147]

R7.28 Notwithstanding the foregoing recommendations, Class B streams (non-alluvial channels) that are confined by stable rock walls, and are classified as having low overall habitat value and low potential to affect downstream reaches have no special management requirements with respect to hydroriparian integrity. Where a V-notch in surficial material occurs immediately above a rock notch, apply the prescription for a trenched channel.

This recommendation seeks to avoid defining special management or reserves for barren rock-bound cascades and waterfalls. Of course, many such sites have special habitat value. Other constraints, in particular cultural or scenic constraints, may also apply.

In community watersheds, the special management zone shall always extend 50 m from any channel.

R7.29 In community watersheds, make all channels above the intake subject to the previous prescriptions. In addition, extend the special management zone 50 m from any channel, even if the hydroriparian zone or entrenchment slope does not extend so far.

This prescription provides additional assurance that the soil near channels is not damaged in any way that would compromise its ability to effectively filter water seeping into the channel.

7.4.2 Lakes

The gradient of lakeshores is variable. Shores with an appreciable gradient have “dry” shore zones and a restricted hydroriparian zone. In comparison, lakes with very low shores may merge into a wetland. These shores should be dealt with according to the recommendations for wetlands.

Even where lakeshores are dry, the shore zone plays a significant riparian role.

Even where shores are dry, the shore zone plays a significant riparian role. It remains a preferred focus of activity for animals, particularly perching birds. The area immediately offshore is also disproportionately important for fish and other animals (e.g., some snakes, amphibians, ducks, and loons). Part of this

[147]Recommendations R7.21, R7.23, or R7.26 will usually cover this requirement.

importance derives from shelter provided by the lakeshore and onshore forest. Recommendations for lakeshores are based on these habitat considerations.

Around all lakes, designate a special management zone that includes all the area under hydroriparian influence, or 50 m.

R7.30 Around all lakes, designate a special management zone that includes all the area under hydroriparian influence, or 50 m, whichever is greater. The first 30 m from the shore shall be a reserve. The remaining zone may be subject to retention systems of harvest provided it is outside the hydroriparian zone proper.

R7.31 Where special inshore lacustrine, ecological, or cultural values are identified (e.g., inshore spawning gravels), and steep slopes occur immediately behind the shore, extend the reserve or special management zone upslope as far as necessary to protect these special values.

R7.32 For Class (2) lakes smaller than 4 ha in area, designate a reserve that includes all the area under hydroriparian influence or 30 m, whichever is greater.

Lakes are superficially equivalent to contemporary floodplains which require a 50 m reserve. For a lake of 4.5 ha, the area of a 50 m surrounding reserve becomes equal to the area of a circular (most compact) waterbody. For smaller waterbodies the reserve is larger than the waterbody. Acknowledging the distance required for climatic factors such as wind, temperature, and humidity to adjust to a change in the character of the surface (e.g., Figure 7.5a), designating a reserve zone very much larger than the protected waterbody appears unreasonable.

7.4.3 Wetlands

The area of high subsurface water table may extend well beyond the edge of the wetland proper.

Wetlands very often are surrounded by areas of continuing low gradient. Hence, the area of high subsurface water table may extend well beyond the edge of the wetland proper.

R7.33 On low gradient edges of a wetland, establish a reserve that extends to the limit of hydroriparian influence.

Low gradient in this case means essentially flat ground, less than 1% slope. Establishment of the “limit of hydroriparian influence” in the foregoing recommendations should be based on understory plant associations or on soil characteristics.

R7.34 On sloping edges of a wetland, establish a special management zone on the same basis as for lakes.

7.4.4 Marine Shores

Ecological relations in the transition zone between terrestrial and saltwater systems are complex.

Marine shores are similar to lakeshores, but ecological relations in the transition zone between terrestrial and saltwater systems are likely to be much more complex given the large diversity of species characteristically found here, and certain special physical features (e.g., sand dunes, brackish water lagoons, backshore log barriers). Open and protected coasts are treated separately because of the much greater natural forces—both wind and waves—on open coasts.

R7.35 On Class A(1) and A(2)(i) shores (low shores adjacent to open waters), extend a riparian reserve inland 150 m from the seaward edge of forest vegetation, or to the inland limit of shore-associated features (e.g., overgrown sand dunes), whichever is greater.

The distance is determined by wind forces and the distance for wind attenuation inside the forest (Figure 7.5a). Measurements on the lower Alaskan coast indicate that 150 m is sufficient to achieve this.[148]

R7.36 On the remaining Class A(2) shores (cliffs, bluffs, and steep shores adjacent to open waters), extend a riparian reserve 100 m inland from the top of the coastal slope or bluff. On eroding shores, a larger distance may be specified if required by slope stability criteria.

R7.37 On Class B marine shores, extend a riparian reserve 100 m inland from the seaward edge of forest vegetation, or to the inland limit of shore-associated features (e.g., sand dunes and lagoons, now within the forest), whichever is greater. For lagoons within the forest, establish a reserve on the inland shore (R7.30).

R7.38 In estuaries proper, make a smooth transition from the marine shore reserve to the streamside special management zone.

7.4.5 Roads

Roads represent a severe and persistent disturbance of natural conditions.

Roads represent a severe and persistent disturbance of natural conditions. In hydroriparian management zones, the following recommendations are made:

Roads should avoid hydroriparian reserves.

R7.39 Avoid road construction in hydroriparian reserves. Where no practical alternative is possible, abandoning the development may be advisable. If the development does proceed, engineer and construct the road to minimize disturbance. Require professional engineering supervision at all stages of road construction. The chief circumstances where a road may have to enter a hydroriparian reserve is for direct crossing from one side to another of a stream reserve, or to follow an active floodplain or

[148] J. Concannon, pers. comm. April 1995.

lakeshore where the higher terrain is not accessible or cannot be safely crossed.

R7.40 In hydroriparian reserves, engineer the road and bridges to ensure that the security of neither the road nor the hydroriparian ecosystem is jeopardized. The road shall not interfere with the circulation of water or with the movement of terrestrial or aquatic animals. In particular, the design must ensure that the roadway does not act as a dam during periods of high flow or storm surge, nor as a source of sediment.

R7.41 Roads constructed near the slope base at the edge of a floodplain or other hydroriparian zone must provide for passage of cross-drainage into the riparian zone. Design traffic and machinery holding places to prevent traffic-associated contaminants from escaping into the hydroriparian zone. Select road surface materials to minimize dust production.

7.5 Phasing in the New Planning Framework

The planning framework differs from current methods of planning.

The new planning framework differs from current planning methods in the following ways:

1 The planning process is area-based, focusing on the distribution of forest to be retained to maintain forest values and ecosystem functions.

2 Forest reserves, based on credible biological and physical criteria, are designated at the watershed level *before* the delineation of harvestable areas and subsequent planning of specific forestry activities.

The volume of cut can only be derived from the planning process.

3 The volume of cut is determined from watershed-based rates-of-cut of the harvestable area designated during planning, and can only be derived from the planning process.

Given the differences in the approach from current methods, the Panel recognizes that it will take time to phase in the new planning framework. The priority is subregional planning, which should be phased in immediately. With a subregional planning committee in place, it will be possible to set priorities for and to start needed baseline inventories and monitoring of resources.

Several recent planning initiatives will contribute to the phase-in period, particularly because planning committees have already been established. The Scenic Corridors Planning Process has a committee (Scenic Corridors Advisory Group) with representatives from most relevant groups except First Nations, who chose to have observer status. The Ursus Creek planning project has a committee that represents interests in the Ahousat area. The Long Beach Model Forest and a planning group addressing the Pretty Girl area also exist.

The number of planning groups in Clayoquot Sound is straining individual and agency resources. The Panel recommends that planning efforts be coordinated through one formal committee, augmented by secondary groups as required. A planning hierarchy wherein a higher-level committee coordinates any lower-level committees is essential to carry out the common planning goals defined in this report.

It is preferable to begin site-level planning using the variable-retention silvicultural system in watersheds that have already experienced some development.

If subregional planning is initiated immediately, it should be possible to begin some watershed-level planning within one year. Site-level planning can begin immediately to incorporate some of the Panel's recommendations, and can gradually include more recommendations as the subregional and watershed-level plans are completed. It is preferable to begin site-level planning using the variable-retention silvicultural system (Chapter 3) in watersheds that have already experienced some development.

8.0 Monitoring

Monitoring is repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system.

Monitoring is repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system. In particular, it entails the comparison of objects (e.g., organisms) and processes (e.g., streamflow) before and after management actions to determine the effect of those actions upon the ecosystem. Monitoring is an integral part of the sequence of management activities that also includes inventory and planning (Figure 7.1). During the inventory, objects and processes are assessed in an area at a particular time to establish the state of a system. Inventory entails gathering baseline information upon which planning is based and to which subsequent monitoring activities are compared.

Monitoring in the forest ecosystems of Clayoquot Sound will have three goals.

In accordance with its mandate, the Scientific Panel has outlined conditions that are required to meet or exceed emerging international standards for forest practices. The objectives of these standards include maintaining ecosystem integrity and the cultural integrity of local peoples. A successful monitoring program must ensure that objectives are being achieved. Consequently, monitoring in the forest ecosystems of Clayoquot Sound will have three goals:

- to ensure that forest activities and practices *comply* with prescribed standards for ecosystem integrity and cultural integrity;
- to determine whether the forest practices standards adopted for Clayoquot Sound are *appropriate for the intended management objectives;* and
- to improve the basis for *understanding* the mechanisms, both natural and those induced by human activity, that cause events and create changes in the ecosystem.

The Panel emphasizes monitoring to evaluate success in attaining objectives.

Information gained from the last two goals must be fed back into the planning process (Chapter 7). This chapter concentrates on the second goal, success in attaining management objectives, and assumes that the Panel's recommendations are adopted. Before considering specific objectives and methods for monitoring in Clayoquot Sound, some general aspects of monitoring require elaboration.

8.1 General Comments on Monitoring

The state of a system (e.g., composition of species present, condition of forest floor) is an indicator of the integrity of the system. Process and state are both aspects of ecosystem performance: processes yield states, which influence further processes. In some cases, processes in the system (e.g., hydrological processes) may be monitored to detect a change of state rather than monitoring the state directly. The choice of whether to monitor states or processes is based on feasibility or cost-effectiveness. Monitoring of processes is most helpful when based on understanding the effect that the process has on states of the system. For some purposes, this will require further research.

Nowhere has sufficient effort been invested in monitoring ecosystem management.

Monitoring activities must be carried out at several scales in Clayoquot Sound. As in planning, monitoring activities at local or site levels must often be designed at regional or subregional levels. Conversely, monitoring observations with regional implications often are made at individual sites. The need to coordinate observations over a range of spatial and temporal scales, juxtaposed on requirements for the program to be practical, meaningful, and affordable, makes monitoring programs difficult to design. The Scientific Panel emphasizes the importance of ensuring that monitoring programs meet their objectives. Nowhere has sufficient effort been invested in this critical aspect of ecosystem management.

The ease of monitoring varies widely from objective to objective. In a few cases, the needed steps are obvious and easily achieved. In others, these steps will be impracticable because of expense. In such circumstances, indirect means must be sought that give the desired answers to an acceptable level of precision. In still other instances, monitoring methods are currently being researched, and only procedures that appear, in the light of existing knowledge, to be the most promising can be recommended. Too little is known about too many ecosystem components to provide a specific protocol for monitoring all features of the forest planning and practices recommended for Clayoquot Sound. This chapter provides a general approach to monitoring and recommends specific methods where information is adequate.

It is worthwhile to devote considerable effort to devising the simplest methods that will give informative results.

For a given monitoring “effort” (time, cost), it may be appropriate to make detailed and precise measurements—perhaps with expensive equipment requiring expert operators—on only a few occasions at widely spaced observation sites. Alternatively, numerous observations may be obtained by less precise methods. Less precise methods allow data to be collected cheaply, at many sites and at short intervals, by observers who have had only minimal training. The ideal is probably some blend of both approaches, allowing simple but extensive observations to be periodically calibrated against complex, intensive measurements. It is worthwhile to devote considerable effort to devising the simplest methods that will give informative results. For ecological and geomorphological data, simple methods are needed in a setting as diverse as Clayoquot Sound: environmental conditions vary so markedly over such short distances that numerous observation points are necessary.

Monitoring of Clayoquot Sound forests requires comparing the state of the ecosystem before and after forestry operations. The dominating goal is

- to ensure that the integrity of ecosystem processes and ecosystem states is maintained. (Scientific Panel 1994a:14)

Detecting the environmental impacts of human activities on natural communities is a central problem in applied ecology.

Detecting the environmental impacts of human activities on natural communities is a central problem in applied ecology (Eberhardt 1976; Schroeter *et al.* 1993). It is a difficult problem because the effects of human activities must be separated from the considerable natural variability displayed by most communities or ecosystems. It is therefore essential that full baseline data be obtained *before* operations begin in an undeveloped area. Deciding when and how often to carry out post-management inspections requires judgement. Unwanted effects should be identified early so that operations can be stopped or modified promptly, before further damage is done. Some effects of forest disturbance, however, take time to appear; for example, slope instability may develop only after the root network of the former forest has decayed and a rainstorm exceeding some threshold has occurred. This time lag means that monitoring must be continued for years after logging operations have ended to ensure that all effects of logging have become apparent.

Monitoring to detect changes caused by forestry activities is best done by comparing conditions at disturbed and undisturbed sites.

Monitoring to detect changes caused by forestry activities is best done by *comparing* conditions at disturbed and undisturbed sites. Such comparisons can be made by comparing conditions: (1) upstream and downstream of a disturbed site; (2) before and after disturbance, at the same site; and (3) in the valley containing the disturbed site and in a nearby similar, undisturbed valley. No one of these three possibilities is best for all purposes. An informed choice must be made for each specific purpose. Consensus is emerging, however, that to detect impacts of human activities, samples should be taken repeatedly and contemporaneously at the potential impact site, and at one or more control sites during periods before and after the impact has begun (Eberhardt 1976; Skalski and Mackenzie 1982; Carpenter *et al.* 1989; Stewart-Oaten *et al.* 1992; Schroeter *et al.* 1993). The objective is to exclude or identify, so far as possible, effects unrelated to human activities.

Monitoring is an essential part of active adaptive management and improving management practices.

Effective monitoring is an essential part of active adaptive management and improving management practices (Walters 1986). Active adaptation is especially important when information is incomplete and social goals are changing—a situation particularly true for forest land management today. Approaches to learning more from management actions are developing (e.g., Walters *et al.* 1988; Walters and Holling 1990) and should be implemented. Acknowledging both the uncertainties and emerging consensus surrounding monitoring, the Panel makes the following recommendations:

R8.1 Initiate a long-term monitoring program that includes both areas that are reserved from land-use practices and areas that will experience land-use practices.

R8.2 Incorporate into the monitoring program the elements summarized in Sections 8.2 through 8.4. Specifically, monitor:

- watershed and coastal integrity – including hillslopes and forest soils, stream channels, regional streamflow and water quality, and the coastal zone;

- biological diversity – including genetic variation, vulnerable and rare indigenous species, terrestrial environments, old-growth characteristics, and aquatic environments;
- human activities and values – including areas important to First Nations; scenic, recreational, and tourist values; and regional commodity production; and
- implementation of forest management plans.

R8.3 Use the findings of this program to modify, as required, management strategies as well as individual plans and practices.

8.2 Monitoring Watershed and Coastal Integrity

Monitoring watershed integrity encompasses the hydrological cycle, sedimentation processes, soils, geochemical cycles, and stream environments.

Monitoring watershed integrity encompasses the hydrological cycle, sedimentation processes (including hillslope stability), soils, geochemical cycles, and stream environments. The overall goal is

- to ensure that ecosystem processes and ecosystem states do not depart from the range of natural variability exhibited before disturbance. (Scientific Panel 1994a:Section 4)

Monitoring processes in a manner that reveals information useful for ecosystem management is a challenging task for several reasons. Hillslope failure is a comparatively rare, episodic event which is highly dependent upon antecedent conditions. Many of the properties of streams and rivers (e.g., stage, discharge, velocity, water depth, sediment load, turbidity) undergo enormous natural variation over short periods, making it difficult to recognize changes caused by human-induced disturbances. The tremendous spatial and temporal variation in the landscape makes it impossible to interpret, with high confidence, sparsely replicated measurements. The number of variables that might be observed and measured is vast, but focusing on key management activities will provide useful information.

Results of principal management activities that may affect watershed integrity are measured at the watershed level. These results include the rate-of-cut in individual drainage basins, distribution of cut and regenerating areas, distribution of forest age classes with respect to elevation and physiography, and the extent and layout of the road system.

8.2.1 Monitoring Hillslopes and Forest Soils

The goal for hillslopes and soils is to maintain the integrity of the soil.

Consistent with the guiding principles for ecosystem management, the goal for hillslopes and soils is to maintain soil integrity. This goal requires that two basic objectives be achieved:

- to retain the soil within the ecosystem; that is, to manage the land so that modes and rates of erosion are not significantly changed and individual erosion events are within the natural range of variability; and

- to maintain the physical, chemical (nutritional), and biological characteristics of the soil so that the capability to maintain a wide range of ecosystem states and options for society is not foreclosed or reduced.

Construction of roads and landings, borrow pits, and other cleared areas necessitates deliberate and unavoidable loss of productive soil, but inadvertent soil damage may also occur and hillslopes may be destabilized. Soil can be lost by debris slides on hillslope and debris flows in gullies, by erosion from road surfaces and ditches, and from the soils exposed on road cuts and fills. Away from roads, the soil surface can be damaged by yarding, using ground-based equipment during logging and stand tending, and constructing backspar trails and fireguards. Consequently, the forest floor is removed, and surface soil may then erode.

In monitoring slope stability, key indicators are the number of failures and the volume of soil displaced in a unit of time.

Key indicators for monitoring slope stability are:

- the number of failures and volume of soil displaced per unit time

  Because these processes are subject to weather conditions, observations on sites subject to forestry activities should be compared with observations on sites that are undisturbed, and with baseline observations obtained on sites before disturbance. Maintaining slope stability within the regime observed on natural slopes is critical to maintaining soils and soil productivity.

In monitoring soil health, key indicators are forest floor cover and foliar analysis.

Key indicators for monitoring soil “health” are:

- forest floor cover (or the obverse, mineral soil exposure)

  Maintaining the forest floor is critical for mineral soil protection in the Clayoquot environment. Loss of forest floor cover is readily measured, and successful repair of disturbed or damaged sites can be measured by re-establishment of a functional forest floor (re-establishment of grass cover for erosion control is only the first step in this process). The forest floor is key to forest nutrition, so monitoring its cover is relevant to monitoring long-term productivity of the soil system. Maintaining the forest floor cover also greatly dampens soil temperature fluctuations, which ultimately can affect stream temperature regimes.

- foliar nutrients

  In analysis of foliar nutrients, the tree is used as a natural integrator of environmental (including soil environment) conditions; that is, as a bioassay. Maintaining the soil nutrient pool is central to long-term productivity, but extremely difficult to monitor directly. Foliar nutrient content varies less than soil nutrient status, and considerable experience exists concerning what constitutes adequate foliar nutrient levels. Foliar nutrient analysis would be triggered when observable signs of deficiency become apparent (e.g., chlorosis or other changes to foliage colour or form).

- soil biology

  This indicator is also very difficult to monitor directly. Indirect integrating measurements, such as soil respiration rate, exhibit great variability. Consequently, as with nutritional status (with which soil biology is inextricably linked), the use of foliar analysis appears most feasible since it encompasses the links among biological, chemical, and physical aspects of the soil complex.

In monitoring hillslopes, key indicators are debris slides, debris flows, and other mass movements.

On hillslopes, the most useful monitoring technique is to maintain a record of all debris slides, debris flows, and other mass movements. For those events detected soon after their occurrence, antecedent weather conditions should be recorded. Unfortunately, most failures probably will be detected retrospectively and will be assignable only to a general period of time. The event record should include location, position and slope gradient of the initial failure (headscarp); measured or estimated length, width, and volume of displaced material; length of runout; ground cover condition; and stream course effects. Actions or conditions known to have caused the failure should be recorded, as should the headscarp position in relation to roads and cutblock boundaries. The most important comparison will be between rates of slope failure on disturbed and undisturbed sites. Analysis should be conducted at watershed and subregional scales or planning levels.

The comparison of slope failure between disturbed and undisturbed sites is important.

For roads and other deliberately converted surfaces, the current B.C. Ministry of Forests methods for determining the percentage of land removed from production are adequate. Erosion from these surfaces can be monitored by direct observation (e.g., of rills and ditch-line erosion), if necessary through reference to driven steel pins. Conditions must be monitored often enough to anticipate slides and accelerated surface erosion, and take corrective action. The quality of road drainage water, particularly the content of fine sediment from active roads, represents a generally uncontrolled problem where the water is routed directly into a stream channel. Monitoring should identify sites where this occurs so that corrective action can be taken.

In monitoring roads and other deliberately converted surfaces, erosion is the key indicator.

Soil properties are measured at individual sample sites. A monitoring program may be conducted on a site level (as part of documentation of the impacts of site disturbance), or on a watershed level (as part of the assessment of regional disturbance). In the latter case, standard statistical methods of sampling for areal proportions should be used.

8.2.2 Monitoring Stream Channels

The overall goal established for stream channels is to maintain the integrity of aquatic ecosystems.

The overall goal established for stream channels is to maintain the integrity of aquatic ecosystems by managing the watershed system to prevent alterations to hydrological regimes and water quality, loss of riparian vegetation, and changes in channel structure that reduce channel integrity and dependent biological productivity. To this end, the following objectives must be achieved:

1 to maintain waterflows and critical elements of water quality within the range of natural variability on both seasonal and event bases;

2 to maintain the character of the riparian area and the full-length integrity of the stream channel system (see also Section 8.3);

3 to minimize deposition of fine sediment and sand in the channel system and maintain the quantity and quality of spawning gravels; and

4 to maintain the structural diversity of channels by maintaining the volume, stability, and distribution of large woody debris, and to manage the riparian area to assure a continuing supply of this debris.

Changes in forest cover and in the hillslope drainage system change waterflows and quality.

Changes in runoff amount and timing, and in water quality drive significant changes in stream systems. Changes in the forest cover (affecting interception and transpiration of water) and in the hillslope drainage system (as by roadbuilding) change waterflows and water quality. Streamflow and water quality changes are principally monitored in gauging networks designed at the subregional level, and observations must be continued for years to resolve significant changes. Potential approaches are discussed further in Section 8.2.3.

Stream channels are a critical focus for monitoring activity because maintaining natural conditions along the channels is essential for maintaining water quality and aquatic ecosystems. Changes in the stream channel are detected by observations at the site to watershed levels. Land use may induce changes in channel morphology by changing the runoff regime or the influx of sediments, or by directly interfering with the channel. Many physical and biological variables indicate change. The most informative variables are those that give the quickest warning that forest operations should be stopped or modified to avoid serious damage, and those that measure the properties of flowing water that most directly affect the aquatic biota.

The following physical factors damage life in fresh water most rapidly:

- loss of shading causes water temperature to rise, disrupting life cycle timing for some organisms and, in extreme cases, posing a mortal threat;
- increased duration of high flows compels organisms to spend unusual amounts of time and energy seeking shelter, and more frequently washes away populations of drift organisms;

- the deposition of fine sediments smothers streambed organisms by depriving them of dissolved oxygen. Suspended sediment in fast-flowing water kills benthic organisms by abrasion and, if persistent, damages the gills of fish;
- shifting of bed material grinds and destroys egg nests; and
- the washing out of log jams releases substantial quantities of stored bed material which is transported downstream, and destroys the deep, calm pools that provide the habitat needed by many species.

In monitoring life in fresh water, changes in factors such as shading of riparian zones and flow levels should be monitored.

Monitoring efforts should therefore concentrate on changes in the following factors: shading of riparian zones; flow levels; quantities of suspended sediment; turbidity; dissolved oxygen in the water column and in gravel interstices; substrate permeability; abrasion at streambed level; bedload movement; and the dislodging or circumvention of natural log jams. For practical purposes, these factors must routinely be inferred from simple measurements of channel disturbance.

To investigate compliance with the *British Columbia Coastal Fisheries/Forestry Guidelines,* a program of audits has recently been conducted for stream channels in and adjacent to forest cutblocks (e.g., Tripp *et al.* 1992; Tripp 1994a and 1994b). This program demonstrates a practical approach for monitoring stream channel morphology. A sampling approach is appropriate because continuous observations at more than a very few sites are prohibitively expensive, and monitoring environmental conditions by sample data from many sites is more valuable than detailed data from only a few sites. Measurements are made at site level for interpretation at the watershed level. The Panel makes three suggestions for stream channel audits:

A program of stream channel audits should become an integral part of planning and post-development monitoring.

1 a program of stream channel audits should become an integral part of planning and post-development monitoring;

2 the program should incorporate audits of undeveloped stream reaches (including pre-development audits) to provide a growing body of reference data of natural conditions (see Section 8.1, R8.1); and

3 the program should incorporate some observations that are not necessary in all audits.

Basic observations in repeated stream audits for designated reaches should include length of channel along which the forest has been cut to streambank (re. channel shading); length of bank with active erosion, and evidence of scour and sedimentation (re. sediment movement); amount and distribution of large organic debris in the channel; and length of pool, riffle, and glide habitat (re. channel structure). Many of the observations should be photographically recorded. For major channels, consideration should be given to obtaining helicopter-based video or 70-mm stereo photography. Audits should also include basic measurements of channel morphology incorporated into a sketch map of the channel which shows principal pools, riffles, log jams, and side channels. Log jam status and side channel access should be carefully noted.

Additional procedures that should be added to some stream audits include sampling of streambed gravel texture (particularly to determine the content of fine materials; Rice 1995), sampling of dissolved oxygen and permeability within streambed gravels (Terhune 1958), and counting benthic organisms. These observations require special equipment or laboratory procedures, and skilled personnel. The level of training is not, however, prohibitively great. Surrogate measures may substitute for the most expensive procedures. For example, dissolved oxygen concentration tends to vary inversely with the amount of fine sediment in the bed sediments; hence particle size analyses give an approximate inverse measure of substrate dissolved oxygen that need be calibrated only occasionally. In research studies, "gravel bags," samples of clean streambed gravel enclosed in mesh sacks or trays, have been planted in the streambed for later recovery to determine the rate of fine sediment deposition (Carling and McCahon 1987). This technique could provide a useful surrogate for assessing several of the key factors previously listed (e.g., suspended sediment, turbidity, substrate oxygen, and permeability), and should be tested for operational use.

Stream systems integrate source effects from everywhere in the contributing catchment.

Stream systems integrate source effects from everywhere in the contributing catchment. Therefore, the proposed monitoring is best achieved by combining measurements at watershed and site levels. Gauging sites provide measurements of runoff processes that summarize the integrated effects of all upstream conditions. But if a gauge site is far from a severe but local disturbance, the effect may remain difficult to detect. In particular, much of the sediment mobilized at a disturbance site may settle out along the channel before it reaches a gauge point. Therefore, channel audits will be the focus of monitoring activity related to site development. Individual audit sites will cover a reach of channel approximately 100 channel widths in length (which should include 15–20 pool/riffle units if the channel has normal fluvial spacing of pools and riffles). To obtain sharper resolution of stream channel disturbance at sites that have evident impact upon the stream channel, observations should be made upstream of the site, and at a sequence of downstream sites to the point where traces of disturbance disappear. To understand short-term, acute response of the stream channel, observations will be required on a seasonal basis for one or two years.

Audits should be conducted on all channels with gradients less than 8% and on all primary channels known to harbour fish.

Audits should be conducted on all Type 1 channels (see Figure 7.4 and Appendix II) and on all primary channels known or expected to harbour fish. Other channels should be audited on a sample basis, except that audits should be conducted in all community watersheds. The schedule of audits should be random except for acute effects monitoring (discussed previously), when contributing to particular sampling designs (e.g., pairwise comparisons), or in community watersheds, which should be audited for stream channel condition on a regular basis. For channels that must be audited, pre-development, immediately post-development, then once in five years will be a reasonable schedule, except that reconnaissance inspections should also be conducted after regionally extreme flooding (i.e., estimated 25-year event or greater).

8.2.3 Regional Monitoring of Streamflow and Water Quality

In monitoring streamflow and water quality, a key indicator is water balance.

As noted, significant changes in stream systems are driven by changes in runoff amount and timing and by changes in water quality. Flows of water vary with changes in climate (affecting water inputs), forest cover (affecting interception and transpiration of water), and physical changes at the surface (affecting water routing). Monitoring these changes and their effects involves monitoring the water balance. The principal quantities involved are precipitation, evaporation (including transpiration), and runoff. For monitoring, it is necessary to measure precipitation and runoff. Runoff usually is measured as streamflow; precipitation is measured at fixed points by bucket gauges. Both measurements entail continuous monitoring for some years to encompass synoptic, seasonal, and year-to-year fluctuations in weather. Therefore, a program of observations is expensive. Standard analytical methods for dissolved oxygen, specific conductance, and optical turbidity are described in Environment Canada (1981). However, modern field probes allow direct measurement and recording in the field.

A long period of measurement is necessary for water quality parameters.

Water quality varies on time scales similar to runoff, and so a long period of measurement is necessary for water quality parameters as well. In the past, grab samples have sometimes been taken to check water quality. With this method, the chance to sample occasional extreme events, which may be of paramount ecological interest, is relatively low. Sampling that does capture such events entails expensive continuous runoff and water quality monitoring procedures. Both time and cost commitments make these procedures impossible in inventory, planning, and monitoring associated with forest site development. Nonetheless, this information is important for assessing the effects of forest development on watershed integrity.

Within the 3500 km^2 area of the Clayoquot Sound region there is no stream gauge.

Precipitation and stream gauging measurements have been recognized as the responsibility of specialized government agencies (specifically the Atmospheric Environment Service (AES) and the Water Survey of Canada (WSC), both agencies of Environment Canada). For these agencies—which maintain stations for several purposes and ensure that data are obtained uniformly with a high level of quality control—collecting information on a regional scale that is useful for forest land management requirements is impractical. Over the last 25 years, land and water management agencies, including the B.C. Ministry of Forests, have gained experience collecting data for land management purposes, sometimes in cooperation with industry. No stream gauge is installed within the 3500 km^2 area of the Clayoquot Sound region, and reporting precipitation gauges are found only in the main settlements. (An example of an intensive hydrological and water quality monitoring program is available from the research watershed at Carnation Creek, on the south side of Barkley Sound.)

Techniques and instruments developed within the past 15 years make gauging and water quality monitoring programs practical at a scale that would detect the effect of forest land use on streamflow and water quality regimes on a subregional basis. It appears most appropriate for the land management agencies and land users to conduct and finance the program. Regional AES/WSC networks remain important in a monitoring strategy as the long-term reference stations by which additional gauging may be assessed for quality of records and significance of trends, and to detect long-term environmental change.

It is reasonable to expect to have three or four operating stream gauges, and perhaps six precipitation gauges.

Within the Clayoquot Sound region, it is reasonable to expect to have three or four operating stream gauges, and perhaps six precipitation gauges (not counting ones established for research purposes). The planned period of record for a gauge should be 10–30 years. This period corresponds with the time to establish the "normal" climate (Landsberg 1958:91–92), and is consistent with the time to establish the effects on runoff of forest harvest (see Section 7.2.4).

In Clayoquot Sound, it would be useful to establish gauges for a large primary watershed and for a small watershed within one of the protected watersheds (e.g., Megin River), and to seek observations for comparison in a basin subjected to development. Because of the long-range nature of the program, it would be appropriate to establish gauging in a basin that is not, at present, highly developed.

As a minimum, individual stream gauges should measure water stage,[149] water temperature, and optical turbidity. It is also possible to install sensors that measure water velocity and discharge directly. Additional measurements should be considered as they become feasible, particularly dissolved oxygen, specific conductance, major nutrients (particularly nitrogen species, because aspects of nutrient cycling at watershed and subregional levels are best determined by monitoring nutrient loading in drainage waters), and organic drift matter. Measurements should yield continuous records of significant fluctuations; regular laboratory analysis of water samples should assess water quality.

The program will be useful only if it includes ongoing analysis and interpretation of the records.

The measurements are conducted within selected watersheds, but the interpretation is made at the subregional level. The data for the region (none exist except for precipitation) may be interpreted to reveal the variability of natural conditions and the effects of disturbance within the wider region of the west coast of Vancouver Island. The program will be useful only if it includes ongoing analysis and interpretation of the records as they relate to climate trends and land use.

The combination of measurements noted for collection at watershed and site levels, and subsequent interpretation at subregional and watershed levels are designed to overcome constraints of great variability and high cost that otherwise would make stream system monitoring onerous.

[149] Water stage is the level of water (in a stream channel, lake, or the sea) measured relative to a fixed datum (which may be arbitrary). Stage establishes a consistent basis for measuring the variation in water level at a place.

8.2.4 Monitoring the Coastal Zone

The goal in the coastal zone is to maintain the integrity of littoral and inshore marine ecosystems.

The goal in the coastal zone is to maintain the integrity of littoral and inshore marine ecosystems. Accordingly, the objective for the coastal zone is

- to maintain the physical integrity of the littoral and inshore marine zone (including all waters in inlets and embayments with restricted circulation).

Most of the coastline is rock, and the exposed coast has exceptionally high wave energy. The main threats to coastal integrity arising from forest activity are increased fine sediments in the water column and sedimentation around certain river mouths (especially near the heads of inlets), and physical damage and sedimentation of bark and wood debris at log dumps, booming grounds, and storage sites. It is unlikely that increased stream-delivered sediments would pose considerable marine problems before concerns had been identified in the contributing stream system. Hence, in both cases, sites where specific attention is required can be identified. Effective monitoring will be site-specific, and may require underwater inspections, depending upon the nature of the marine resources threatened (e.g., herring spawn sites, shellfish beds; see also Section 8.3.5).

The security of beaches and of the intertidal zone is subject to a more widespread concern. Drift logs, or a locally changed pattern of longshore sediment drift created by facility installation, may influence patterns of natural scour and sedimentation in the long term. Aerial photographic surveys about every five years may provide the best early warning of change.

8.3 Monitoring Biological Diversity

Definitions of biological diversity consider three levels of organization: genetic, species, and community or ecosystem levels.

Maintenance of biological diversity is inextricably related to the long-term maintenance of healthy, productive ecosystems.

Almost all definitions of biological diversity (or "biodiversity") consider biodiversity at three levels of organization: genetic, species, and community or ecosystem levels. Many definitions, particularly those of management agencies, recognize ecological processes or functions as well. Careful reading of international agreements and other policy statements indicates that definitions of biological diversity attempt to encompass four major public concerns or goals through maintenance of biological diversity: (1) reduce rates of species extinction, (2) retain future options, (3) maintain healthy ecosystems, and (4) respect other species (Bunnell 1995b). In both reality and policy, maintenance of biological diversity is inextricably related to the long-term maintenance of healthy, productive ecosystems. The Panel recognized this relation in its goals for maintaining biological diversity:

- to maintain all naturally-occurring species and genetic variants such that they are able to persist over the long term and adapt to changes in their environment within the normal range of variation;

- to maintain the functional integrity of ecosystems recognizing the connections between terrestrial, freshwater, and marine processes. (Scientific Panel 1994a:36)

The maintenance of biological diversity thus consists in maintaining ecosystem integrity and connections, and ensuring the survival of all the species and species' variants of plants, animals, and fungi that together form the natural indigenous biota of an area. Biodiversity objectives thus depend upon attaining objectives for watershed integrity (Section 8.2). In framing objectives for these goals, the Panel acknowledged relations between ecosystem function and biological diversity, and the role that maintenance of diverse habitats must play in maintaining biological diversity. These objectives are as follows:

- to maintain ecosystem function by protecting the integrity of riparian areas from the terminus to the headwaters of watersheds;
- to protect habitats of known importance to particular species;
- to maintain old-growth and forest-interior habitats; and
- to use forest management techniques that produce stand structures, species composition, and landscape patterns similar to those generated by the natural disturbances of forests in Clayoquot Sound. (Ibid.)

Maintaining habitat is the first step in maintaining biological diversity.

Monitoring for these other objectives might be pursued by focusing on the organisms themselves, or on habitat availability. Panel recommendations for planning (Chapter 7) and silviculture (Chapter 4) are intended to maintain habitats either through reserves or retention of habitat elements during harvesting. These recommendations are meant to avoid habitat fragmentation and the consequent isolation of small populations of normally widespread species, and to produce stand structures and landscape patterns similar to those generated by natural disturbances. Unnaturally small and isolated (fragmented) populations are at risk of extirpation or extinction for two reasons: they may simply die out, because of chance fluctuations in population size; and inbreeding may have deleterious effects on population viability by altering natural heterozygosity. Approximating naturally occurring stand structures and landscape patterns should maintain habitat, the first step in maintaining biological diversity.

Nowhere has an effective approach for maintaining biological diversity within a managed forest been demonstrated.

Because many species are either poorly known, or unknown, and Panel recommendations focus on habitat, monitoring also focuses on habitat. That approach invokes a major assumption that current measurements of habitat usefully represent the organisms themselves; this assumption must be evaluated by research and long-term monitoring. Hence, both organisms and habitats must be monitored in complementary contexts. It is important to recognize that, although widely believed to be possible, an effective approach for maintaining biological diversity within a managed forest has never been demonstrated.

Monitoring for biological diversity must initially test two major assumptions made by the Panel in its efforts to make maintenance of biological diversity an attainable, practical goal in managed areas: (1) the assumption that maintaining recognized habitats serves to maintain biological diversity; and (2) the assumption that Panel recommendations for planning of reserves and maintenance of a diverse forest through new silviculture strategies, which centre on habitat, will serve to attain the goals and objectives noted on the previous two pages.

Monitoring will necessarily be largely indirect.

Though organisms and habitats must both be monitored, monitoring of biological diversity at the species and genetic levels will necessarily be largely indirect. It will concentrate on the maintenance of representative habitats and connectivity among habitats. Monitoring at all levels of planning has consistent elements because movement or dispersal abilities of organisms span an enormous range of spatial scales. What constitutes an appropriate distribution or sufficient amount of habitat to facilitate movement and interbreeding is distinct for each species and unknown for most species. Management will have failed if the range of any species gradually shrinks, or if naturally well-distributed species are absent from large areas for several decades.

Concentrate on the maintenance of representative habitats and connectivity among habitats.

Other than the indirect monitoring to ensure that representative habitats are retained without barriers to movement between them, monitoring should exploit approaches offered in Sections 8.3.2 through 8.3.4. It should be augmented, however, with a concerted inventory and research effort in a selected group of watersheds (some contiguous) to ascertain if Panel recommendations serve to maintain genetic exchange among populations and genetic diversity across the landscape.

8.3.1 Monitoring Genetic Variation

Genetic variation is the underlying basis for biological diversity.

Although genetic variation is the underlying basis for biological diversity, direct monitoring of genetic diversity for all species is wholly impracticable. Moreover, maintaining the processes that create and maintain genetic variation within and among populations is more important than preserving a “snapshot” of existing genetic diversity. Nonetheless, actions that deplete known genetic diversity contravene the *United Nations Convention on Biological Diversity* (June 1992).[150] To attain the complex goal of maintaining both genetic richness and the processes creating genetic variation, three objectives must be attained:

1 to maintain known genetic variation within the biota;

2 to ensure sufficient connectivity within naturally widely distributed populations such that viable populations of all indigenous species and their genetic richness are maintained; and

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[150]One of four documents produced at UNCED ’92 (the “Earth Summit” held at Rio de Janeiro in June 1992). The *United Nations Convention on Biological Diversity* commits signing nations to conserve biological diversity, to use biological resources sustainably, and to fairly and equitably share the benefits of biodiversity. It is the first international agreement to cover all genes, species, and ecosystems.

3 to maintain the *total* genetic variation within species comprising naturally isolated populations.

Usually, genetic diversity is undetectable without costly and time-consuming work.

Patterns of genetic variation within the biota are poorly known for most species. Visible polymorphisms and subspecies could be monitored relatively easily; in most instances, however, the degree to which visible differences reflect genetic variation is unknown. Usually, genetic diversity is undetectable without costly and time-consuming laboratory work. Such effort could be justified for only a few species. The first step should be to maintain visible variation. Monitoring for this step is the same as that needed for monitoring biological diversity in the general sense (e.g., Section 8.3.3), but recognizes visible distinctions within species.

A key indicator is the dynamics of species ranges.

With respect to the second objective, for species with large continuous geographic ranges, scientists believe that maintaining the ranges of these species (i.e., preventing the loss of local populations and preventing peripheral erosion of the ranges) will maintain the genetic richness of the species. Maintaining connectivity within such populations helps to maintain viability by ensuring that small, isolated, and vulnerable subpopulations are not created. A key indicator is the dynamics of species ranges: appropriate monitoring should focus on detecting whether ranges are shrinking, or new gaps are appearing in the interior of the range. In large part, that monitoring must initially be accommodated through approaches described in Section 8.3.3, but interpreted at the subregional level. At the watershed and subregional levels, a key indicator to evaluate apparent connectivity is the continuity of habitat. This approach is necessarily indirect, and must be augmented by research to ensure that habitat linkages that ensure connectivity are effective in allowing movement of organisms.

The most species-rich habitat islands are hydroriparian systems in deep valleys.

The first two objectives focus on maintaining existing genetic richness; the third objective directly addresses some processes creating genetic variation within discontinuously distributed species. Many species do *not* have extensive continuous ranges. These species survive only in isolated, sometimes widely separated “habitat islands” where conditions are right for them; and they rarely, if ever, migrate from one “island” to another. In Clayoquot Sound the most species-rich habitat islands are hydroriparian systems in deep valleys, enclosed by the sea on one side and surrounded on the landward sides by high mountain ridges (Sections 2.2.3 and 2.2.4). The majority of species confined to such areas have existed as local, reproductively isolated populations for such long periods that the local populations have diverged genetically. The *total* genetic diversity of a species with many independent populations that rarely interbreed is likely to be considerable.

The challenge is to avoid increasing the rate at which naturally small and localized populations become extinct while not decreasing the rate at which similar, but new, populations are established. Meeting that challenge will maintain genetic variation and the processes creating it. Researchers and practitioners face a dilemma: isolation occurs naturally and produces genetic variation, but isolation also can reduce existing genetic richness and lead to local extinction. Currently, there is little guidance regarding potential outcomes of isolation for different species (e.g., Slatkin 1987). The first step must be to evaluate the interchange within species known or suspected to have continuous distributions (e.g., most birds, bears, and deer), and to maintain the scattered habitats of species naturally occurring as largely isolated populations (e.g., sedentary amphibians, resident fish populations, and flightless invertebrates).

A key indicator of probable success is the degree to which the natural range of habitats is represented within reserves.

Given that all species occurring naturally as small, genetically distinct populations are not known in Clayoquot Sound, a key indicator of probable success is the degree to which the natural range of habitats or ecosystems is represented within the reserve system. Monitoring the success in attaining this objective initially must focus at the subregional and watershed levels to ensure that the full range of natural habitats are represented in reserves. Given that hydroriparian systems tend to be isolated from other ecosystems, it follows that both species and habitats should be monitored diligently in those systems.

Maintaining riparian ecosystems contributes significantly to maintaining biological diversity at larger scales.

Monitoring of genetic variation must be indirect and should focus on the maintenance of representative habitat and connectivity among habitats. Although not fully tested, it appears that maintaining the integrity of riparian ecosystems contributes significantly to maintaining components of biological diversity at larger scales (e.g., subregional and watershed levels; Naiman *et al.* 1993). Intact riparian networks not only maintain many small, genetically distinct populations, but likely permit movement within larger, more widely distributed populations as well. Monitoring generally relies on approaches of Sections 8.3.2 through 8.3.5 but usually is interpreted at the larger scales (subregional and watershed levels). Because it is especially indirect, augmentation by a concerted, more intensive inventory and research effort is particularly important.

8.3.2 Monitoring Vulnerable and Rare Indigenous Species

Monitoring effort required is not the same for all species.

In Clayoquot Sound, the monitoring effort required is not the same for all species. One monitoring objective is

- to ensure that particular species known or suspected to be at risk are monitored and their habitats protected.

The Panel's recommendations for planning of reserves and maintenance of habitat during harvesting cycles are intended to maintain sufficient old-growth habitat.

To meet this objective, species at greater risk may require greater monitoring effort. These species are largely restricted to late seral (old-growth) forest habitat. Such habitat is not currently limiting these species in Clayoquot Sound, but it is impossible or requires very long periods to replace once removed. Moreover, current logging in Clayoquot Sound removes older forests. The Panel's recommendations for planning of reserves and maintenance of habitat during harvesting cycles are intended to maintain sufficient old-growth habitat that no such species are placed at risk.

It is important that habitats and species be monitored jointly.

All the *known* endangered, threatened, or rare species of the province are currently red- or blue-listed. For some of these species, relationships with specific habitats are poorly known; all merit special attention. There are no generalizable indicators for monitoring these species. Each species is unique, and advice on monitoring procedures must be sought from appropriate experts. Given that forestry practices usually alter habitats rather than impact species directly, it is important that habitats and species be monitored jointly. There also will be several as-yet undiscovered rarities among the vast collection of organisms for which monitoring procedures are poorly defined (e.g., insects, spiders, microfungi, and soil organisms). These species can only be monitored indirectly, by maintaining Clayoquot Sound's great diversity of habitats.

Very intensive monitoring, including measures of genetic and population dynamics, may be appropriate for some vulnerable species. Morphological characteristics can be useful (e.g., regression of weight upon length of the young in some amphibian species reflects population health and may presage population declines). Monitoring of vulnerable and threatened plant species could include measures of growth or reproductive output. But, for many species, a checklist approach (Section 8.3.3) must suffice until they are well enough understood that efficient alternative means of monitoring are developed.

8.3.3 Monitoring Terrestrial Environments

The Panel considers the sustained, widespread distribution of indigenous species and their habitats to be an operational, but untested, strategy for maintaining genetic diversity (Section 8.3.1). Species at risk merit special attention (Section 8.3.2). Persistence of most species, however, must be assessed by other means. This section discusses the general monitoring of species and their habitats to meet objectives of Section 8.3 directly relating to the goal of maintaining all naturally occurring species, and contributes to the more specific objectives of Sections 8.3.1 and 8.3.2.

Monitoring contributes to evaluating the success of the proposed forest management system, and to determining potential thresholds of habitat change.

Indicators that should be monitored fall into two broad categories: (1) those that research indicates are detrimental to maintaining biological diversity (e.g., forest fragmentation and isolation, deleterious edge effects, invasive introduced species); and (2) species and their distributions that relate directly to the goal of maintaining natural species and their genetic variation. Monitoring can thus contribute not only to evaluating the success of the proposed forest management system, but also to determining potential thresholds of habitat change and early warnings of population declines. Processes contributing to the maintenance of biological diversity operate over a wide range of spatial and temporal scales (Soulé 1985; Bunnell and Kremsater 1994), and monitoring must incorporate those scales.

Subregional Level

Analysis of species' distributions as a strategy for maintaining genetic richness occurs at the subregional level.

At the subregional level, managers must assess whether objectives for forest age-class distribution, rate-of-cut, and connectivity among habitats are being achieved. Variables that can be measured at the subregional level include the frequency distribution of patch sizes and age-class distributions for major forest types; location and extent of linkage areas between habitat units (conversely, degree of fragmentation); frequency and extent of major disturbances (such as fire and wind); rate of forest removal by all causes; road density; and amounts of edge. Some of these measures involve only map and air photo interpretation. Others require more effort. For example, determining the effectiveness of cross-watershed linkage areas requires monitoring the use of these corridors by particular species. Analyzing the distribution of species as a strategy for maintaining genetic richness also occurs at the subregional level.

Watershed Level

At the watershed level, appropriate variables are similar to those of the subregional level, with additional measures of patch shape, more detailed records of events contributing to the natural disturbance regime, and indicators of watershed integrity noted earlier (Section 8.2). For example, the objective of maintaining the soil nutrient pool partly depends on the soil biota, but that biota is not itself monitored; its general health is monitored by foliar analysis (Section 8.2.1).

Comparisons of data collected at different levels can reveal trends important to management.

Detailed accounts of wildfires, windstorms causing blowdown, landslides, stream avulsions and other such events that influence the natural disturbance regime should be recorded for developed and undeveloped areas. These latter records will document the range of natural variation. Interpretation of potential habitat effects (e.g., amounts of edge, forest age-class distribution, snag abundance) on species should occur at this level. Acquisition of data on species, however, will occur at the site level and be aggregated at the watershed level.

Site Level

Most work to acquire species-specific information must take place at the site level.

At the site level, indicators of habitat diversity and utility include patchiness; vertical structure of the forest; and presence of habitat elements such as snags, wildlife trees, and downed wood. An important index of biological diversity is species composition, including the frequency and extent of any invasive exotic species. Most species-specific information must be acquired at the site level (see Species, below). It is important to monitor both habitats and their elements, and the amount and kind of use that these habitats or elements receive. For example, measuring the use of wildlife trees by wildlife is far more useful than simply counting the numbers of wildlife trees. Where individual wildlife trees are retained, a representative sample should be monitored to determine what species are using them before and immediately after logging or stand tending, and at intervals thereafter.

Wetlands are an important component of the natural forest. The location and extent of wetlands should be mapped, and their type (e.g., lake, pond, swamp, fen, bog) recorded; any unusual species they contain should be noted. Also, changes in the extent and flora of wetlands may indicate undesired hydrological changes.

At the watershed and site levels, monitoring activities generally will require on-the-ground assessments.

Species

Species are monitored at the site level for interpretation at all three levels. For general monitoring of species present (see Section 8.3.2, Rare Species), the Scientific Panel recommends two approaches: using indicator species and using checklists. The two approaches address different questions. For each approach the level at which assessments are conducted is important, and comparisons of data collected at different levels can reveal trends important to management.

An indicator species is intended to document trends occurring in a number of species.

An indicator species is intended to document trends occurring in a number of species (e.g., cavity nesters of a particular size class). Ideal indicator species occur widely in the region of concern; have changes in population size that foreshadow habitat change; are easy and inexpensive to observe during all seasons; and respond differently to natural and human-induced environmental changes. No such ideal indicators exist and one species never fully indicates the requirements or responses of many other species (Sidle and Suring 1986; Landres *et al.* 1988). The Panel suggests realistic and moderate expectations of indicator species and a broad use of the indicator species concept, including monitoring key species, key habitats (e.g., old growth), and key components of structure and function (e.g., forest floor cover). Candidate indicator species should be selected to evaluate known potential threats. Some species have large area requirements, some are sensitive to human disturbance, and some rely on particular structural elements of the forest (potential candidates are presented in Appendix III). Attention should focus on such species. Each indicator species will be subject to specific monitoring techniques.

Indicator species should be selected to evaluate known potential threats.

Checklists are a simple listing of all species found in an area. They should provide a comprehensive listing of species and are particularly informative when compared to baseline checklists from large natural areas. When checklists are used for monitoring their shortcomings should be kept in mind. Checklists are strongly affected by the extent of the area and the mobility of species monitored; cannot indicate the future viability of any species; have little predictive value themselves for impending problems; and show decreasing sensitivity to changes in distribution and abundance as the sample area within which data are collected increases.

Despite their limitations, checklists provide an overview of species diversity.

Despite their limitations, checklists provide an overview of species diversity. When applied at the site level in conjunction with habitat measurements they indicate relations among monitored habitat elements (e.g., snags, downed wood) and individual species. When compared across a range of sites they help to address questions concerning how much of each element should be retained. At the watershed and site levels they help to evaluate the role of reserves in maintaining species and permit evaluation of the distribution of forest type and age class, including forest patch size and potential edge effects. At watershed and subregional levels the interpretation of repeated and well-distributed site-level checklists can reveal growing "holes" or empty areas in a species range, thus potential problems.

Number of species is not a satisfactory indicator.

Checklists should be analyzed primarily for the identities of species present. Number of species is *not* a satisfactory indicator because it can include undesirable invasive species, such as starlings, cowbirds, or Scotch broom, that may have been absent formerly. Moreover, the number of species present in an area varies naturally among ecosystems; more is not necessarily better. Upward trends in pioneer species, such as savannah sparrows or fireweed, in areas intended to maintain old-growth characteristics would indicate that the intentions likely were not being met.

Checklists can be compiled for the following non-motile organisms: vascular plants, mosses, macrofungi, liverworts, and many lichens. Motile organisms that can be checklisted include all mammals, birds, amphibians, and molluscs. Checklisting is impracticable, however, for many kinds of organisms, in spite of their ecological importance and abundance. Current lack of taxonomic knowledge and sampling difficulties make it impracticable to use a checklist approach for organisms such as: insects, spiders, and other arthropods; microfungi, including moulds; and the soil biota generally. Epiphytes restricted to higher levels of the canopy are practically inaccessible.

Locations must be coordinated with habitat monitoring to permit effective interpretation.

Standardized methods of collecting data, must be established and used consistently by checklist compilers. A growing body of literature on the approach (e.g., Kremen 1992; Green and Young 1995) can be adapted to conditions in Clayoquot Sound. Locations must be coordinated with habitat monitoring to permit effective interpretation. The most effective approach is likely a nested hierarchy with focal sites in selected watersheds (monitored seasonally to annually) nested within more extensive monitoring done every two to five years.

8.3.4 Monitoring Old-Growth Characteristics

One of the Panel's objectives in maintaining biological diversity is to maintain old-growth and forest-interior habitats.

One of the Panel's objectives in maintaining biological diversity is to maintain species associated with old-growth and forest-interior habitats.

As noted in Section 8.3.3, interpretation of checklists at the watershed and site levels helps to evaluate the success of reserves in maintaining such species. Old-growth forests represent distinct habitat types for two reasons: they sustain a distinct biota, and once removed they are impossible, or require long periods, to replace. Considered as a whole, old-growth characteristics comprise the characteristics of: the trees themselves, all other life forms in the forest, and many distinctive habitats and their elements (e.g., large downed wood), as well as distinctive aquatic habitats associated with old-growth forests. Trees are treated separately from other species because big, old trees themselves provide a variety of habitats for other species and form the major structural elements in the forest. These features are considered in turn.

1 The size class and age class distributions of each tree species are inevitably altered within cutting units. To meet the intent of the variable-retention silvicultural system recommended by the Panel, these changes in size class and age class distributions must be constrained to ensure that the forest within a watershed does not lose species from its natural fauna and flora. The stringency of constraints necessary to achieve these objectives is poorly known.

Monitoring should address two broad questions:

Does the current system defining forest age classes accurately reflect changes in biological diversity among stands of different age?

- First, does the current system defining forest age classes accurately reflect changes in biological diversity among stands of different age? The Panel considers age classes 8 and 9 (141 years plus) as late successional, but recognizes that some old-growth features likely become common only in forests much older than 140 years (e.g., large branches high in the canopy with their associated flora and fauna). For practical monitoring, a subdivision of the oldest age class (e.g., 400 years plus) may be important. Alternatively, because forests attain recognizable old-growth features at different rates on different sites, some index of old-growth features may be more useful. Moreover, old-growth features tend to appear at different rates: canopy gaps at 100–200 years, well-developed multi-storied canopies at 250–300 years, large snags at 300–400 years. Given the all-aged nature of natural forests in Clayoquot Sound (Section 2.2.2), an old-growth index will be more accurate and should be developed and tested for these forests, but designation of one or more new, older age classes may be more practical in the short term.

At what rate are microhabitats or habitat elements created within aging forests?

- Second, at what rate are microhabitats or habitat elements (e.g., decayed snags) created within aging forests? Projection of future habitats is relatively easy in even-aged forests, but natural forests of Clayoquot Sound appear all-aged and rates of habitat development are poorly known. Plots (likely larger than any appropriate for checklisting) should be established to estimate rates of habitat development in an array of harvested and unharvested forest types, including reserved areas. These plots would be broadly equivalent to permanent sample plots, but would incorporate elements of items 2 and 3 following. After initial concentrated efforts to establish an old-growth age class or index of old-growth, they should be sampled every five years.

Information should be acquired at the site level for interpretation at the watershed level to monitor success in maintaining old growth and its associated biota.

2 Monitoring all other forest life is the same as monitoring biological diversity, and has been described in Sections 8.3.2 and 8.3.3. Most species can only be monitored indirectly because they are numerous; are mostly unseen or unnoticed; occupy an enormous array of different habitats and microhabitats; or are presently unknown to science. As discussed earlier, the only feasible way to monitor them is by monitoring habitats.

The diverse array of microhabitats and their elements is a defining characteristic of old-growth forests.

3 The diverse array of microhabitats and their elements is a defining characteristic of old-growth forests, and offers promise for creating an index of old-growth features. Most simply, the diversity of habitats within old-growth forests results from the range of tree sizes and ages; the presence of dying, dead, or fallen trees, among healthy, growing trees; and consequent canopy gaps with associated, productive understory. Until research provides specific focus, the range of these habitats is best monitored by means of checklists of features known or suspected of being important to maintaining biological diversity and associated functions. These lists should be compiled at the same time as those described in Section 8.3.3. Items to list include gaps and larger openings created by the death of a tree or group of trees; dead-topped and dead trees; downed trees and logs, classified by degree of decay; root wads of blowdowns; wide branches of living trees that support beds of moss; hollow trees; and trees of distinct structure.[151]

Monitoring these features (many of which are in the vegetation inventory methodology being developed by the provincial Resource Inventory Committee) contributes to planning by estimating the rate (age) at which habitats develop and the period that they last (snag and downed wood decay), and by evaluating the utility of age-class or habitat elements in assessing resident biological diversity.

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[151]For example, large trees (often remnants from an earlier stand) which are broad-crowned, dominant, and very limby, or trees with “witch’s broom” (an abnormal tufted growth of small branches on a tree or shrub caused by dwarf mistletoe or viruses).

Special habitats are associated with the streams and rivers of old-growth forests.

Equally important are the special habitats associated with the streams and rivers of old-growth forests: submerged logs of various sizes and other woody debris; log or debris dams and the pools they create; pools under overhanging, root-bound banks; backwaters and side channels; flood channels; and stable, long-established floodplains. These features are related to both the physical (Section 8.2) and biological components (Section 8.3.5) of streams. The rationale for monitoring these features is the same as for terrestrial components of old growth: to establish linkages between ecosystem structure and biological diversity, and to focus monitoring on practically measurable features of the system. In addition to periodic sampling, these habitats and their features should be surveyed after major floods.

Monitoring for biological diversity must be undertaken through all stages of forest development.

Biological diversity must be monitored through all stages of forest development. Old-growth characteristics will develop in managed forests as they age. Structures typical of old growth will gradually appear and should be present to some degree within all stages of managed forests developed by the variable-retention silvicultural system.

8.3.5 Monitoring Aquatic Environments

The freshwater aquatic environments of Clayoquot Sound comprise rivers, streams, lakes, ponds, bogs, fens, and swamps.

The freshwater aquatic environments of Clayoquot Sound comprise rivers, streams, lakes, ponds, bogs, fens, and swamps. The Panel's objective in managing and monitoring these areas is to maintain a functioning ecosystem without significant loss of biological diversity. Monitoring of physical habitat characteristics has been considered under watershed integrity (Section 8.2). Biological monitoring also is necessary to ensure that organisms are flourishing in the environment. Sampling will take place at the site or stream reach level. Synthesis and interpretation should be at the watershed level for resident organisms (e.g., plants and amphibians), and at the watershed and subregional levels for migratory animals (e.g., anadromous fishes, many species of waterfowl, and shorebirds).

Indicators are intended to serve as biomonitors of the viability of the environment.

In aquatic environments, as for terrestrial environments, the Panel recommends both an indicator and checklist approach. Indicators are intended to serve as biomonitors of the viability of the environment. For example, the effect on organisms of increased streamflows, or of sediment movement cannot be observed directly. Criteria that include only physical and chemical measurements are presently insufficient to measure biological integrity. The most useful biomonitoring program would record several major taxa and would be very expensive. Micro-organisms and invertebrates are difficult and time-consuming to sample, sort, and identify, and life-history information is often lacking. But extensive life-history information is available for many fish species, representing various trophic levels. In areas where communities of fish are relatively complex, species composition has been used to provide an index of biotic integrity (Karr 1981; Karr *et al.* 1986). As indicators or biomonitors, fish represent a potentially useful, but incomplete, element of a monitoring program. Sampling must be representative of the fish community and include a representative survey of riffles, pools, and other habitat units.

As biomonitors, fish represent a potentially useful, but incomplete, element of a monitoring program.

The protocols that already exist for monitoring salmonid stocks have been inconsistently applied in Clayoquot Sound (Section 2.2.5). Because of the commercial and cultural importance of salmon stocks, consistent monitoring of wild salmon escapements on a watershed and subregional basis is desirable in any case, and a consistent sampling program should be established which also serves ecosystem monitoring purposes. To distinguish the effects of the oceanic environment and harvesting pressures on anadromous fish from those related to the Clayoquot stream environment, sampling of juvenile fish may be required at some sites. Juvenile fish also are often more sensitive to environmental changes than are adults.

Fish are not present in all streams; for completeness a checklist approach is necessary.

Fish, however, are highly mobile, difficult to count, and many are subject to various external factors (especially fishing pressure); they do not represent ideal biomonitors. Nor do fish appear to accurately reflect the state of other aquatic organisms. Moreover, they are not present in all streams. Because the plants and animals of rivers, streams, and lakes form part of the Clayoquot Sound region's biological diversity, for completeness a checklist approach is necessary. For aquatic invertebrates, standard methods for sampling are available. Identifying captured invertebrates to the species level is impracticable, but that precision may be unnecessary for monitoring environmental conditions. A coarse classification into taxonomic orders and families may be sufficient. Changes in the relative proportions of animals in specific groups are potential indicators of changes in water quality and other environmental stresses (Newbold *et al.* 1980; Murphy and Hall 1981). Appropriate indicators have been developed for other areas (e.g., Plafkin *et al.* 1989; Kerans and Karr 1994), and are being explored for south coastal British Columbia.[152]

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[152]W. Neill, J. Richardson, pers. comm., March 1995.

Brackish-water and saltwater environments also require monitoring.

Brackish-water (i.e., estuarine) and saltwater (i.e., marine) environments also require monitoring. Development of appropriate monitoring protocols for estuaries, the intertidal zone, inshore waters, and offshore waters has proceeded rapidly since the oil spills in Prince William Sound (see Dethier 1991, Schroeter *et al.* 1993, and their references). As with other efforts to detect environmental impacts of human activities on natural communities, sampling any aquatic environment encounters the problem of separating human-induced changes from the considerable natural temporal variability of most populations. It is, however, evident that disturbance produced by land-based activities, by logs escaped from booms, and by fish farms can influence the physical environment of the intertidal and shallow subtidal zone, hence the viability of eelgrasses, shellfish, herring spawning areas, and other important inshore marine habitats. Correspondence with individuals developing protocols elsewhere suggests that while research from other areas will prove helpful, a protocol specific for Clayoquot Sound is required.[153] Sources dealing specifically with wood waste, benthic organisms, and log dumps include McDaniel (1973); Levings *et al.* (1985); McGreer *et al.* (1985); and Stanhope and Levings (1985).

One lesson from elsewhere on the Pacific Coast is that frequent sampling of organisms that are long-lived and recruit young sporadically (many marine organisms) will introduce serial correlations,[154] making data difficult to interpret (Schroeter *et al.* 1993). The Panel recommends that the period between censuses for any protocol in Clayoquot Sound should initially be once in every five years, but more frequently in areas of suspected degradation. Monitoring required in connection with maintaining production levels of marine products in the region is discussed in Section 8.4.3.

It is essential that monitoring of the forest not be divorced from monitoring of the sea. Forest and sea are interacting parts of a single ecosystem (Section 2.2.5).

8.4 Monitoring Human Activities and Values

8.4.1 Monitoring Areas and Sites Important to First Nations

First Nations people should participate actively in monitoring.

A detailed consideration of First Nations' perspectives in relation to forest practices standards in Clayoquot Sound, including monitoring, is presented in the third report of the Panel (Scientific Panel 1995b). First Nations people should be requested to participate actively in all aspects of monitoring. Areas and resources of special significance to them should be monitored by them or under their direction.

Many cultural areas and resources should be monitored, including sacred, historic, and current use areas, and a variety of populations and habitats of

[153]For example, M. Dethier, C. Levings, pers. comm., March 1995.

[154]Current status of the population is associated more closely with previous status than with new impacts.

culturally important plants and animal species. Some areas contain sites where visible artifacts, such as unfinished canoes, culturally modified trees, and pictographs require protection. Others—for example, places featured in traditional stories, used for spiritual training, or providing important medicines—are less obvious. Knowledge of such places may be restricted to a very few individuals. Thus it is essential that those people directly affected by possible impacts to such areas participate in monitoring and ensuring their protection.

A complete inventory of culturally important areas and resources is required to enable appropriate planning and monitoring in the context of ecosystem management. Some of this inventory has been completed.[155]

8.4.2 Monitoring Scenic, Recreational, and Tourism Values

Because of the strong interrelationships among scenic, recreational, and tourism values, it is efficient to monitor them jointly. This section describes goals and objectives for scenery and recreation, and monitoring methods to determine the degree to which the objectives are accomplished.

The two goals for maintaining scenic values, first presented in the Panel report *Progress Report 2: Review of Current Forest Practice Standards in Clayoquot Sound* are:

- to manage scenic resources to maximize the enjoyment of those present by ensuring that opportunities for tourism and recreation reflect the inherent quality of resources in an area; and
- to ensure that First Nations [peoples] and other residents are satisfied that the essential elements of the scenery around them are maintained. (Scientific Panel 1994a:43–44)

An abbreviated set of Panel objectives from the same report includes:

- to provide for a range of visual landscape experiences, and to plan these experiences in relation to existing and potential recreational routes;
- to conduct sustainable forest practices and related educational and interpretive programs [for the benefit of the public];
- to apply landscape design principles in all areas; and
- to maintain examples of different types of landscape in a relatively unaltered state.

The two goals for recreation and tourism (ibid.:49) are:

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[155] For example, see *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound Appendices V and VI* (Scientific Panel 1995c).

- to manage resources to protect features that are important to tourism and recreation; and
- to provide recreational and tourism opportunities that reflect the inherent quality of the resources in Clayoquot Sound and the recreational desires of residents and visitors to the area.

The recreational and tourism objectives most relevant to monitoring are:

- to provide for a range of recreational and tourism opportunities…that are sensitive to and based on the area's natural resources;
- to protect valuable resources for recreation and tourism; and
- to integrate into recreation planning the use patterns and needs of tourist and resident groups including First Nations.

Any alteration or development has an effect on scenic values.

Any alteration or development affects scenic values. The effect can be minimal (e.g., a small clearing in an area not visible from high-use areas) or significant (e.g., large cutblocks adjacent to major use corridors). In areas where there is existing or potential recreational use, alteration, development, and other activities (even recreation) can affect recreational values. For both scenic and recreational values, one major alteration or activity can have significant effects, or incremental use can cumulatively affect the values.

What to Monitor

Monitor perceptions and experiences of people and the physical condition of resources.

Monitoring for scenic and recreational values includes investigating the perceptions and experiences of people in the area, and analyzing the physical condition of the resources perceived and used.

The way people feel about scenery and recreation indicates their sense of the "health" of the resources. A range of groups, including First Nations and other residents, recreationists and tourists, and tourism operators, must be interviewed to determine: their enjoyment and level of satisfaction with scenic and recreational resources in specific areas; satisfaction with the range of experiences and opportunities available; factors contributing to positive and negative perceptions; and their future interest in areas with given characteristics. An important topic is the level of alteration, development, and use that people consider appropriate to specific activities or key areas. In addition to logging and other development, factors such as a high level of recreational use can have negative effects on resources and perceptions.

Use is a strong indicator of the capability of resources and of how people perceive resources.

Use, especially by the recreation and tourism sectors, is a strong indicator of how people perceive resources. Monitoring use over time is particularly important in areas where scenic and recreational resources are changing (either because of new logging or development), or where visually effective green-up of previously logged areas is occurring. This monitoring will show the interrelationship between existing levels of alteration and actual use.

The perceived physical condition of scenic and recreational resources must be monitored where logging or other development has occurred. The resources are analyzed to determine if the alteration meets the stated visual landscape management and recreational objectives (e.g., maintaining examples of different types of natural landscapes in a relatively unaltered state, protection of recreational resources, development of areas with sustainable forest practices suitable for interpretation and education). Landscape design must be assessed, noting items such as compatibility of cutblocks with the landform, visual dominance of structures, and visual prominence of roads. The detailed effects of alteration and development should be analyzed to determine their influence on the perceived quality of recreation sites.

The actual physical and biological condition of scenic and recreational resources should also be monitored. Areas reserved from harvest for other reasons (e.g., Section 7.3.2) may have high or low scenic value commensurate with their purpose, and may also become “destinations” for ecotours or wilderness experience. Reserves designated to maintain ecosystem integrity are not meant to provide scenic values or recreational opportunities: some reserves (e.g., to protect sensitive soils or wildlife sensitive to disturbance) may be harmed by relatively low levels of human use. Physical and biological consequences of recreation and tourist activity should be monitored where working units are specifically designed to host such activity and especially where reserves become sites of such activity.

Methods of Monitoring

Monitoring of perceptions and experiences is accomplished by asking the appropriate people. The perceptions of recreationists, tourists, and the general public, can be obtained from questionnaires given to clients by tourism operators at the end of a trip, distributed at tourism information centres, and administered in local areas such as Tofino or Hot Springs Cove. Photo-questionnaires are useful in assessing perceptions about scenic resources. To obtain the perceptions of tourist operators and local residents, questionnaires and workshops are potential monitoring methods.

Use patterns can be monitored with questionnaires to recreation groups and tourism operators or by conducting user counts in the field. User counts require more effort than questionnaires but are a more accurate survey method.

Monitoring the perceived and actual physical condition of scenic, recreational, and tourism resources involves inventory and analysis. Some of these activities are best conducted by landscape and recreation experts; others, by individuals familiar with the techniques of Sections 8.2 and 8.3. Experts can provide detailed information on how resources have been affected by alteration or development, and can identify what steps might be taken to meet specific objectives (e.g., rehabilitation). Local people can be trained to assist in the analysis.

The forms and methods of monitoring are the same at all planning levels.

Most forms and methods of monitoring are the same at all planning levels. Monitoring at all three planning levels and using that information as appropriate at all levels is critical. At the subregional level, resources over large areas (e.g., major use corridors) must be considered as a whole to account for the cumulative effects of changes on scenery and recreation. This information is relevant in guiding watershed- and site-level activities. Watershed-level monitoring will provide important detailed information on the effects of alteration. Site-level monitoring will be useful in guiding design criteria. Most assessments of potential negative impacts of recreation and tourism will occur at the site level.

8.4.3 Monitoring Regional Production

Determining whether sustainable development has been achieved requires monitoring the flow of resource products over the long term.

The viability of local communities and sustainable development of the land and sea resources of the Clayoquot Sound region are inextricably linked. The Scientific Panel has asserted that developing the resources of Clayoquot Sound sustainably depends on adopting an ecosystem approach to resource management. Determining whether sustainable development has been achieved requires monitoring the *flow* of resource products over the *long term*—in terms both of quantity and quality, the latter being particularly important in an assessment of sustainability. Assuring sustainability of all forest values will be difficult because the growing population in the region will steadily increase the pressure for land and resource uses. Furthermore, changing social priorities, both within and beyond the region, will influence the ways in which resources will be used. The Panel cannot give a detailed discussion of criteria for monitoring regional production due to these economic and social complexities. However, it does make some observations related to its charge to consider sustainable forest practices.

Production of commodities from the forest will remain a significant factor in the overall regional productivity.

Production of commodities from the forest will remain a significant factor in the overall regional productivity. Monitoring the production of forest commodities differs from monitoring the flow of “forest products” as that term has usually been used in British Columbia. Wood and fibre constitute only a part, albeit a major part, of the resources of Clayoquot Sound forests, and their estimated harvest is noted as one objective of subregional planning (Section 7.3.1). Other products from the land include the many natural foods, medicines, and materials traditionally used by the First Nations population; tourist and recreation “products” which have growing economic importance; and non-traditional forest products that are, or may become, useful to small, local enterprise, such as edible mushrooms and other botanical forest products (see B.C. Ministry of Forests 1995a). Clean fresh water, and major subsistence, commercial, and recreational fisheries are also products of the forest. All of these “products” need to be monitored in any comprehensive assessment of regional production.

In Clayoquot Sound, the products of the sea are as important as those of the forest. In addition, a potentially major aquaculture industry is being established in the inlets of Clayoquot Sound, despite opposition. These circumstances make it imperative that forest operations do not harm the marine environment or marine resources. Monitoring the regional production of the sea will require keeping complete records of fish, shellfish, and other marine resources harvested. This monitoring has not been achieved in the past, and the Panel acknowledges the difficulty in establishing a comprehensive records system due to the diverse nature of marine activities.

8.5 Implementation

Because monitoring requires substantial labour it must be undertaken or directed by the public or by public agencies.

Environmental monitoring is a labour-intensive and expensive task if undertaken entirely by professionals. Because monitoring is obviously in the general public interest (i.e., it helps to guarantee the integrity and productivity of the land in the long term), but possibly not entirely in the interest of any individual resource user, it must be undertaken or directed by the public or by public agencies. Beyond basic programs of regional interest, however, it probably is unrealistic to expect continuous close attention to monitoring programs from public agencies over long periods of time. Therefore, local interest and involvement in monitoring (as mobilized, for example, in follow-up committees) are essential to ensure a successful monitoring program.

Some aspects of monitoring require technical expertise. To assure attention to the organization and technical excellence of a monitoring program, a professional land manager with a broad mandate is required. This individual must be charged with effective coordination of all monitoring programs at the subregional level to assure timely collection and archiving of data and, more importantly, to continue data analysis and take appropriate actions as the results indicate. Effective coordination includes on-the-ground familiarity with the area and involvement with programs.

Clayoquot Sound is an excellent place to test the concept of local responsibility for sustainable ecosystem management.

Because of labour requirements, the value of cumulated experience in many aspects of monitoring, and the need to secure local commitment to ensure the continuation of the program, many aspects of monitoring should be the responsibility of participants from local communities who are interested in working regularly and conscientiously. This approach will entail training and an administrative structure that includes such individuals and their communities. The establishment of wardenship of community watersheds would be an effective first step in this direction: the interest of the local community is obvious in such a case. The Streamkeepers and Water Stewardship programs of the provincial Resources Inventory Committee can provide training for school and community groups. In Clayoquot Sound the traditions, experience, and concerns of the Nuu-Chah-Nulth people help to ensure that they will understand and respond to the need for wardens within a comprehensive program of monitoring for environmental integrity. Clayoquot Sound is an excellent place to test the concept of local responsibility for sustainable ecosystem management.

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Appendix I

Summary of the Panel's Recommendations Concerning Planning and Practices in Clayoquot Sound

Recommendations Relating to Silvicultural Systems

R3.1 Within the watershed planning unit, determine a rate-of-cut based on the watershed area. Specifically:

- Limit the area cut in any watershed larger than 500 ha in total area to no more than 5% of the watershed area within a five-year period.
- In primary watersheds of 200–500 ha in total area, limit the area cut to no more than 10% of the watershed area within a 10-year period. (This prescription provides flexibility for harvesting within small watersheds.)
- In any watershed larger than 500 ha in total area, and primary watersheds of 200–500 ha in total area in which harvest has exceeded 20% of the watershed area in the most recent 10 years, allow no further harvest until the watershed conforms with the specified rate-of-cut.
- In any watershed specified in the previous recommendations and in which the recent harvest is greater than 5% in the last five years, but less than 20% in the last 10 years, allow no further cutting until a watershed sensitivity analysis and stream channel audit have been completed. If these assessments indicate significant hydrological disturbance, substantial or chronic increase in sediment yield, or significant deterioration in aquatic habitat, cease harvesting until undesirable conditions are relieved. Otherwise, harvest may continue at a rate which will bring the drainage unit within the recommended rate-of-cut limits within five years.
- In any watershed larger than 500 ha in total area (and primary watersheds of 200–500 ha in total area) in which harvest has occurred, require a watershed sensitivity analysis and stream channel audit once every five years. Where such assessments identify hydrological disturbance, substantial increase in sediment yield, or significant deterioration in aquatic habitat, cease harvesting until these conditions are relieved. If such conditions are recognized at any other time, sensitivity analysis and/or stream channel audit shall be undertaken immediately.
- In watersheds where the harvestable area is less than 30% of the total area, allow resource managers to use professional judgement to vary these standards without changing the intent to regulate rate of harvest to minimize hydrological change.
- Periodically review these recommendations and reformulate as the results of monitoring accumulate.

- In watersheds important for their scenic values, complying with the visual landscape management objectives may restrict the rate-of-cut below the limits specified above.

R3.2 Within the harvestable areas, determine the size and configuration of cutting units based on consideration of topography, site and stand conditions, adjacent reserve areas, visual landscape management objectives and design principles, and operational constraints.

Once an annual rate-of-cut (in hectares per year) from the watershed is determined, no arbitrary limit on the size and adjacency of individual cutting units within a watershed is needed because the rate-of-cut limits proposed (R3.1) restrict the amount and rate of disturbance within a watershed. Exceptions occur where size and adjacency must be considered in relation to visual landscape management objectives. Riparian and other reserve areas established at the watershed planning level will protect values that require reserve forest.

R3.3 Adopt new terms to describe non-conventional silvicultural systems. Conventional terms are inappropriate to describe systems designed to protect multiple values, maintain ecosystem function, and produce a diversity of forest products.

R3.4 Replace conventional silvicultural systems in Clayoquot Sound with a “variable-retention silvicultural system.” The purpose of this system is to preserve, in managed stands, far more of the characteristics of natural forests.

The variable-retention system provides for the permanent retention after harvest of various forest “structures” or habitat elements such as large decadent trees or groups of trees, snags, logs, and downed wood from the original stand that provide habitat for forest biota.

Forest structures are retained to meet the following specific ecological objectives:

- to provide, immediately after harvest, habitat (e.g., large trees, snags, and logs) important to the survival of organisms and processes that would otherwise be lost from the harvested area either temporarily or permanently;

- to enrich current and future forests by maintaining some remnant structural features and organisms from the previous stands. These features might otherwise be absent from the cutting unit for decades after logging; and

- to improve “connectivity” between cutting units and forest areas by facilitating the movement of organisms through the cutover areas.

Retention silvicultural systems facilitate protection of culturally important sites (e.g., culturally modified trees), and scenic and recreational values. The variable-retention silvicultural system provides for a range of retention levels. The type, amount, and spatial pattern of the retained material depend on site characteristics and management objectives.

R3.5 Specify prescriptions for variable-retention cutting units in terms of the types, spatial distribution, and amount of forest structures that are to be retained.

"Types of structures" refers to the kind of material that is selected for retention (e.g., snags, large live trees).

"Spatial distribution of structures" refers to whether retained trees are *aggregated* in small intact patches or strips of forest, or are *dispersed* as individual structures over the cutting unit. Aggregates are particularly useful in providing opportunities for safely retaining snags and "danger trees" important to biological diversity.

"Amounts of structures" refers to their density or cover within the cutting unit. The amount of live tree retention is described in terms of *numbers of stems* when retention is *dispersed*, and in terms of *area* when retention is *aggregated*.

R3.6 On cutting units *with* significant values for resources other than timber (e.g., visual, cultural, or wildlife resources), or *with* sensitive areas, implement high levels of retention. Examples of sensitive areas include dry floodplains (outside of riparian reserves), areas with high visual landscape management objectives (currently described by visual quality objectives of "preservation, retention, or partial retention"), steep slopes, and marginally stable slopes and soils (stability class IV). On such units:

- retain at least 70% of the forest in a relatively uniform distribution;
- when harvest occurs in small patches, limit opening sizes to 0.3 ha or less;
- retain at least some larger diameter, old, and dying trees; snags; and downed wood throughout the forest (but not necessarily in harvested patches); and
- identify "no-work zones" representing a minimum of 15% of the cutting unit area (i.e., areas including snags and other danger trees) before any harvesting takes place.

R3.7 On cutting units *without* significant values for resources other than timber, or *without* sensitive areas (e.g., with no steep slopes or unstable soils), implement low levels of retention. On such units:

- retain at least 15% of the forest;
- retain most material as forest aggregates of 0.1–1.0 ha well dispersed throughout the cutting unit;
- ensure aggregates are representative of forest conditions in the cutting unit (i.e., should not be disproportionately located in less productive portions of the cutting unit);
- retain aggregates intact as "no-work zones";
- regardless of retention level, ensure that no place in an opening is greater than two tree heights from the edge of an existing aggregate or stand; and
- when dispersed retention is employed, select the most windfirm, dominant trees present on the unit.

R3.8 Tailor prescriptions for retention to stand characteristics, topographic conditions, and other resource values on the working unit.

- In general, retain a representative cross-section of species and structures of the original stand.
- Select specific structures and patches to meet ecological objectives (e.g., provide future habitat for cavity-using species).
- Select patches to protect culturally important features (e.g., culturally modified trees, recreation sites, scenic features).
- Determine appropriate amounts of retention based on ecological sensitivity and forest values within the working unit.

R3.9 Exempt very small working units (i.e., less than four tree heights across) from the minimum 15% retention requirement in R3.7.

R3.10 Do not salvage blowdown in retention cutting units except where it threatens desired values (e.g., by establishing the potential for unnaturally large or frequent debris flows, especially ones that might threaten special sites such as spawning areas). Areas of blowdown provide live trees, snags, downed wood, or wood in streams which are habitat for many organisms in present and future stands. Abundant coarse woody debris is an important element in the forests and stream channels of Clayoquot Sound; its removal is potentially disruptive to the objectives of retention and, in most cases, is unnecessary.

R3.11 Design the size, shape, and location of areas to be harvested within a cutting unit to comply with topography and visual landscape management objectives established for the area.

R3.12 Develop restoration plans for areas where forest values have been degraded. Restoration plans should initially target:

- the restoration of hydroriparian zones; and
- large areas which have been clearcut in the past without retention of late successional features (e.g., large, old living trees; snags; and downed logs).

One feature of these plans would be to restore or hasten late successional conditions within the harvestable area through either extended “rotations” or appropriate stand tending (e.g., R3.16).

R3.13 In applying the variable-retention system, augment understanding of retention objectives with judgement and local experience. For example, use aggregated retention, mitigative measures, and local knowledge to reduce risks of windthrow, especially when mid-levels of retention are prescribed.

R3.14 Initiate training programs in new techniques (e.g., wildlife tree assessment, no-work zones, and riparian management) for forest workers.

R3.15 Provide incentives for tenure holders to implement the variable-retention system and to apply greater than minimum levels of retention. For example, incorporate flexibility in the stumpage appraisal system so that innovation is not discouraged by undue reliance on historic costs.

R3.16 Encourage innovative approaches to silvicultural practices throughout the stand rotation to promote diverse forest structure and habitats, and to attain structural features of old-growth forests. For example, patches of wide spacing during pre-commercial and commercial thinning can encourage more rapid development of characteristics similar to old growth in both the overstory and understory.

R3.17 Post-harvest silvicultural treatments should approximate natural patterns. For example, regeneration of naturally occurring species mixes should be encouraged and prescribed burning should be limited to small areas.

R3.18 Devise methods of monitoring the multiple objectives of retention silvicultural prescriptions (i.e., expand the Pre-harvest Silviculture Prescription (PHSP) beyond the current emphasis on attaining regeneration).

R3.19 Implement an adaptive management strategy to incorporate new knowledge and experience. Establish research and monitoring programs to assess effectiveness of these initial recommendations in meeting ecological, cultural, scenic, and economic objectives, and to improve recommendations on an ongoing basis.

R3.20 Because innovative practices may have unanticipated consequences, policy also must be adaptive. Establish policies to modify standards and practices when consequences contrary to the objectives of sustainable ecosystem management are clearly documented or when alternative approaches for achieving objectives are recognized. Act to ensure that monitoring procedures anticipate surprise and that regulations can be quickly modified to reflect new information.

R3.21 Phase in the variable-retention silvicultural system in Clayoquot Sound over a five-year period, according to the following schedule of *minimum* achievements:

- 20% of the annual area harvested by end of 1996;
- 50% of the annual area harvested by end of 1998; and
- 100% of the annual area harvested by end of 1999.

R3.22 Fast-track watershed-level planning. While the Panel recognizes that some harvesting by the variable-retention system will be undertaken *before* appropriate watershed-level planning can be completed, harvest without requisite watershed-level planning should be minimized.

Recommendations Relating to Harvesting Systems

R4.1 Select a harvesting system that meets safety and other specified objectives (e.g., minimal ground disturbance) consistent with variable-retention silvicultural prescriptions.

R4.2 Plan and implement yarding to minimize soil disturbance, site degradation, and damage to retained trees. Restrict ground-based logging to hoe forwarding or similar low-impact yarding methods appropriate to the prevailing weather and soil conditions in Clayoquot Sound. Use partial or full suspension cable yarding and helicopter logging as required to minimize detrimental soil disturbance and damage to retained trees.

R4.3 Undertake operational trials of harvesting with the variable-retention silvicultural system at a range of levels and distributions of retention to establish design parameters and procedures for cutblock layout, falling, and yarding, particularly for skyline methods involving lateral yarding. Because this information is needed to support the recommended phase-in of a variable-retention silvicultural system, a cooperative effort (e.g., B.C. Ministry of Forests Engineering Branch, Forest Engineering Research Institute of Canada, and members of the forest industry) is warranted, including consultation with experienced operators in the Pacific Northwest.

R4.4 Develop education and training programs to provide forest engineers, technicians, and forest workers with the knowledge and skills required to plan and implement harvesting operations appropriate to a variable-retention silvicultural system in Clayoquot Sound. Provide continuing education opportunities to encourage development of a skilled, motivated, and stable workforce.

Training must address silvicultural objectives (e.g., habitat, biological diversity, regeneration) and operational constraints (e.g., harvesting system requirements, windfirmness, yarding patterns, falling patterns) at all levels, including:

- professional foresters who prescribe the level, type, and distribution of retention in the Pre-harvest Silviculture Prescription;
- forest engineers who formulate logging plans, and technicians who lay out retention cutting units; and
- fallers who make on-site decisions about safe and efficient falling, bucking, and yarding, and other forest workers involved in harvesting.

This education and training is urgent in view of the recommended phase-in schedule.

R4.5 A university-level program of study in forest engineering that would qualify its graduates for professional registration in both forestry (registered professional forester) and engineering (professional engineer) is needed to fulfil the greater demands for complex forest engineering and planning that the Panel's recommendations require.

R4.6 Government, forest companies, and labour, through discussion, must address issues of increased manpower requirements, reduced productivity (i.e., cubic metres per shift), and increased costs involved with the variable-retention silvicultural system.

Recommendations Relating to Transportation Systems

R5.1 Respect the following priorities in resolving conflicts related to road location:

- Where irreplaceable values or highly sensitive features are on or near a proposed road location, select another road location or do not build a road. Such features and values include special or rare habitats (including habitats known to be occupied by endangered, rare, and vulnerable species), heritage and cultural features, active floodplain areas and channels, areas mapped as stability class V or Es1, and all but highly localized areas of marginally stable terrain.

- Where damage to watershed integrity and ecosystem function is possible, construct roads only if: no alternative route is available; the road is required to access a substantial harvestable area; *and* mitigating measures (e.g., special construction, rehabilitation) are biologically and physically feasible. Seek professional advice from appropriate specialists approved by the B.C. Ministry of Forests (e.g., professional agronomists (soil scientists), professional biologists, professional engineers, professional geoscientists) whenever road construction is contemplated in areas including: mapped stability class IV terrain; highly erodible soils; mapped Es2 areas; localized areas of marginally stable terrain; or areas where significant impact on growing sites, riparian zones, or aquatic ecosystems can be anticipated.

- Where significant damage to visual or recreational values is possible, use the proposed location only where mitigating measures are feasible according to appropriate specialists.

R5.2 Improve on-the-ground performance in construction and maintenance of road drainage structures (ditches, culverts, bridges) to meet the demands of the wet climate. Reduce the impact of roads on hydrological regimes by constructing roads that allow the passage of shallow subsurface groundwater. Achievement of this recommendation will require research.

R5.3 Require an overall road deactivation plan that addresses and effectively integrates the needs for long-term access for stand tending, protection, and recreation. The plan should reflect the fact that roads are a long-term investment, often needed to facilitate future land management.

R5.4 For main or branch roads on slopes consistently greater than 55%, use full bench cuts and endhaul construction, or seek professional advice to ensure that slope stability is maintained and potentially affected resource values are not diminished. In rock cuts, use controlled blasting techniques and follow manufacturers' specifications to: avoid damage to standing timber, retain shot-rock on the right-of-way, maximize the utility of the rock for subgrade or rip-rap, minimize over-breakage, and prevent blast-triggered slides.

R5.5 Revegetate all disturbed areas associated with roads. Promptly apply erosion control, grass-legume (or equivalent) seed mixes to all denuded mineral soil surfaces (i.e., surfaces other than clean shot-rock or bedrock associated with road construction), including cutslopes, fillslopes, borrow pits, and waste disposal areas. Use indigenous, non-invasive species for revegetation wherever possible to avoid deleterious effects on non-forest communities (e.g., white clover, *Trifolium repens,* can invade saltmarsh communities and replace the native springbank clover, *Trifolium wormskjoldii*). Research is anticipated to increase the number of indigenous species available for rehabilitation.

R5.6 With the increased skyline yarding to central landings, and helicopter yarding that are expected to accompany the variable-retention silvicultural system, many roads will serve only transportation requirements (i.e., will not be used as a landing). Therefore, determine required road widths based on anticipated vehicles (i.e., vehicles that will use the road) and traffic volumes. Road widths should not exceed 4.25 m except as required on curves for sidetracking of trailer units and for turnouts. Wider or higher standard roads may be justified by special needs or safety, such as heavy industrial or recreational use, or regular use by local communities.

R5.7 Determine the percentage of the productive forest landbase to be converted to permanent access (roads and landings) on a watershed-specific basis during watershed-level planning. The maximum percentage of the *harvestable* area designated for permanent access should normally be less than 5%. All other temporary roads and access trails must be rehabilitated to a productive state.

R5.8 Standards are required for dryland sort and log dump construction, operation and maintenance. Construct and operate dryland sorts to ensure that:

- the surface of the dryland sort slopes landward, rather than seaward; and
- surface runoff is intercepted by a ditch on the landward side of the dump. The ditch should direct runoff to a collecting basin from which solids are filtered and regularly removed.

R5.9 On all proposed log dump sites, undertake an ecological assessment that permits DFO to evaluate productivity and sensitivity of the system (including non-commercial species); a physical assessment to determine site exposure to waves and storms, anticipated wave velocities and direction, and near-shore terrain conditions; and an assessment of probable impacts (including noise) on heritage, scenic, wildlife, and recreational values.

R5.10 Minimize time logs are in the water, especially shallow water, by sorting on land and storing log bundles in deep water.

R5.11 Locate log dumps at sufficient distances from sensitive areas such as herring spawning sites, shellfish beds, estuaries, or eelgrass beds, to preclude physical disturbance or deposition of deleterious organic materials.

R5.12 Ensure log dump sites are deep enough to avoid problems with the propeller wash of dozer boats and grounding of booms or bundles.

R5.13 Restore sites that have been damaged by excessive accumulations of bark, woody material, or fine organic material.

Recommendations Relating to Scenic, Recreational, and Tourism Values and Resources

R6.1 Involve the provincial government, First Nations, regional and local governments, recreation and tourism groups, industry, and other public interest groups in the inventory, analysis, and planning of scenic resources. Provide opportunities for meaningful involvement by the public at large.

R6.2 Develop an inventory system for scenic resources with the following characteristics:

- Map scenic resources for all of Clayoquot Sound at a scale of 1:250 000 which considers overall landscape patterns and the role of the landscape in relation to existing and potential use.

- Develop a new inventory system for visual landscape units which would be used during subregional and watershed planning. During this inventory, divide the study area into landscape units based on similarities in landscape characteristics (e.g., physiography and level of alteration), the degree and type of human activity, and viewer-related factors. For each landscape unit, describe the landscape characteristics, including the degree of alteration or development and major land and water uses.

- Develop a new scale to describe visual quality objectives which: describes alteration by less technical terminology, is easier for the public to understand, is unrelated to silvicultural system terminology, and accounts for uses other than forestry. The following terms could be used: unaltered/undeveloped, natural-appearing, minimal alteration/development, moderate alteration/development, highly altered/developed, intensively altered/developed.

- Clearly summarize the landscape inventory information on maps (e.g., landscape characteristics, degree of alteration/development) so that participants in the planning process can understand and provide input to the inventory.

R6.3 Use the information from the landscape inventory, existing and potential use patterns, and public preferences in the area to analyze scenic resources. Determine the patterns in the landscape, levels of scenic quality, and opportunities and constraints for use related to future scenic resources. Conduct this analysis at the subregional and watershed levels. Computer modelling is an effective way to analyze the landscape inventory information. Involve the planning group in the analysis.

R6.4 Based on the analysis in R6.3, develop a long-term management plan (e.g., 100 years with review every five years) for scenic resources. This plan should identify visual landscape management units for all of Clayoquot Sound. For each management unit, include:

- a description of the essential characteristics of the scenery;

- existing and potential resource values and human uses;

- the relative value of scenic resources in the unit; and

- visual landscape management objectives, including the desired character of the area, the proposed level of alteration or development, needs and methods of rehabilitation, acceptable land and water uses, and any specific measures that may be required to protect scenic values.

Quantification of alteration should be avoided. Examples are a better way of showing intent. The plan should be developed in consultation with the planning group identified in R6.1.

R6.5 Integrate the recommendations of the visual landscape management plan into all other forest plans during subregional-level, watershed-level, and site-level planning. Where visual concerns must be reconciled with those of other resource values, do so in a collaborative manner with all disciplines represented, recognizing that the primary goal is to maintain ecosystem integrity.

R6.6 Use landscape design principles in the development of detailed silvicultural plans and development plans for other uses. Having someone with visual landscape skills involved in the initial layout of cutting units facilitates the design process. Require visual impact assessment and subsequent refinement of proposed alterations to meet visual landscape objectives on all of the most important scenic areas. Involve the public in the review of proposed harvest areas, providing illustrations that can be easily understood.

R6.7 Continue the development of visual landscape guidelines in consultation with interdisciplinary teams, using monitoring and research results to refine the guidelines so that all resource values are appropriately addressed.

R6.8 Integrate planning for recreational and tourism resources. Because of their strong interrelationships, plan recreation and tourism in concert with planning for scenic resources.

R6.9 Ensure that the First Nations, provincial, regional, and local governments, and recreation and tourism groups are the principals involved in the inventory, analysis, and planning of tourism and recreational resources. Create opportunities for meaningful involvement by other public and industry groups.

R6.10 Ensure that recreation inventories are conducted at subregional scales (e.g., 1:250 000) and watershed scales (e.g., 1:50 000 or 1:20 000). Display inventory information in a form that is easy for the public to understand.

R6.11 Analyze recreational and tourism opportunities, and develop plans for recreation and tourism at the subregional, watershed, and site levels. At the subregional level, these plans should include recreation opportunity spectrum (ROS), scenic, and other management objectives for all areas, including identification of acceptable activities and uses. At the watershed level, plans should include potential uses and facilities for specific sites, and management objectives for protecting the resources at those sites. Management objectives should include the level of protection required, from complete protection to protection of key features. At the site level, plans should ensure that key characteristics of the site are retained and that alteration or development is sensitive to the value of the resources to the public.

R6.12 Ensure that forest planning addresses recreational and tourism values and resources through explicit objectives.

Recommendations Relating to Planning for Sustainable Ecosystem Management in Clayoquot Sound

R7.1 Adopt an ecosystem approach to planning, in which the primary planning objective is to sustain the productivity and natural diversity of the Clayoquot Sound region. The flow of forest products must be determined in a manner consistent with objectives for ecosystem sustainability. This entails abandoning the specification of AAC as an input to local planning.

R7.2 Adopt physiographic or ecological land units, rather than administrative units, as the basis for planning. Use the watershed as the basic unit for planning and management, recognizing that more than one watershed may be required to plan for values such as biodiversity, scenery, and cultural features.

R7.3 Use practices that represent the best application of scientific and traditional knowledge and local experience in the Clayoquot region. To accomplish this, collect appropriate baseline information about the full range of biophysical and cultural forest resources and values, and use this information and knowledge to assess ecological responses to change.

R7.4 Engage the Nuu-Chah-Nulth and other local people in all phases of planning and managing the land, freshwater, and marine resources of Clayoquot Sound.

R7.5 Develop plans at subregional, watershed, and site levels, and establish internal consistency among these plans, so that plans developed for smaller areas and shorter time periods are consistent with plans for larger areas and longer time periods.

R7.6 Ensure that plans are consistent with land-use objectives for adjacent Protected Areas and special management zones.

R7.7 Base planning on a long-term perspective, at least in the order of 100 years when considering large areas, and 10 years for operational planning of smaller areas. These time frames are required to incorporate the cycles of many natural processes, and to ensure that operational plans address post-harvest management.

R7.8 Inventory, analyze, and plan for a full range of forest resources, forest uses, and forest management activities. Undertake new inventory as needed at an early stage of planning, prior to analysis.

R7.9 Monitor the effects of plans and check against management objectives to facilitate adjustments to better achieve intended goals; that is, employ adaptive management procedures.

R7.10 Recognize that the rate (percentage of area cut per unit time) and geographical distribution of timber harvesting are more important determinants than is the volume removed when wood harvest is planned. *After* analysis of resources and development of area-based plans, determine the anticipated annual volumes of timber to be cut for watershed-level planning units.

R7.11 Appoint a planning committee, which includes stakeholders and other interested parties and experts at all levels of planning, to coordinate the planning process in Clayoquot Sound. Committee members must be highly motivated, knowledgeable about resources, and willing to adopt the protocol described in R7.14.

R7.12 Open planning committee meetings to public observation and participation. Interested members of the public should be able to request time on meeting agendas for making presentations. All papers, reports, and documents used by the planning committee should be available for public review.

R7.13 Notify subregional- and watershed-level planning committees about site-level plans. These committees do not need to be involved in site-level plans, although they should monitor the implementation of these plans to ensure that they are in accordance with watershed and subregional plans (e.g., Tsitika Follow-up Committee adopted a similar role). At the site level, the forest manager involved (i.e., tenure holder, licensee, or government agency) should undertake planning in accordance with higher level plans, and with appropriate expert assistance.

R7.14 Planning should include the following steps:

- Develop and agree on a working protocol, based on mutual respect, that will guide the planning process. The protocol must clarify how the group will work together, how disputes will be settled, how decisions (consensus or other) will be reached, and how the process (including meeting and work schedules) will proceed.

- Establish planning objectives in terms appropriate for each planning level. Identify the types of environmental and cultural resources that are to be protected.

- Based on these objectives, determine the methods and scope of the inventory required.

- Analyze data to determine status of resources, rates of biological processes, and consequent land and resource sensitivities and capabilities. Support planning as needed with technical analysis by experts from appropriate resource management agencies, forest companies, First Nations, and other parties. Identify areas to be reserved and areas where resource extraction or development may occur, including constraints that may limit the amount and type of activity.

- Develop plans for specific management activities based on input from members of the planning team and the public. Evaluate various plan options to determine which best meets planning objectives.

- Implement plans primarily at the site level (i.e., confirm boundaries of harvestable areas and specific locations of resource extraction and development activities). As noted in the Panel’s second report, workers with education and training in ecosystem management must conduct this step; worker skills should be upgraded as required. Effects of implementation extend beyond the site. Monitoring should be instituted at site and watershed levels to track effects.

- Monitor ecosystem processes and components to assess the extent to which objectives are being met.

R7.15 Implement the following time frames for planning:

- 100 years for subregional-level planning with major revisions every 10 years, or more frequently if required;
- 100 years for watershed-level planning, showing projected activities in 10-year increments, with revisions every five years, or more frequently if required; and
- 10 years for site-level planning, starting five or more years ahead of the work, with revisions every year during active operations.

Resource planning should be conducted within a 100-year horizon, and operational planning should occur within a 10-year horizon. Planners and managers must realize, however, that factors operating on the longer time scales of the ecosystem may affect plans and activities within the 10- to 100-year scales. A very significant effect may be associated with the changing resiliency of animal populations in the face of clearing and fragmentation of formerly continuous forest habitat.

R7.16 At the watershed level, map and designate reserves in which no harvesting will occur to protect key hydroriparian ecosystems, unstable slopes and sensitive soils, red- and blue-listed species, late successional forest with forest-interior conditions, important cultural values, and areas with high value scenic and recreational resources. Integrate reserve establishment with the refinement and detailed mapping of various land-use zones (e.g., Protected Areas). Reserves include:

- Reserves to protect hydroriparian resources.

  Identify reserves that include the drainage system and hydroriparian zone around streams, lakes, wetlands, and marine shores to ensure adequate protection for aquatic and riparian ecosystems. Drainage features and their hydroriparian zones are critical to protecting ecosystems, especially in Clayoquot Sound. The approach to maintaining their functional integrity proceeds from a classification system based on both physical and biological features.

- Reserves to protect sensitive soils and unstable terrain.

  Identify reserves for unstable slopes by the extent of stability class V terrain as determined by the methodology outlined in the forthcoming *Mapping and Assessing Terrain Stability Guidebook.* Sensitive soils (e.g., blocky colluvium, very shallow folisols) which decline in productivity when disturbed must also be reserved. Only stable terrain and resilient soils should be available for forest harvesting operations.

- Reserves to protect red- and blue-listed plant and animal species.

  Red- and blue-listed species are either threatened, endangered, vulnerable, or rare. Identify and reserve habitats for species on these lists, recognizing that protection is often better implemented at the site level for widely ranging, rare species; and that planning their protection may occur at the subregional level.

- Reserves to protect forest-interior conditions in late successional forest.

  Some species of plants and animals are closely associated with microclimatic conditions found inside older forests. It is important, therefore, to maintain some patches of older forests that provide conditions similar to the interior of historic forests. Assuming tree heights of 50 m, a reserve width of 300 m will provide at least some forest-interior conditions. The Panel recommends that 20% of the forests in age classes 8 and 9 of a watershed-level planning unit should constitute forest-interior conditions.

  Use 1:10 000 to 1:20 000 scale air photos and forest cover maps to identify forest-interior conditions. Providing no evidence is found that age class 9 requires further subdivision, the Panel assumes that this habitat information is readily available from forest cover maps. Monitoring should be designed to evaluate this assumption.

- Reserves to protect cultural values.

  The Panel's report *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* discusses a variety of culturally important areas, including sacred areas, historic areas, and current use areas. These areas must be determined by the Nuu-Chah-Nulth Nations and protected in ways consistent with traditional knowledge.

- Reserves to protect scenic and recreational values.

  Protect areas with especially high scenic and recreational values from alteration. These areas include unprotected unaltered areas with the highest scenic values, unaltered scenic areas of high value which are important because of their location (e.g., visible from a community or an important recreation site), and important recreation sites such as beaches or bays with primitive use objectives. Identify these areas through the scenic and recreational planning processes.

- Reserves to represent all ecosystems.

  Calculate areas of each biogeoclimatic site series (or surrogate) contained within all designated reserve areas. Note that the previously mentioned reserves will commonly overlap. Add to these reserves, as necessary, to ensure that the entire variety of ecosystems is represented in the reserve system to maintain plants, animals, and other organisms that have specific habitat requirements. Reserve ecosystems that are rare in greater proportion than their representation in the area.

- Reserves to ensure linkages among watershed-level planning areas.

  Based on information from the subregional planning level, add to the reserve as necessary to allow migrations of animals, to provide connectivity among plant and animal populations, or to accommodate recreational opportunities.

R7.17 Designate the entire hydroriparian zone as a special management zone.

A special management zone is an area to which particular land management rules or constraints apply. These rules are the direct consequence of the quality of the terrain or features found in the area. The hydroriparian zone consists of the entire floodplain of the stream, alluvial fan surfaces, and, where channels are entrenched, the entire slope that rises immediately from the channel. Hydroriparian zones delimited by none of these features are defined according to microclimate influences around the stream, as previously discussed. The floodplain is the flat valley floor ("valley flat") constructed by the river, hence underlain by alluvial sediments.

R7.18 Reserve the entire "contemporary floodplain" of streams in Class A(1) (alluvial channels with gradient less than 8%), except areas of "dry floodplain" more than 50 m from a perennially or seasonally active channel or site of seasonal standing water. Dry floodplain may be a special management area harvested by a silvicultural system with high retention, provided that appropriate access can be arranged.

The "contemporary floodplain" is the valley flat adjacent to a stream channel that is subject to inundation in the contemporary streamflow regime and that, consequently, has soils composed of recently deposited stream sediments. "Active floodplain" denotes that part of the floodplain subject to frequent inundation; that is, occupation by standing or flowing water more often than once in five years. The five-year period is chosen because regional analyses of stream flooding in western North America show that nearly all streams with contemporary floodplains exceed "bankfull" and occupy at least a part of the floodplain at least once in every five years. At a frequency of once in five years, the annual and partial duration flood sequences essentially coincide: that is, water levels are unlikely to be so high more than once within the same year.

This one-in-five-year frequency definition of the active floodplain is operationally identical with that of "riparian woods" given in the *Proposed Wetland Classification System for British Columbia*.

"Dry floodplain" means floodplain areas subject only to occasional inundation (i.e., occupation by standing or flowing water at least once in 30 years), and not otherwise classified as "wetland." A period beyond 30 years is difficult to establish.

In practice, frequency of inundation on many floodplains cannot be precisely determined: the presence of water-tolerant understory plants will be the best indicator of the extent of the active floodplain. Dry floodplain areas may be discriminated by the presence of overbank stream sediments deeper than in the active floodplain, on which a substantial litter layer (LFH soil horizon) has accumulated. "Appropriate access" in this recommendation (R7.18) means access that does not, in the opinion of a professional biologist with expertise in riparian ecology, constrain or threaten ecosystem function in any way (as by establishing a barrier to waterflows or to the movement of animals).

R7.19 In Class A(2) (alluvial channels with gradient of 8–20%), reserve areas within 50 m of present channels (30 m for A(2)(i): channels less than 3 m wide), recently active channels, and any other routes that appear, in the opinion of a professional geoscientist or professional engineer with expertise in fluvial geomorphology or river engineering, to be subject to avulsion. Other portions of the hydroriparian zone of Class A(2) streams may be harvested by a high retention system. In the case of alluvial fans, the “contemporary fan surface” shall be treated the same as the contemporary floodplain (R7.18) and reserved from logging.

R7.20 Treat streams in Class B(1)(a) (non-alluvial channels with gradient less than 8%, not entrenched) as Class A(1) (see R7.25 for exceptions).

It is probable that, in this class, a much larger portion of the valley flat will be dry floodplain, hence available for high retention harvest. In many cases, the “valley flat” will consist of a low terrace, but it will be difficult to obtain unequivocal evidence that the stream does not inundate the surface, or to obtain expert agreement on such a classification. This physiographic situation is common in British Columbia; in many situations, streams are very slightly degraded into early Holocene alluvium but have immediately armoured their bed with large rocks and have not formed trenches. In addition, the absence of hydrological measurements on most streams means that flood levels cannot be established with legal precision. This recommendation seeks to avoid the need for controversial decisions because frequent inundation is easy to demonstrate.

R7.21 For streams in Class B(1)(b) (non-alluvial channels with gradient less than 8%, entrenched), designate a reserve that extends to the top of the entrenchment slope or 50 m from the streambank (30 m for B(1)(b)(i), width less than 3 m), whichever is greater. Feathering for windfirmness may be permitted at the outer edge of the reserve (see also following comment). An additional reserve or “no machinery” zone of at least 30 m width will be designated beyond the top of slopes that are being actively undercut by the stream.

The top of the entrenchment slope coincides with the limit of the “inner gorge” as specified in the *British Columbia Forest Practices Code Standards with Revised Rules and Field Guide References*. The purpose of the additional reserve or special management zone above undercut slopes is to avoid aggravating potential instability by destroying the root network. Mature trees in this zone may be harvested if they can be felled away from the stream within a high retention harvest plan. Streams confined by stable rock slopes constitute a special case (see R7.28).

R7.22 Treat streams in Class B(2)(a) (non-alluvial channels with gradient 8–20%, not entrenched) as Class A(2) (see R7.25 for exceptions).

Streams in this category will often be flowing on steep alluvial fans where it is difficult to decide whether the surface is “active” (subject to frequent inundation). They may be subject only to very rare (but major) debris-flow events. Defining any part of the fan surface that is not liable to experience avulsion will be more difficult than in the case of Class A.

R7.23 Treat streams in Class B(2)(b) (non-alluvial channels with gradient 8–20%, entrenched) as B(1)(b).

R7.24 For streams in Class B(3)(a)(i) (non-alluvial channels with gradient greater than 20%, not entrenched, seasonal or perennial flow), designate a reserve that extends 20 m from the channel.

Seasonal or perennial streams, unlike ephemeral streams, have regular base flow, derived either from springs or persistent seepage through the banks.

R7.25 Designate no general reserve for streams in Class B(3)(a)(ii) (non-alluvial channels with gradient greater than 20%, not entrenched, ephemeral flow), and those channels in classes B(1)(a)(i) and B(2)(a)(i) (non-alluvial channels with gradient less than 21%, not entrenched, less than 3 m wide) that carry only ephemeral flow. But, require evaluation by a professional biologist to determine whether special management prescriptions are warranted for ecological reasons, and employ special management where deemed necessary.

This recommendation seeks to avoid excessive division of the landscape around small ephemeral channels. Nearly all of these channels will be directly downslope from channels in Class B(3)(a)(ii), which are similarly treated.

Ephemeral streams carry storm runoff only, which is derived from bank seepage or from overland flow. Ephemeral streams should be classified during ground-based terrain checking. Most of these streams will be less than 1 m wide. Special management prescriptions might specify local reserves, and no machinery (falling and yarding away from the hydroriparian zone).

R7.26 For streams in Class B(3)(b) (non-alluvial channels with gradient greater than 20%, entrenched), designate a reserve that extends to the top of the entrenchment slope or 20 m from the channel, whichever is greater. However, if the sidewalls adjacent to the channel (and including the channel zone) are classified as having low or no potential for instability, then apply criteria for Class B(3)(a). Apply gully assessment procedures to channels that are classified as gullies according to the *Gully Assessment Procedures for British Columbia Forests.* Most streams in this category in Clayoquot Sound will be gullies.

R7.27 Apply the gully management prescription according to the *Gully Assessment Procedures for British Columbia Forests.* However, modify the pre-logging management strategies described in their procedure for use in Clayoquot Sound so that all channels assessed as having high or moderate potential for downstream impact, and high or moderate potential for debris flow, water flood, or fan destabilization shall have no logging within the gully.

R7.28 Notwithstanding the foregoing recommendations, Class B streams (non-alluvial channels) that are confined by stable rock walls, and are classified as having low overall habitat value and low potential to affect downstream reaches have no special management requirements with respect to hydroriparian integrity. Where a V-notch in surficial material occurs immediately above a rock notch, apply the prescription for a trenched channel.

This recommendation seeks to avoid defining special management or reserves for barren rock-bound cascades and waterfalls. Of course, many such sites have special habitat value. Other constraints, in particular cultural or scenic constraints, may also apply.

R7.29 In community watersheds, make all channels above the intake subject to the previous prescriptions. In addition, extend the special management zone 50 m from any channel, even if the hydroriparian zone or entrenchment slope does not extend so far.

This prescription provides additional assurance that the soil near channels is not damaged in any way that would compromise its ability to effectively filter water seeping into the channel.

R7.30 Around all lakes, designate a special management zone that includes all the area under hydroriparian influence, or 50 m, whichever is greater. The first 30 m from the shore shall be a reserve. The remaining zone may be subject to retention systems of harvest provided it is outside the hydroriparian zone proper.

R7.31 Where special inshore lacustrine, ecological, or cultural values are identified (e.g., inshore spawning gravels), and steep slopes occur immediately behind the shore, extend the reserve or special management zone upslope as far as necessary to protect these special values.

R7.32 For Class (2) lakes smaller than 4 ha in area, designate a reserve that includes all the area under hydroriparian influence or 30 m, whichever is greater.

Lakes are superficially equivalent to contemporary floodplains which require a 50 m reserve. For a lake of 4.5 ha, the area of a 50 m surrounding reserve becomes equal to the area of a circular (most compact) waterbody. For smaller waterbodies the reserve is larger than the waterbody. Acknowledging the distance required for climatic factors such as wind, temperature, and humidity to adjust to a change in the character of the surface, designating a reserve zone very much larger than the protected waterbody appears unreasonable.

R7.33 On low gradient edges of a wetland, establish a reserve that extends to the limit of hydroriparian influence.

Low gradient in this case means essentially flat ground, less than 1% slope. Establishment of the “limit of hydroriparian influence” in the foregoing recommendations should be based on understory plant associations or on soil characteristics.

R7.34 On sloping edges of a wetland, establish a special management zone on the same basis as for lakes.

R7.35 On Class A(1) and A(2)(i) shores (low shores adjacent to open waters), extend a riparian reserve inland 150 m from the seaward edge of forest vegetation, or to the inland limit of shore-associated features (e.g., overgrown sand dunes), whichever is greater.

The distance is determined by wind forces and the distance for wind attenuation inside the forest. Measurements on the lower Alaskan coast indicate that 150 m is sufficient to achieve this.

R7.36 On the remaining Class A(2) shores (cliffs, bluffs, and steep shores adjacent to open waters), extend a riparian reserve 100 m inland from the top of the coastal slope or bluff. On eroding shores, a larger distance may be specified if required by slope stability criteria.

R7.37 On Class B marine shores, extend a riparian reserve 100 m inland from the seaward edge of forest vegetation, or to the inland limit of shore-associated features (e.g., sand dunes and lagoons, now within the forest), whichever is greater. For lagoons within the forest, establish a reserve on the inland shore (R7.30).

R7.38 In estuaries proper, make a smooth transition from the marine shore reserve to the streamside special management zone.

R7.39 Avoid road construction in hydroriparian reserves. Where no practical alternative is possible, abandoning the development may be advisable. If the development does proceed, engineer and construct the road to minimize disturbance. Require professional engineering supervision at all stages of road construction. The chief circumstances where a road may have to enter a hydroriparian reserve is for direct crossing from one side to another of a stream reserve, or to follow an active floodplain or lakeshore where the higher terrain is not accessible or cannot be safely crossed.

R7.40 In hydroriparian reserves, engineer the road and bridges to ensure that the security of neither the road nor the hydroriparian ecosystem is jeopardized. The road shall not interfere with the circulation of water or with the movement of terrestrial or aquatic animals. In particular, the design must ensure that the roadway does not act as a dam during periods of high flow or storm surge, nor as a source of sediment.

R7.41 Roads constructed near the slope base at the edge of a floodplain or other hydroriparian zone must provide for passage of cross-drainage into the riparian zone. Design traffic and machinery holding places to prevent traffic-associated contaminants from escaping into the hydroriparian zone. Select road surface materials to minimize dust production.

Recommendations Relating to Monitoring

R8.1 Initiate a long-term monitoring program that includes both areas that are reserved from land-use practices and areas that will experience land-use practices.

R8.2 Incorporate into the monitoring program the elements summarized in Sections 8.2 through 8.4. Specifically, monitor:

- watershed and coastal integrity – including hillslopes and forest soils, stream channels, regional streamflow and water quality, and the coastal zone;
- biological diversity – including genetic variation, vulnerable and rare indigenous species, terrestrial environments, old-growth characteristics, and aquatic environments;
- human activities and values – including areas important to First Nations; scenic, recreational, and tourist values; and regional commodity production; and
- implementation of forest management plans.

R8.3 Use the findings of this program to modify, as required, management strategies as well as individual plans and practices.

Appendix II

Classification of the Hydroriparian System

1.0 Bases For Classification

The most basic division is defined by the nature of the waterbody, because this fundamentally determines the nature of the associated ecosystems. Lotic (streams), lentic (standing fresh water), and marine are the basic units.

Within stream channels, the most basic division is between alluvial channels (ones flowing through their own deposits), and non-alluvial channels (flowing on bedrock, or on sediments other than alluvium). This criterion is coincident with the criterion of “confinement,” because an unconfined channel is always one flowing with at least one alluvial bank. The next most important criterion is stream gradient, because this determines important aspects of fluvial processes and morphology. A third criterion is entrenchment: entrenched channels are those confined within fluvially eroded gullies or valleys of some depth. A final criterion is stream size, which influences some of the physical and biological processes. These criteria exert a powerful influence over the associated ecosystems. They can be determined (for purposes of classification) during terrain mapping. The latter is an important practical requirement.

Within the class of alluvial stream channels, the definition of a “floodplain” presents some difficulty. The genetic definition—the surface of a body of sediment deposited by the stream—ignores whether a change of stream regime has led to degradation and consequent development of a terrace (which is not subject to inundation). The difference is ecologically significant. A definition based on the possibility for inundation to occur needs some qualification about the frequency of inundation, but it is not practically applicable in terrain analysis procedures. The best discriminators probably are the presence of indicator plant species in the understory and immature cumulic soils, which can definitively be decided at the stage of field checking. Adoption of such criteria will require local guidelines.

Lentic freshwater environments are divided according to whether the water environment consists of permanent open water more than 1 m deep (a lake) or is a wetland. A second significant distinction is based on the nature of the lacustrine ecosystem: oligotrophic lakes are distinguished by relatively poor nutrient status. Wetlands have been further classified (e.g., as fen, marsh, swamp, bog). A second criterion is waterbody size. As in streams, this criterion determines some of the physical and biological processes between the waterbody and the adjacent land.

Marine units are classified by the physical nature of the shore, and by the nature of near-shore waterbody depth and circulation. A fundamental division, analogous to that between alluvial and non-alluvial channels, is that between shores with a beach and without.

(Figure 7.4) Classification of the hydroriparian system.

Stream Environment

- **A alluvial channels**
  - **1 gradient ≤8%**
    - channel width
      - i <3 m
      - ii 3–30 m
      - iii >30 m
  - **2 gradient >8%**
    - i <3 m
    - ii 3–30 m
    - iii >30 m
- **B non-alluvial channels**
  - **1 gradient ≤8%**
    - a not entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
    - b entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
  - **2 gradient 8–20%**
    - a not entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
    - b entrenched
      - i <3 m
      - ii 3–30 m
      - iii >30 m
  - **3 gradient >20%**
    - a not entrenched
      - i seasonal or perennial
      - ii ephemeral
    - b entrenched

Standing Waterbodies and Wetlands

- **A lakes**
  - **1 oligotrophic**
    - i sand or gravel beach
    - ii low, rocky shore
    - iii cliffed or bluff shore
    - iv wetland shore
  - **2 non-oligotrophic**
    - i sand or gravel beach
    - ii low, rocky shore
    - iii cliffed or bluff shore
    - iv wetland shore
- **B wetlands**
  - i marsh
  - ii fen
  - iii swamp
  - iv shrub-carr
  - v meadow
  - vi bog

Marine Shores

- **A adjacent to open waters**
  - **1 beach**
    - i sandy (incl. dunes)
    - ii gravelly shore
    - iii bouldery shore
  - **2 non-beach**
    - i low shore
    - ii shore bluffs
    - iii rock cliffs/ steep slope
- **B adjacent to protected waters**
  - **1 lagoon**
    - i sandy (incl. dunes)
    - ii gravelly shore
    - iii bouldery shore
    - iv saltmarsh
  - **2 estuarine**
    - i marsh
    - ii mudflat
    - iii sandflat
    - iv gravel or boulder flat
    - v low, rocky shore
    - vi bluffs, cliffs, or steep slopes

2.0 Classification

2.1 Stream (Lotic) Environment

A Alluvial channels

These are channels with a flanking floodplain, including estuarine channels in deltas, and alluvial fans (also called "fluvial fans"):

1 with gradient less than 8%
(i) channel width less than 3 m
(ii) channel width between 3 m and 30 m
(iii) channel width greater than 30 m

Notes: Channels with gradient less than 8% (4.6˚) have primary morphological units consisting of pools separated by riffles or extended rapids. Anadromous salmonids are found in these channels. Channels with gradients greater than 8%, up to 20% (11.3˚) have step-pool morphology. Resident fish may be present.

2 with gradient greater than 8%
(i)–(iii) width criteria (as in A(1))

Notes: In the case that the channel has one bank alluvial, and one bank non-alluvial, it will be classified as alluvial. The bed need not be alluvial, but cases of a non-alluvial bed with contemporaneously active alluvial bank will be rare to non-existent. In Type (1), many channels less than 3 m wide will be secondary channels on floodplains, which will be incorporated into the unit defined by the main channel. Type (2) will usually be alluvial fans; in Type (2), width criterion (iii) will be rare to non-existent.

B Non-alluvial channels

1 with gradient less than 8%

a) not entrenched
(i)–(iii) width criteria (as in A(1))

b) entrenched
(i)–(iii) width criteria (as in A(1))

Notes: These groups may include fairly large channels which have degraded and are now flowing on lag armour (unconsolidated material—typically cobbles or boulders—that the stream is not capable of moving, so that it is not alluvial in the current regime) between terraced banks. An entrenched channel is one that is continuously confined within banks sufficiently high that overflow may not occur, as the result of downward fluvial erosion. Gullies, ravines, and bedrock gorges are typical landforms of entrenchment.

2 with gradient in the range 8–20%

a) not entrenched
(i)–(iii) width criteria (as in A(1))

b) entrenched
(i)–(iii) width criteria (as in A(1))

Notes: (a) will principally be steep alluvial fans. In this gradient range, width class (iii) probably is non-existent. Most debris flows will stop in this gradient range.

3 with gradient greater than 20%

a) not entrenched
(i) seasonal or perennial
(ii) ephemeral

b) entrenched

Notes: Although streams in this class are steep, they retain significant hydroriparian function for maintaining water quality downstream, and significant values as animal travel routes and the growth site of riparian herbs and shrubs—including some with otherwise limited distribution. Fish are not normally present. Gradient is usually bedrock-controlled. In (a), one will classify mainly seasonal to ephemeral rills on hillsides. In (b), one will classify mainly gullies, but the class will include possibly sizable rivers cascading down bedrock-controlled channels from hanging valleys. Stream width will usually be less than 3 m. Gully floor width is more significant than channel width, but usually will not be critical for processes. Debris flows may start and will be maintained on these gradients. An upper limit for stream channel gradients (other than cascades and waterfalls on bedrock) is 60%.

In the Clayoquot Sound region, most of the channels belong either to A(1) or to B(3). This is a reflection of the dominantly steep slopes and glaciated main valleys. Class A(2) streams occur on footslopes, alluvial fans, and cones.

2.2 Standing Waterbodies and Wetlands (Lentic Environment)

A Lakes

1 oligotrophic
(i) sand or gravel beach
(ii) low, rocky shore
(iii) cliffed or bluff shore
(iv) wetland shore

2 non-oligotrophic
(i)–(iv) shore types (as in A(1))

B Wetlands

(i) shallow open water
(ii) marsh
(iii) fen
(iv) swamp
[(v) shrub-carr]
[(vi) wet meadow]
(vii) bog

Notes:

Types in square brackets do not occur in the Clayoquot Sound region.

Shallow open water denotes ponds and sloughs with submerged aquatic plants and less than 2 m water depth in midsummer.

A marsh has free-standing water with emergent vegetation or remains waterlogged throughout the growing season.

A fen (minerotrophic mire) is a wetland with limited peat accumulation, maintained by groundwater and runoff. Fens often occur as shoreline wetlands peripheral to lakes, ponds, and low gradient streams. These are particularly important as prime sources of the tall basket sedge (*Carex obnupta*), used by Nuu-Chah-Nulth people for basketry. The most productive sites for this sedge are near or under western redcedar and red alder where open fens grade to sparsely forested swamps.

A swamp is a forest or high shrub mineral wetland or peatland that is periodically flooded. Swamps include sparse, open-canopy to closed canopy forests of various mixes of western redcedar, red alder and shore pine (the latter is more commonly associated with bogs). Most of the surface is usually submerged, but there are periods when the soil may be dry and aerated. Very poorly drained, sparsely forested swamps are characterized by western redcedar, yellow-cedar (increasingly at higher montane to subalpine elevations), red alder, crabapple, salmonberry, stink currant, skunk cabbage, giant horsetail—all of which are culturally important. The poorly drained, closed-canopy forested swamps are less variable, with a predominance of western redcedar and an understory of western hemlock, both growing on raised microsites comprised largely of accumulations of rotting wood. Characteristic minor vegetation includes skunk cabbage growing in wet, mucky organic materials situated in depressions between the drier hummocks. On the minor hummocks, grows minor vegetation similar to that of mesic sites—*Vaccinium* spp., *Cornus canadensis, Hylocomium splendens, Rhytidiadelphus loreus,* etc. This latter type is properly classified as a western redcedar swamp forest, but is not generally recognized as such. Historically, only this type has been logged.

[In Clayoquot Sound, fens include shore-pine fens, and swamps include cedar swamps and *Carex* swamps within the forest.]

Shrub-carr is a shrub-dominated wetland developed on mineral soils that is periodically saturated but rarely inundated; a wet meadow is a herbaceous wetland that is rarely inundated. The latter two types are not waterlogged in the growing season. All six foregoing types are fed by inflowing surface or groundwater.

A bog (ombrotrophic mire) is a peat accumulation which has grown above the local water table so that the water in the upper peat is sustained by precipitation.

These definitions are consistent with the *Proposed Wetland Classification System for British Columbia* (Kistritz and Porter 1993).

Appendix III

Information Requirements for Planning

Information about the variety and composition of ecosystems in the Clayoquot Sound area, including all natural resources, is a basic requirement for planning. Inventory information also provides baselines for monitoring management activities. The detail of inventory required will vary with the decisions to be made. Where existing information is inadequate to support informed decision-making, additional information must be collected before planning continues. Information should be periodically updated as management activities proceed.

At time of writing, an interministry task force of the provincial government—the Resource Inventory Committee (RIC)—is developing and testing detailed provincial standards for about 80 categories of inventory, covering plant and animal species, soils, and other features. These standards will ensure that information collection, analysis, and interpretation are consistent; they may require adjustment for regional variations in the environment. In addition to these inventory standards, about 65 field guides are being developed in association with the proposed Forest Practices Code to provide standards for implementation of the Code. Some of these guides will specify procedures for resource inventory.

The ecosystem-based approach to forest planning advocated by the Panel may necessitate the collection of information additional to, or different from, that addressed in the RIC inventory standards or in the Forest Practices Code field guides. Accordingly, this appendix lists information required for ecosystem-based planning as detailed in Chapter 7 of this report. Information requirements for each planning level (subregional, watershed, and site) are organized by major themes considered during planning: watershed integrity, biological diversity, cultural values,[156] scenic resources, and recreation and tourism. Methods for monitoring growth and yield of wood fibre have a long history in forest management, are well-defined, and are not included here.

1.0 Historical Information

To ensure that the knowledge gained from past experience is used effectively, information on the history of logging and, where possible, natural disturbances, in Clayoquot Sound must be assembled, mapped, and made readily available to planners at all levels. Such information should include, but not be limited to:

- cutblocks – noting dates and details related to harvesting system, volume of wood of each species harvested, site preparation, rehabilitation, regeneration, and stand tending activities
- road network – noting dates and location of construction, deactivation activities, and any road-related slope failures or landslides

[156] The Panel's discussion of values in this appendix highlights First Nations' values. This focus is not intended to deny other values (see Sections 1.1 and 6.0).

- natural disturbances – noting extent and frequency of wind, insect, landslide, and fire
- human-induced disturbances – noting their type, duration, area of influence, and effects on resources.

2.0 Subregional-Level Information

Subregional planning addresses issues and resources that span large areas and often cross watershed boundaries. While the entire Clayoquot Sound area might be considered as a subregion, the Panel recommends dividing Clayoquot Sound into three subregions (see Section 7.3.1) because of the abundance of data and logistical difficulties of dealing with so large an area. Appropriate subregional mapping scales range from 1:50 000 to 1:125 000, depending on the resource of interest.

2.1 Watershed Integrity

At the subregional scale, information related to watershed integrity consists of basic geological and drainage information that provide the framework for mapping surficial materials, soils, drainage, and stream channel features at watershed and site scales, and that supply the context for understanding water quality and soil nutrient conditions. This includes:

- map of bedrock geology
- map and report of glacial and Holocene earth history[157]
- map of drainage basins and the drainage network showing all points for which hydrological and climatological information are available.

2.2 Biological Diversity (Aquatic and Terrestrial)

Subregional concerns related to biological diversity focus on maintaining adequate habitats to allow migration of animals and connectivity among plant and animal populations across watershed boundaries. The following information will help to identify those linkages:

- maps of major ecosystems showing:
    - areas of older forest[158] that link across watershed boundaries
    - major vegetation types (e.g., biogeoclimatic zones and subzones, and forest age classes), highlighting those that are rare

[157] The glacial and Holocene earth history provide the context for predicting the occurrence of certain surficial materials, soils, and natural stability problems that must be confirmed in more detailed mapping at a watershed scale.

[158] See footnote 132.

- maps showing current forest condition, including areas cut (from forest cover maps), state of regeneration, and silvicultural treatments on all disturbed sites
- maps of migration areas for species that migrate among watersheds (e.g., Roosevelt elk, black-tailed deer)
- maps showing areas of wildlife habitat particularly sensitive to human disturbance, and indicating where and how human interaction and development should be constrained
- maps showing private land boundaries, forest tenure boundaries, planning units (e.g., LRUPs), existing and proposed Protected Areas (e.g., Ecological Reserves), mineral claims, traplines, and guide-outfitter territories
- maps of existing developments such as roads (active and deactivated), bridges, major culverts, log sorts and dumps, and camps.

Inventory at the subregional and watershed planning levels requires some knowledge of vertebrate species presence, distribution, and habitat use.

2.3 Cultural Values

The regional geography of cultural activity—most particularly the long-established patterns of First Nations' activities—must be identified and mapped to highlight the scope of human concerns and interests in Clayoquot Sound. These include:

- maps of ***h̲ah̲uulhi*** areas and description of ***h̲ah̲uulhi***[159]
- maps of culturally important areas that extend across watershed boundaries
- map notations of culturally important plant and animal species
- map notations of non-timber forest product species and summaries of literature on their sustainable use.

2.4 Scenic Resources[160]

Much of the planning to maintain scenic values is done at the subregional scale. Information requirements include:

- maps of scenic landscape areas based on similarities in landscape characteristics (e.g., physiography, topography, slope, degree of alteration) and viewer-related characteristics (e.g., level of visibility, present and potential public use, and perceptions and expectations of specific groups) with descriptions of those characteristics.

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[159] ***H̲ah̲uulhi*** refers to the plenary authority exercised by Nuu-Chah-Nulth hereditary chiefs over the people, land, and resources of their tribal territories. See *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b).

[160] For more detailed information on attributes, see *Clayoquot Landscape Inventory Phase 1: Methodology Development and Initial Inventory* (Juan de Fuca Environmental Consultants *et al.* 1994).

Examples of scenic landscape areas at the subregional level include:

- a fjord used primarily by kayakers, where there has been a moderate amount of forestry activity
- a highly scenic, largely undeveloped fjord with high potential for various types of boating
- a high elevation area not highly visible from public use corridors with an extensive amount of past forestry activity

The Clayoquot Sound Scenic Corridors Planning Process has completed such an inventory (Juan de Fuca Environmental Consultants *et al.* 1994; Juan de Fuca Environmental Consultants and Viewpoint Recreation and Landscape Consulting 1994).

2.5 Recreation and Tourism

Subregional-level recreational and tourism resources have largely been inventoried by the B.C. Ministry of Small Business, Tourism and Culture (coastal tourism resource inventory and Vancouver Island tourism resource inventory; see ARA Consulting Group 1992, 1993). These inventories should be revised by updating and refining:

- recreational and tourism use corridors (e.g. driving, boating, hiking), including notations about level of use
- locations and level of use of recreational and tourism use sites (e.g., parks, recreation sites, lodges)
- particular biophysical or cultural features of interest for recreational and tourism uses
- perceptions and expectations of First Nations and other community residents
- perceptions and expectations of specific groups (e.g., recreation groups, tourists, tourism operators).

3.0 Watershed-Level Information

At the watershed level, information is required to specify reserve (no-harvesting) areas required to maintain long-term ecosystem integrity, and to delineate harvestable areas. The mapping area is a specific watershed or group of small watersheds, generally under 35 000 ha in area. Appropriate mapping scales range from 1:10 000 to 1:20 000.

3.1 Watershed Integrity

At the watershed level, all features relevant to delineating and describing the hydroriparian zone must be identified and recorded. These include:

- maps showing the classification of surface waters (see Appendix II)

Drainage feature mapping can be incorporated into terrain mapping for cost-effectiveness. Information on published topographic maps is not sufficient, and ground checking is important.

- terrain map (field checked)
- site map (field checked)
- interpretive maps, derived from terrain maps and other assembled information (e.g., geology, drainage features, soils), showing slope stability classes and erodible materials.

  Details required in the interpretive map include:

  - detailed terrain stability mapping (classes I–V); especially class V (unstable under natural conditions) and class IV (potentially unstable)
  - erosion potential classes; especially terrain subject to surface erosion by running water under natural conditions
  - landslide inventory; all recognizable landslides (symbols for each slide scar, extent of tracks, code for approximate age)
  - avalanche tracks (for applying avalanche protection zones)
  - floodplains, alluvial fans, blocky and bouldery materials (some alluvial and colluvial fans, talus slopes, rockslide debris) where regeneration may be a problem
  - bedrock terrain:
    - that is bare or covered only with lichen, moss, or shallow organic material (less than 10 cm)
    - that is mantled by freely draining organic soils (folisols)
    - limestone and any other bedrock with special problems or attributes
  - poorly drained organic terrain.

3.2 Biological Diversity (Aquatic and Terrestrial)

At the watershed level, all features relevant to delineating and describing reserves for species at risk, late successional forests, and other important habitats must be identified and recorded. These include:

- descriptions of ecosystems:
  - map and refine subzone and variant boundaries at 1:20 000 or 1:10 000
  - describe and map major ecosystems within variants by site series mapping or by using forest cover maps to create general ecosystem description based on lumping polygons by leading species and height/age information.

For each major ecosystem (e.g., site series), map:

- tree species abundance and distribution (from forest cover maps)
- age class distribution[161] by tree species (from forest cover maps)
- an indication of level of fragmentation by describing the distribution of patch sizes in old growth and also of patches less than 20 years of age; note the locations of patches of old growth greater than 300 m wide
- baseline information on abundance of snags by size class and volumes of downed wood by leading tree species (collected during preliminary field cruises)

• other watershed information:

  - location and extent of special ecosystems (e.g., spawning areas; eagle and osprey nest sites; heron rookeries; oldest trees, especially western redcedar and yew stands; areas with rare plants)
  - baseline information for threatened or vulnerable species,[162] (e.g., species presence or absence, major ecosystem where located during each season, structural information on the habitat where located, and relative abundance)
  - baseline information on species that are closely associated with particular habitats or habitat characteristics, for example:
    - coho, chinook, chum, pink, and king salmon (associated with stream estuary and ocean habitats)
    - eelgrass (associated with estuaries)
    - elk, Vaux's swift, and marten (associated with older forest)
    - black bear and hairy woodpecker (associated with interspersion of coniferous and deciduous trees)
    - pileated woodpecker and common merganser (associated with wildlife trees)
    - bald eagle and great blue heron (associated with large trees)
    - northwest and clouded salamanders (associated with downed wood)
    - beaver, river otter, and mink (associated with riparian habitats)
    - savannah sparrow and cowbirds (associated with open habitats including disturbed sites).

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[161] Current forest age classes or refinement of the oldest age class if that proves necessary; see footnote 132.

[162] Examples of threatened species include the bat Keen's myotis and the Queen Charlotte Islands' goshawk. Examples of vulnerable species include marbled murrelet.

Vertebrate species can be inventoried through a combination of breeding and winter bird counts; riparian and estuarine transects to observe river otter sign, beaver sign, and common merganser broods (some riparian surveys can be done during drainage and terrain ground checks); winter track counts for elk, deer, and marten; and surveys of marked trees, and day beds for black bear. Several standard methods exist for fish surveys. Where possible, areas where animal surveys are carried out should be coordinated with placement of cruise plots that gather snag and downed wood information.

3.3 Cultural Values[163]

At the watershed level, all features relevant to delineating and describing reserves to protect important culturally important areas must be identified and recorded. These include:

- specific cultural areas requiring protection (e.g., sacred sites, historic areas, current use areas)
- culturally important species and areas
- hereditary/traditional ownership of specific areas.

The confidentiality of cultural inventory information must be respected.

3.4 Scenic Resources[164]

At the watershed level, all features relevant to delineating and describing specific landscape units[165] must be identified and recorded. These include:

- maps of specific landscape units based on similarities in physiography, vegetative cover, degree and type of land and water uses, viewer-related characteristics, and relationship to existing and potential tourism and recreation areas, with descriptions of those characteristics.

  Examples of landscape units might be:

  - a steep slope with a moderate amount of forestry activity oriented to a water use corridor
  - an unaltered, well-defined valley extending back from the shoreline.

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[163] First Nations' values are discussed more fully in the Panel report: *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b).

[164] For more detailed information on attributes, see Juan de Fuca Environmental Consultants *et al.* (1994).

[165] "Landscape unit" is the term used by the B.C. Ministry of Forests. This departs from the Panel's use of the term "working unit" throughout this document.

The Clayoquot Sound Scenic Corridors Planning Process has completed such an inventory (Juan de Fuca Environmental Consultants *et al.* 1994; Juan de Fuca Environmental Consultants and Viewpoint Recreation and Landscape Consulting 1994).

3.5 Recreation and Tourism

At the watershed level, all features relevant to delineating and describing specific recreation areas[166] must be identified and recorded. These include:

- biophysical features that support recreation and tourism
- cultural features that support recreation and tourism
- existing recreation and tourism use activities and levels of use.

Attributes for these features can be based on the existing B.C. Ministry of Forests Recreation Inventory method, ensuring that:

- features described are particularly important to recreation and tourism
- scenic resource information is addressed in a general way in relation to specific sites (e.g., scenery is significant or not) to avoid duplicating the scenic resource inventory
- there is no limit to the number of features and activities relevant to a recreation area.

4.0 Site-Level Information

Site-level planning includes planning specific management actions for a variety of working units (e.g., recreation units, cutting units; see Section 7.3.3). Because of the range of management activities, working units may range in size from one to several tens of hectares. Typical mapping scales range from 1:2000 to 1:5000.

Site-level inventory identifies features requiring protection that were not identified during watershed-level planning (e.g., culturally modified trees) and features that affect operational decisions (e.g., bald eagle nest or danger trees). It also establishes baseline information for monitoring purposes.

4.1 Watershed Integrity

The objective at the site level is to identify all features that could affect operational management of the site, and to establish baseline information for subsequent audits to confirm the success or failure of management activities. Information collected at this level includes:

- classification and map of all drainage features
- description of drainage features to permit detailed road and harvest layout

[166] Similar to the B.C. Ministry of Forests recreation land unit or polygon.

- detailed terrain mapping including site inspections to confirm operational constraints
- baseline stream channel audits (see Section 8.2.2).

Some of this information will be aggregated for interpretation at the watershed or subregional scales.

4.2 Biological Diversity (Aquatic and Terrestrial)

The objective at the site level is to confirm the presence or absence of species or habitats that will affect operational management of the site, and to establish baseline information on stand structure for subsequent monitoring to confirm the success or failure of site management activities. Information should include:

- pre-harvest baseline information on wildlife tree species, sizes, and abundance; volumes and decay classes of downed wood; and numbers and sizes of very large trees
- for red-listed, forest-dependent species (plants or animals) identified at the watershed level, field confirmation of the presence of species within the proposed working units.

4.3 Cultural Values

The objective at the site level is to identify any features in working units that limit management activities. These features include:

- detailed mapping of areas and species important to First Nations as determined by the Nuu-Chah-Nulth of Clayoquot Sound
- identification of any areas requiring archaeological investigation.

4.4 Scenic Resources

The objective at the site level is to assist detailed planning for maintaining scenic landscapes in conjunction with management activities. Relevant information includes:

- key viewpoints, and the type and level of existing and potential public use
- accurate mapping of visible and non-visible areas from key viewpoints
- from the key viewpoints, descriptions of landscape form, line, colour, texture, and pattern.

4.5 Recreation and Tourism

The objective at the site level is to refine recreation information. This includes updating and refining the watershed-level recreation inventory by:

- identifying specific working units dedicated to recreation

- refining inventory boundaries
- adding information on features and use.

Appendix IV

Glossary

Active floodplain: the portion of the floodplain that is frequently (more than once in five years) inundated by flooding.

Adaptive management: the rigorous combination of management, research, and monitoring so that credible information is gained and management activities can be modified by experience. Adaptive policy acknowledges institutional barriers to change and designs means to overcome them.

Adjacency: see *Green-up.*

Age class: any interval into which the age range of trees, forests, stands, or forest types is divided for classification and use.

Aggregated retention: retaining trees in patches throughout a cutblock or cutting unit.

Alienate: to voluntarily transfer title to property; to convey.

Alienation: any land that has had its “right-to-use” transferred from the Crown through grant, lease, or permit or has a special interest noted, as in reserves. Land may be so designated permanently or temporarily.

Allochthonous: originating outside the area, as food sources for stream residents entering from the surrounding terrestrial landscape to support the stream food chain.

Allowable annual cut (AAC): the annual rate of timber harvesting specified for an area of land by the chief forester of the B.C. Ministry of Forests. The chief forester sets AACs for timber supply areas (TSAs) and tree farm licences (TFLs) in accordance with Section 7 of the *Forest Act*, and for Certified Tree Farms in accordance with the *Assessment Act*. In sustained yield theory (Hanzlik and followers) it is also a volume of timber equal to the mean annual increment, or mean annual increase in standing volume; therefore, the quantity that can be harvested continuously from the area.

Alluvial fan: a fan-shaped deposit of fluvial sand and gravel, usually located at the mouth of a tributary valley.

Alluvium: material deposited by a stream; fluvial (alluvial) materials.

Anadromous: describing fish that spawn in freshwater and migrate to sea to grow to maturity.

Annual flood sequence: the sequence of highest streamflows in each year, sometimes recorded as the highest daily mean flow, and sometimes as the highest instantaneous flow in the year. On small streams, there may be large differences between these two flows. The annual flood sequence is commonly analyzed to determine the frequency with which a flow of a given specified magnitude is apt to recur or (which is the same thing) how many years may elapse, on average, between successive recurrences of flows of the same magnitude; thus, for example, one specifies the “once in five years” flood.

Autotrophic: describing organisms that can produce their own organic material from inorganic chemicals and an external source of energy (e.g., plants and specialized bacteria).

Avulsion: an abrupt shift in the location of a stream channel on a floodplain.

Backspar trail: a pathway over which a mobile backspar travels.

Bag booms: temporary enclosures of logs (“boomsticks”) chained together for short-term log storage. Bag booms may be towed short distances in sheltered waters but cannot be towed far, or in exposed waters.

Balloon yarding: yarding done using cables attached to balloons, which provide lift and carry logs to a stationary yarder at a landing.

Basal till: material that accumulates underneath a glacier by melting out from basal ice; includes lodgement till and basal meltout till.

Baseline information: information collected to provide a standard against which future measurements can be compared.

Bedrock: solid rock, usually older than Quaternary (except rock formed by cooling of lava); either exposed at the land surface or underlying surficial deposits or regolith of varying thickness.

Benthic: pertaining to organisms living on the floor of a waterbody.

Biodiversity: See *Biological diversity.*

Biogeoclimatic ecosystem classification (BEC): a hierarchical classification system with three levels of integration: regional, local, and chronological; and combining climatic, vegetation, and site factors.

Biogeoclimatic zone: a large geographic area with a broadly homogeneous macroclimate. Each zone is named after one or more of the dominant climax species of the ecosystems in the zone, and a geographic or climatic modifier.

Biological diversity: the diversity of plants, animals, and other living organisms in all their forms and levels of organization, including genes, species, ecosystems, and the evolutionary and functional processes that link them.

Biomonitors: organisms that are used to assess effects of physical and other stresses (e.g., waterflow or water quality) on themselves and other organisms.

Biota: living organisms; the flora and fauna of a region or time period.

Blowdown (windthrow): uprooting by the wind; also refers to a tree or trees so uprooted.

Blue-listed species: In British Columbia, the designation of an indigenous species, sub-species, or population as being vulnerable or at risk because of low or declining numbers or presence in vulnerable habitats. Included in this classification are populations generally suspected of being vulnerable, but for which information is too limited to allow designation in another category.

Bog: is a peatland with the water table at or near the surface. The bog surface (which may be raised or flat) is unaffected by minerotrophic ground water. The major source of water is precipitation, which is low in nutrients. Bogs may be treed or treeless, and they are usually covered with *Sphagnum* moss and ericaceous shrubs. A peat accumulation that has grown above the local water table so that the water in the upper peat is sustained by precipitation.

Boom (log boom): a floating enclosure comprised of logs chained together to contain logs during storage and/or transportation on the water.

Borrow areas or borrow pits: areas of land from which materials such as sand and gravel are extracted for use elsewhere, mainly for road surfacing purposes.

Botanical forest products: non-timber based products gathered from forest and range land. There are seven recognized categories: wild edible mushrooms, floral greenery, medicinal products, fruits and berries, herbs and vegetables, landscaping products, and craft products.

Brackish: possessing a moderate degree of salt; hence, water produced by the mixing of salt and freshwater (approximately 0.5–17.0 parts per thousand).

Bunks: cradle-like structures in which logs of various species and grades are accumulated until the desired log bundle size—usually about 50 m^3—is attained.

Cable logging: a yarding system employing winches, blocks, and cables.

Cants: partly manufactured logs that are roughly squared, usually for export.

Channel avulsion: an abrupt diversion of the stream from one course to another during a flood, or as a result of blockage of the original channel by sediment or woody debris.

Chokers: cables attached to logs during yarding operations.

Clearcut-with-reserves: a variation of the clearcutting system which retains a variable number of reserve trees either uniformly or in small groups for purposes other than regeneration.

Clearcutting silvicultural system: a system in which the timber crop is cleared from an area at one time and an even-aged, replacement stand is established. Clearcutting is designed so that most of the opening has full light exposure and is not dominated by the canopy of adjacent trees (this produces an open area climate). The minimum size of a clearcut opening is generally considered to be 1 ha.

Coarse woody debris: sound and rotting logs and stumps that provide habitat for fungi, plants, animals, and their predators.

Colluvial fan: a fan-shaped mass of sediments deposited by mass wasting, most commonly debris flows.

Colluvium: (i) materials that have reached their present positions as a result of direct, gravity-induced mass movements; no agent of transportation such as water or ice is involved, although the moving material may have contained water or ice. Includes talus, landslide debris, and debris flow deposits. (ii) As above definition, but also including deposits resulting from slope wash.

Commercial thinning: a partial cut in older immature stands where trees have reached merchantable size and value, carried out to provide an interim harvest while maintaining or restoring a high rate of growth on well-spaced final crop trees.

Commission on Resources and Environment (C.O.R.E.): a body established by the British Columbia government, that is independent of the various provincial ministries, and whose mandate is to deal with resource and environmental management issues.

Community watersheds: those watersheds designated by the B.C. Ministry of Environment, Lands and Parks for domestic water production.

Conductance: the ability of a substance to transmit an electrical current (the reciprocal of electrical resistance); here, it is specifically the ability of water to transmit an electrical current, which depends upon the dissociation of molecules into ions in water. Because many mineral impurities in water dissociate ionically, electrical conductance is a useful measure of the mineral contaminant load of water.

Constrained maximization approach: in this report, a planning approach where timber production receives top priority and consideration of other resources occurs as restrictions or constraints on the allowed timber harvest.

Contemporary floodplain: valley floor adjacent to stream channel subject to inundation by current hydrological regime.

Conventional ground skidding: log yarding using any combination of rubber-tired or tracked skidding equipment to drag, slide, or carry logs on the ground.

Conventional logging: any combination of mechanical or hand felling and rubber-tired or tracked skidding equipment. On the British Columbia coast, cable logging is considered conventional.

Critical wildlife habitat: part or all of a specific place occupied by a wildlife species or population that is recognized as essential for maintaining the population.

Crop tree: a tree in a young stand or plantation selected to be carried through to maturity until an interim or final harvest.

Crown land: land that is owned by the Crown; referred to as federal Crown land when it is owned by Canada, and as provincial Crown land when owned by the Province.

Culvert: a pipe, pipe arch, or log structure covered with soil and lying below the road surface, used to carry water from one side of the road to the other; a *cross-drain culvert* is a pipe or log structure covered with soil and lying below the road surface.

Cumulative effects: effects on biota of stress imposed by more than one mechanism (e.g., stress in fish imposed by both elevated and suspended sediment concentrations in the water and by high water temperature).

Cumulic: of soils, persistently aggrading by the addition of mineral materials to the surface. Typically occur on floodplains where mineral sediments are deposited from flood waters.

Cut: (i) the excavation required to lower the natural ground line to the desired road profile; (ii) the forest harvesting operation.

Cut-and-fill: a system of bench construction on hillslopes to produce road rights-of-way and landings whereby convex slopes are excavated and concave slopes (gullies) are filled; also, excavation of the upslope side of the right-of-way, and fill on the downslope side ("half-bench" construction).

Cutblock (or cutting unit): a specific area, with defined boundaries, authorized for harvesting.

Cutting cycles: the planned, recurring interval of time between successive cuttings in a crop or stand.

Cutting Permit: a legal document that authorizes the holder to harvest trees under a licence issued under the *Forest Act.*

Danger tree: a tree or any part of a tree that has sufficient structural weakness to pose a high risk of falling and causing personal or property damage.

DBH (diameter breast height): the diameter of the tree stem at "breast" height (approximately 1.3 m above the point of germination).

Deactivation: measures taken to stabilize and close roads and logging trails during periods of inactivity, including the control of drainage, the removal of sidecast where necessary, and the re-establishment of vegetation for permanent deactivation.

Debris avalanche: rapid downslope movement on steep slopes of saturated soil or surficial material, commonly including vegetative debris; a very rapid to extremely rapid debris flow.

Debris flow: rapid flow of a slurry of saturated debris, including some or all of soil, surficial material, weathered rock, mud, boulders, and vegetative debris. A general designation for all types of rapid downslope flow, including mudflows, rapid earthflows, and debris torrents.

Debris slide: the sliding of soil and vegetation cover downslope. Usually the slip plane is the sharp boundary between partially saturated soils and unweathered surficial material or bedrock.

Debris torrent: a variety of debris flow that includes little fines (silt and clay) and that follows a pre-existing stream channel.

Deferred area: a forest area in which a restriction of activity order is put into effect for a specific period of time.

Designated skid road or skid trail: a pre-planned network of skid roads or skid trails, designed to reduce soil disturbance and planned for use in subsequent forestry operations in the same area. Multiple passes by tracked or rubber-tired skidders or other equipment are anticipated.

Detritus: materials worn or detached from forest organisms, usually referring to partially disintegrated leaves and twigs from trees.

Developed watersheds: watersheds having some degree of development. Development may include forestry operations, roads, or housing.

Dispersal: movement of organisms away from their birth place to establish living space elsewhere.

Dispersed retention: retaining individual trees scattered throughout a cutblock.

Dissolved oxygen: the quantity of oxygen contained in solution in water; the characteristic range of dissolved oxygen content in stream waters is 3–12 mg/l.

District (forest district): an administrative unit within a forest region.

Downed wood: see *Coarse woody debris.*

Drainage basin: area of the Earth surface from which surface drainage all flows to a single outlet stream; a watershed in North America.

Drainage system: (i) the network of stream channels in a drainage basin; (ii) a culvert, cross-ditch, swale, or outslope/inslope to move water from one side of the road to the other.

Dropline: a skidding line that can be dropped from below the carriage to increase the lateral reach of the chokers.

Dryland sort: an area on land where logs are sorted, graded, and often bundled.

Ecosystem: a functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size (a log, pond, field, forest, or the Earth's biosphere) but it always functions as a whole unit. Ecosystems are commonly described according to the major type of vegetation, for example, forest ecosystem, old-growth ecosystem, or range ecosystem.

Ecosystem integrity: the soundness or wholeness of the processes and organisms composing the ecosystem. The Panel defines "maintaining ecological integrity" as maintaining functioning, self-sustaining ecosystems with characteristics similar to the original ones.

Ecosystem productivity: the ability of an ecosystem to produce, grow, or yield products whether trees, shrubs, of other organisms.

Edaphic: related to or caused by particular soil conditions, as of texture or drainage, rather than physiographic or climatic factors.

Edge effect: habitat conditions (such as degree of humidity and exposure to light or wind) created at or near the more-or-less well-defined boundary between ecosystems, as, for example, between open areas and adjacent forest.

End hauling: removal of excess materials from one section of road to another or to a designated waste area, instead of sidecasting.

Endangered species: see *Red-listed species.*

Entrenched: describing stream channels that are confined within fluvially eroded gullies or valleys of some depth.

Environmentally Sensitive Areas (ESAs): areas requiring special management attention to protect scenic values, fish and wildlife resources, historical and cultural values, and other natural systems or processes. ESAs for forestry include potentially fragile, unstable soils that may deteriorate unacceptably after forest harvesting (Es), and areas of high value to non-timber resources such as fisheries, wildlife (Ew), water, and recreation.

Ephemeral: applies to streams and lakes that may contain water for only a short period of time. Ephemeral streams carry only storm runoff, derived from saturation seepage or from overland flow.

Epiphytic: refers to a plant (epiphyte) that grows above the ground, supported non-parasitically by another plant or object, and derives its moisture and nutrients from the air and rain.

Escapement: an estimate of the numbers of adult fish returning to a stream to spawn.

Estuary: the embayed mouth of a river where the tide meets the river flow. (Locally, the term also connotes the lowermost, tidal reach of a river.)

Even-aged silvicultural system: a silvicultural system designed to regenerate and maintain an even-aged stand (e.g., clearcutting, seed tree, and shelterwood systems).

Existing visual condition (EVC): the level of human alteration in the landscape.

Felling and bucking: the processes of cutting down standing timber and then cutting it into specific lengths for yarding and hauling.

Fen: is a peatland with the water table usually at or a few centimetres above or below the surface. The waters are nutrient-rich and derived from mineral soils. Dominant vegetation is sedges, grasses, reeds, and brown mosses with some shrubs and, at times, a sparse tree cover.

Fill: the height of material required to raise the desired road profile above the natural ground line.

Fillslopes: slopes created by fill material (used to support the road); can be excavated from adjacent cutslopes when building roads, or trucked in from elsewhere.

Flood discharge criterion: the volume of flood that a bridge or culvert must be designed to accommodate.

Floodplain: level or very gently sloping surface bordering a river that is formed of fluvial sediments, and is subject to flooding.

Fluvial: pertaining to streams and rivers; similar to alluvial; *fluvial sediments* are materials transported and deposited by running water.

Foliar analysis: analysis of the nutrient content of leaves or needles. Foliar analyses can be used as a bioassay of environmental conditions affecting tree growth.

Folisols: well-drained organic soils derived from forest litter. These consist primarily of the organic forest floor layer and typically rest directly on bedrock. If a shallow mineral soil layer is present over the bedrock, the forest floor must be more than twice the thickness of the mineral layer, otherwise the soil is considered a podzol, gleysol, or other mineral soil type.

Forest cover: forest stands or cover types consisting of a plant community made up of trees and other woody vegetation, growing more or less closely together.

Forest cover map: a map showing relatively homogeneous forest stands or cover types, produced from the interpretation of aerial photos and information collected in field surveys. Commonly includes information on species, age class, height class, site, and stocking level.

Forest development plan: an operational plan guided by the principles of integrated resource management (the consideration of timber and non-timber values), which details the logistics of timber development over a period of usually five years. Methods, schedules, and responsibilities for accessing, harvesting, renewing, and protecting the resource are set out to enable site-specific operations to proceed.

Forest floor: comprised of layers of fresh leaf and needle litter, moderately decomposed organic matter, and humus or well-decomposed organic residue.

Forest practice: any activity that is carried out on forest land to facilitate uses of forest resources, including but not limited to timber harvesting, road construction, silviculture, grazing, recreation, pest control, and wildfire suppression.

Forest Practices Code (FPC): legislation, standards, and field guides that govern forest practices in British Columbia.

Forest resources: resources or values associated with forest land, including but not limited to water, wildlife, fisheries, recreation, timber, range, and heritage.

Forest-interior conditions: conditions found deep within forests, away from the effect of open areas. Forest-interior conditions include particular microclimates found within large forested areas.

Free-growing: an established seedling of an acceptable commercial species that is free from growth-inhibiting brush, weed, and excessive tree competition; or young trees that are as high as or higher than competing brush, with one metre of free growing space around their tops.

Fully benched road: a road where the entire running surface is supported by a cut into the hilltop. In contrast, a partially benched road has only part of the running surface on a cut into the hillside and part supported by fill material excavated from the cut.

Genetic diversity: variation among and within species that is attributable to differences in hereditary material.

Geographic Information System (GIS): a computer system designed to allow users to collect, manage, and analyze large volumes of spatially referenced information and associated attribute data.

Geological processes: actions and events that take place at and below the Earth's surface, and result in effects such as earthquakes and volcanism, mountain building, erosion, and the development of the landscape. See *Geomorphology*.

Geomorphology: the study of the origin of landforms, the processes whereby they are formed, and the materials of which they consist.

Glacial abrasion: the scouring action of particles embedded in glacier ice.

Glacial drift: sediments associated with glaciers, comprised of such varied deposits as till, outwash gravel, and sand.

Glacial lake: a lake that is dammed by a glacier or resting on glacial ice.

Glacial trough: a valley with a U-shaped cross profile due to erosion by a valley glacier.

Glaciofluvial: pertaining to the channelized flow of glacier meltwater (meltwater streams); *glaciofluvial materials* are sediments that exhibit clear evidence of having been deposited by glacial meltwater streams either directly in front of, or in contact with, glacial ice.

Glaciolacustrine: pertaining to glacial lakes; *glaciolacustrine materials* are sediments deposited in or along the margins of glacial lakes; primarily fine sand, silt and clay settled from suspension or from subaqueous gravity flows (turbidity currents), and including coarser sediments (e.g., ice-rafted boulders) released by the melting of floating ice; also includes littoral sediments (e.g., beach gravels); accumulated as a result of wave action.

Glaciomarine: pertaining to processes, sediments, and landforms associated with glacier termini in marine waters, such as receding glaciers in fjords and ice shelves; *glaciomarine materials* are sediments of glacial origin laid down from suspension in a marine environment in close proximity to glacier ice, and deposits of submarine gravity flows; includes particles released due to the melting of floating ice and ice shelves; primarily fine sand, silt and clay, and stony muds; marine shells or shell casts may be present.

Gleysols: poorly drained mineral soils with a high or fluctuating water table that are characterized by gleyed or mottled colours. Gleyed soils are dull, blue to olive in colour, indicative of reducing (rather than oxidizing) conditions. Mottled soil horizons consist of dull colours interspersed by brighter, usually yellow to orange patches, indicative of periodic entry of air to allow localized oxidation of minerals (notably iron oxides).

Grapple yarding: a cable-based yarding method that uses a grapple on a swing yarder (a yarder with a 15–17 m crane built on a hydraulic excavator-like chassis).

Green tree retention: the retention of live trees within a cutblock or cutting unit.

Green-up: the minimum height and stocking levels which trees on a cutblock must achieve before an adjacent stand of timber may be harvested.

Group selection: an uneven-aged silvicultural system in which trees from a stand are removed and regenerated in small groups. The size of each group is usually no larger than twice the height of the mature trees.

Guideline: an optional practice or new practice not currently in the Forest Practices Code. Although guidelines are generally voluntary, the implication is that practitioners will use these concepts and principles in meeting their resource objectives.

Gully: a small valley or ravine, longer than wide, and typically from a few metres to a few tens of metres across.

Hahuulhi: the plenary authority exercised by Nuu-Chah-Nulth hereditary chiefs over the people, land, and resources of their tribal territories.

Harvest pattern: the spatial distribution of cutblocks and reserve areas across the forested landscape.

Harvestable area: specific areas within a watershed where forest harvesting or other resource uses will not compromise the long-term integrity of the forest ecosystem, its use by First Nations people, or its recreational or high scenic value.

Harvesting prescription: detailed plan on how, when, and where timber will be harvested from an area.

Harvesting system: the mix of felling, bucking, and yarding systems used in logging a stand of timber.

Height class: an interval into which the range of tree or stand heights is divided for classification and use. Also, the trees or stands falling into such an interval.

Helicopter logging, or heli-logging: logging in which yarding is done using cables attached to a helicopter. Typically used in sensitive or inaccessible terrain.

Heritage areas: sites of historical, architectural, archaeological, paleontological, or scenic significance to the province.

Highgrading: the removal of only the best trees from a stand (e.g., trees above a certain size class), often resulting in a residual stand of poor quality trees.

High sensitivity areas: areas associated with special concerns, issues, or having the potential for negative impacts on forest values, including any soils with high hazard of compaction, erosion, mass wasting, or displacement.

Holocene (Epoch): the most recent 10 000 years of Earth history; more generally, the time since the end of the last major glaciation. In Clayoquot Sound, post-glacial conditions were established about 12 000 years ago.

Humic: a descriptor applied to organic materials; refers to material at an advanced stage of decomposition; it has the lowest amount of fibre, the highest bulk density, and the lowest saturated water-holding capacity of the organic materials; fibres that remain after rubbing constitute less than 10% of the volume of the material.

Hydrological features: refers to water-related features visible at the land surface, such as stream channels, seepage zones, springs, and soil moisture, including soil moisture characteristics as deduced from vegetation characteristics.

Hydrological regime: the pattern of occurrence in time of water at or near the surface of the Earth; e.g., temporal changes in streamflow, soil moisture, groundwater levels, precipitation.

Hydrology: the scientific study of the distribution and characteristics of water at and close to the Earth's surface.

Hydrophobic: describing an entity that repels water.

Hydroriparian ecosystem: aquatic ecosystems plus those of the immediately adjacent terrestrial environment; the latter occupying all land adjacent to waterbodies that is both influenced by and influences the aquatic system and its associated biota.

Hydroriparian zone: the entire floodplain of the stream, alluvial fan surfaces, and, where channels are entrenched, the entire slope that rises immediately from the channel.

Hyporheic: pertaining to the interstitial spaces in the phreatic (saturated) sediments of riverbed and floodplain, which are inhabited by small riverine organisms.

Igneous rocks: rocks produced under conditions involving intense heat (i.e., of volcanic or molten magma origin).

Impact assessment: a study of the effect of resource development on other resources.

Indicator species: a species whose response to a change in ecosystem condition may be used to indicate the likely response of other species.

Integrated resource management (IRM): The identification and consideration of all resource values, including social, economic, and environmental needs, in land use and development decision-making. It focuses on resource use and land use and management, and is based on a good knowledge of ecological systems, the capability of the land, and the mixture of possible benefits.

Intrusive rock: a rock that solidified from a mass of magma that invaded the Earth’s crust but did not reach the surface.

Invertebrates: creatures without a backbone (vertebrae); e.g., insects, worms, slugs, spiders, crustaceans.

Karst: pertains to landforms and processes associated with dissolution of soluble rocks such as limestone, marble, dolomite, or gypsum; characterized by underground drainage, caves, and sinkholes.

Lacustrine materials: sediments that have settled from suspension or underwater gravity flows in lakes; also includes littoral sediments (e.g., beach gravels) accumulated as a result of wave action.

Lagoon: a shallow body of salt water separated from the sea by a spit or barrier beach.

Land and Resource Management Plan: a strategic, multi-agency, integrated resource plan at the subregional level. It is based on the principles of enhanced public involvement, consideration of all resource values, consensus-based decision-making, and resource sustainability.

Landform: any physical, recognizable form or feature of the Earth’s surface, having a characteristic shape, and produced by natural processes.

Landing: an area that has been constructed for logs to be yarded or skidded to for sorting and/or loading.

Landscape inventory: the identification, classification, and recording of the location and quality of visual resources and values.

Landscape management unit (LMU): a large area with similar characteristics visible from a scenic corridor that is assigned a visual quality objective (VQO).

Landscape sensitivity: a component of the landscape inventory that assigns a landscape sensitivity rating (LSR) based on the visual prominence or importance of features; conditions that affect visual perception; and social factors that contribute to viewer perceptions. LSR summarizes the visual importance based on a combination of biophysical characteristics and viewing and viewer-related factors.

Large organic debris (LOD): entire trees or large pieces of trees that provide channel stability or create fish habitat diversity in a stream channel.

Lateral reach: the ability to reach perpendicular from the main yarding corridor into the stand to yard logs from the stand to the main corridor.

Lateral yarding: See *Lateral reach.*

Leave trees: all trees, regardless of species, age, or size, remaining on a harvested area as a result of a predetermined silviculture prescription to address a possible range of silviculture or resource needs.

Lentic: pertaining to standing fresh water.

Lift: the upward force applied to a log by a cable yarding system.

Line loader: a log loader employing wire rope (cable), rather than hydraulics (as in hydraulic log loaders) for controlling machine movements.

Littoral zone : strictly speaking, the intertidal zone; customarily, the zone between the upper limit of wave action (the back of the storm beach or cliff base), and the seaward limit of frequent wave action on the seabed (approximately the 10 m depth contour).

Load line: the line or cable that hangs from a helicopter to which the chokers are attached.

Log barge: a self-propelled or towed vessel used to transport logs.

Log bundling: the tying of several logs into bundles during or after sorting operations.

Long snorkelling: short yarding from roads using modified line loaders.

Lotic: pertaining to streams (flowing fresh water).

Marine borers: ocean-dwelling organisms, usually molluscs, that bore holes in logs or wood found in marine waters.

Marine materials: sediments deposited in the ocean by settling from suspension and by submarine gravity flows, and sediments accumulated in the littoral zone due to wave action.

Marine sensitive zone: area of the sea or seabed supporting an easily disturbed ecosystem; includes herring spawning areas, shellfish beds, marsh areas, juvenile salmonid rearing areas, and adult salmon holding areas.

Marsh: a mineral wetland that is permanently or seasonally inundated up to a depth of two metres by standing or slowly moving water. The waters are nutrient-rich and the substrate is usually mineral soil. Marshes have emergent rushes, grasses and reeds, and submerged or floating aquatic plants in open water areas.

Mass movement: a general term for downslope gravitational movement of earth materials by processes such as rockfall and debris slides.

Mass wasting: (i) a general term for a variety of processes, including weathering and erosion, that together effect reduction of slopes and lowering of the land surface; (ii) see *Mass movement.*

Mature timber: stands of timber where the age of the leading species in a stand is greater than the specified cutting age. In even-aged management, those trees or stands that are sufficiently developed to be harvestable, and which are at or near rotation age (includes overmature trees and stands if an overmature class has not been recognized).

Meadow (wet meadow): a seasonal wetland developed on mineral materials that are periodically saturated but seldom inundated. Vegetation is a mixture of flood-tolerant grasses, low sedges, rushes, and forbs.

Metamorphic rock: “changed-form” rock, any rock that has been changed in texture or composition by heat, pressure, or chemically active fluids after its original formation.

Microclimate: the climate conditions (wind, temperature, humidity, etc.) of a local area. The area may range from a few centimetres (e.g., for micro-organisms in the forest floor) to several tree heights in diameter.

Micro-organisms: unicellular or simple many-celled organisms (e.g., bacteria).

Mineral soil: soil made up of eroded parent geologic materials; mineral soils contain no, or very little, organic material.

Ministry of Environment, Lands and Parks (MOELP): provincial government ministry responsible for the protection, management, and enhancement of British Columbia’s environment, while sustaining the quality of life.

Ministry of Forests (MOF): provincial government ministry responsible for the management and protection of the province’s forest and range resources for the best balance of economic, social, and environmental benefits to British Columbians.

Monoculture: in general, even-aged, single-species forest crops.

Multi-span configuration: involves two or more spans of the skyline by using intermediate supports.

Mycorrhizae: describing a symbiotic relationship between trees and fungi that grow in and around their roots that enables tree roots to better take up nutrients from the soil.

Natural disturbance regimes: the historic patterns (frequency and extent) of fire, insects, wind, landslides, and other natural processes in an area.

Natural regeneration: the renewal of a forest stand by natural (rather than human) means, such as seed on-site from adjacent stands or deposited by wind, birds, or animals.

No-work zones: an area in which equipment and people are not allowed during forestry operations, usually for safety or ecological reasons.

Non-timber resource values: values within the forest other than timber which include but are not limited to biological diversity, fisheries, wildlife, minerals, water quality and quantity, recreation and tourism, cultural and heritage values, and wilderness and aesthetic values.

Non-vascular plants: plants without conducting tissue (e.g., algae, mosses, liverworts).

Off-highway trucks: logging trucks of a size (width or weight) that exceeds legal highway specifications.

Old growth: a forest that contains living and dead trees of various sizes, species, composition, and age-class structure. Old-growth forests, as part of a slowly changing but dynamic ecosystem, include climax forests but not sub-climax or mid-seral forests. The age and structure of old growth varies significantly by forest type and from one biogeoclimatic zone to another.

Old-growth attributes: structural features and other characteristics (e.g., microclimate) of old-growth forests including: large live trees, variable spacing, variable tree sizes, dead and dying trees, understory patchiness, and deep canopies.

Old-growth management areas: areas that contain specific structural old-growth attributes, and which are mapped out and treated as special management areas.

Oligotrophic: containing few nutrients and few organisms.

Operational plans: within the context of area-specific management guidelines, operational plans detail the logistics for development. Methods, schedules, and responsibilities for accessing, harvesting, renewing, and protecting the resource are set out to enable site-specific operations to proceed.

Optical turbidity: the property of water which limits the transmission of light through it as the result of the presence of (fine) particulate materials in suspension. The property is measured in standardized geometric arrangements between light source and detector and the observed turbidity can be correlated with the concentration of particulate materials, hence providing a convenient index measure of suspended sediment concentration.

Organic soil: soil derived from plant material which contains greater than 30% organic matter.

Outwash (outwash fan): (i) the mass of detritus deposited by fast-flowing, heavily loaded water whose velocity is suddenly checked (e.g., at the mouth of a gorge); (ii) glaciofluvial deposits.

Parallel yarding corridors: describes parallel paths along which logs are yarded to a landing.

Partial cutting: an ill-defined term commonly encompassing both genuine silvicultural systems (e.g., selection cutting) and selective harvest (not a silvicultural system).

Partial duration flood sequence: is the sequence of all flows that exceed some specified threshold level (e.g., bankfull). At moderate threshold levels, there is apt to be more than one such event in each year, so this sequence diverges from the annual flood sequence, but at high threshold levels, more than one such flow in a year is unlikely. The two sequences coincide for flows more extreme than the one-in-five-year flood. The partial duration sequence is the relevant flow record for assessing extreme flow effects on aquatic biota, or for assessing the associated sediment transport, since all events exceeding the threshold for effective action are significant.

Phreatic zone: the earth below the water table which is saturated with water; in particular, the region below a floodplain and stream course which is saturated.

Physiography: the assemblage of features and attributes that form the landscape, including relief and topography, bedrock geology and structure, and geomorphological history.

Plankton: small organisms (plant or animal) floating in the water column (in fresh or salt water).

Pleistocene (Epoch): the first epoch of the Quaternary Period, lasting approximately two million years and ending 10 000 years ago; the epoch of the most recent major glaciations on Earth.

Podzols: rapidly to imperfectly drained mineral soils characterized by accumulations of humified (well decomposed) organic matter combined with various iron and aluminum oxides. The dominant soil horizon is typically reddish-brown, which may be overlain by a distinct grey horizon.

Polymorphism: simultaneous presence in a population of two genetically different forms of a trait at frequencies higher than could be maintained by recurrent mutation.

Porosity: the amount of pore (void) space present, expressed as a percentage of the total volume of the material.

Post-glacial: pertaining to the time interval since the disappearance of glaciers or an ice sheet from a particular area; similar to the Holocene Epoch.

Pre-commercial thinning: see *Spacing*.

Pre-harvest Silviculture Prescription (PHSP): a site-specific management plan; since 1987 a legal prerequisite to logging on Crown land. PHSPs specify planned forest activities, the methods to be used, and the proposed constraints necessary to protect the site and its resource values.

Prescribed burning: the knowledgeable application of fire to a specific area to meet management and silvicultural objectives.

Primary watershed: a watershed that drains directly into the ocean.

Productive forest landbase: that part of the landbase able to support trees of sufficient quality to be economically important.

Protected Areas: areas such as provincial parks, federal parks, wilderness areas, ecological reserves, and recreation areas that have protected designations according to federal or provincial statutes. Protected areas are land and freshwater or marine areas set aside to protect the province's diverse natural and cultural heritage.

Quaternary (period): the most recent period in Earth history, approximately the last two million years, comprising the Pleistocene and Holocene Epoch.

Radiating yarding corridors: see *Yarding corridors.*

Rain-on-snow events: rainstorms that result in large amounts of surface runoff due to the combined effects of heavy rainfall and snow melt. Rapid snow melt is caused by heat supplied from the warm air that is characteristic of intense rainstorms, and by heat released during condensation of moisture from the air onto the snow surface.

Rate-of-cut: the proportion of the watershed area allowed to be cut each year. It should be an input to the planning process.

Recreation feature: biological, physical, cultural, or visual features that have an ability to attract and sustain recreational use.

Recreation inventory: the identification, classification, and recording of the types and locations of recreation features.

Recreation opportunity spectrum (ROS): a range of outdoor settings based on remoteness, area size, and evidence of humans, which provides for a variety of recreation activities and experiences. The settings are classified on a continuum and are described as: rural, roaded resource, semi-primitive motorized, semi-primitive non-motorized, and primitive.

Red-listed species: In British Columbia, the designation of an indigenous species, sub-species, or population as endangered or threatened because of its low abundance and consequent danger of extirpation or extinction. *Endangered* species are any indigenous species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in B.C. *Threatened* species are any indigenous species that are likely to become endangered in B.C. if factors affecting that vulnerability are not reversed.

Referral: the process by which applications for permits, licences, leases, etc., made to one government agency by an individual or industry, are given to another agency for review and comment.

Regeneration: the renewal of a tree crop through either natural means (seeded on-site from adjacent stands or deposited by wind, birds, or animals) or artificial means (by planting seedlings or direct seeding).

Reserved trees: trees specifically reserved from harvesting and often referenced in Pre-harvest Silviculture Prescriptions or cutting authorities or by map notations.

Reserves: areas established to protect ecosystem integrity or various forest resources. These areas are normally excluded from harvesting.

Resident fish: fish that spend their entire life cycle in one stream or lake.

Resource Inventory Committee (RIC): a committee with representatives from various ministries and agencies for the federal and provincial governments and First Nations peoples, established to develop a common set of standards and procedures for provincial resources inventories.

Retention: retaining, during logging, or saving a portion of the original stand in clusters, clumps, or as scattered individual trees.

Rigging: setting up spars and supports for cable-yarding systems.

Right-of-way logging: cutting of linear strips that will become a road; essentially a right-of-way easement corridor.

Riparian area: the land adjacent to the normal high water line in a stream, river, lake, or pond and extending to the portion of land that is influenced by the presence of the adjacent ponded or channelled water. Riparian areas typically exemplify a rich and diverse vegetative mosaic reflecting the influence of available surface water.

Road deactivation: the process of rendering a road impassable to vehicular traffic. See *Deactivation*.

Road prism: the geometric shape formed by the road from the top of the cut to the toe of the fillslope. *Road prism width*: the distance from the top of the cut to the toe of the fillslope (several meters less than the clearing width which is the width in which all trees are cut prior to road construction).

Rotation: the planned number of years between the formation or regeneration of a tree crop or stand and its final cutting at a specified stage of maturity. In the variable-retention silvicultural system recommended by the Panel, rotation length does not consistently have the same meaning as when applied to conventional clearcutting. Although specific areas may be subject to long-term even-aged management, both reserves and trees retained during logging may differ during subsequent harvest; that is, time between harvest at any one location can be highly variable.

Saltmarsh: a marsh influenced by brackish or saline waters of tidal marine origin.

Salvage harvesting: logging operations specifically designed to recover damaged timber (dead or in poor condition) but still yield a wood product. Often carried out following fire or insect attack, or wind disturbances.

Seasonal streams: streams that flow throughout most of the year but may dry up during portions of the dry season.

Secondary watershed: a watershed that drains through a primary watershed before emptying into the ocean.

Sedimentary rock: rock formed by the laying down of sediments in marine or lake environments.

Sedimentation: the process of deposition of matter carried in water; usually the result of the reduction of water velocity below the point at which it can transport the material.

Seed orchard: a plantation of specially selected trees that is managed for the production of genetically improved seed.

Seed tree silvicultural system: an even-aged silvicultural system that leaves selected standing trees scattered throughout the cutblock to provide seed sources for natural regeneration. The number of seed trees to be left depends on the desired number of seedlings per hectare, the seed crop frequency, seed dissemination distance, and the length of time that the seedbed remains receptive, but is commonly 30 trees/ha.

Seed trees: trees selected to be left standing to provide seed sources for natural regeneration. Selection is usually on the basis of good form and vigour, the absence of serious damage by disease, evidence of the ability to produce seed, and wind firmness.

Seepage zone: an area where soil is saturated due to emerging groundwater.

Selection silvicultural system: a silvicultural system that removes mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where the continual establishment of regeneration is encouraged and an uneven-aged stand is maintained.

Selective logging: removal of certain trees in a stand as defined by specific criteria (species, diameter at breast height, or height and form). It is analogous to "high grading." Not to be confused with the selection silvicultural system.

Sensitive slopes: any slope identified as prone to mass wasting. See *Mass wasting.*

Sensitive soils: forest land areas with a moderate to high likelihood of increase in landslide frequency due to logging or roadbuilding activities.

Sensitive species: see *Blue-listed species*.

Sensitive watershed: a watershed used for domestic water supply purposes or having significant downstream fisheries values, and in which the quality of water resource is very responsive to changes in the environment. Such watersheds typically lack settlement ponds, are relatively small, are located on steep slopes, and have concerns such as high risk of erosion.

Seral stage: any stage of development of an ecosystem from a disturbed, unvegetated state to a climax plant community.

Shelterwood silvicultural system: a silvicultural system that removes the old stand in a series of cuttings to promote the establishment of an essentially even-aged new stand under the overhead or side shelter of the old one. Regeneration may be obtained naturally or by planting. Cuts may be done uniformly, in groups, or in strips. The "shelterwood" is removed once regeneration is well-established.

Shot-rock: bedrock that has been fragmented by explosives, consisting of a variable mixture of angular fragments.

Shrub-carr: a seasonal, shrub-dominated wetland, developed on mineral materials, that is periodically saturated but rarely inundated. The shrub layer is 1–2 m high (occasionally to 3 m); species include birch and willow that commonly grow on tussocks.

Sidecast: material moved onto the downslope side of the road during road construction; *sidecasting* refers to moving excavated material onto the downslope side during construction.

Siltation: deposition of silt (mud or fine soil) causing build-up of material.

Silvicultural regime: a series of site-specific silviculture treatments planned over time.

Silvicultural system: a planned cycle of activities by which a forest stand is harvested, regenerated, and tended over time. Any harvesting done *without* planning of subsequent regeneration and stand tending cannot be considered part of a silvicultural system.

Silvicultural treatment: any silviculture activity (e.g., harvesting, site preparation, stand tending) on forest stands to meet stand-specific objectives.

Silviculture: the art of producing and tending a forest, and the application of the knowledge of silvics in the treatment of a forest; the theory and practice of controlling forest establishment, composition, and growth.

Silviculture prescription: a site-specific integrated plan to carry out one or a series of silviculture treatments.

Site preparation: the preparation of a site by manual, mechanical, or chemical means to create favourable conditions to promote the establishment of the regeneration crop. The soil may be prepared for either naturally or artificially disseminated seed or for planted seedlings.

Site-level planning: the most detailed planning level; working unit level.

Site: an area described or defined by its biotic, climatic, and soil conditions in relation to its capacity to produce forest; the smallest planning unit.

Skid road: an excavated or bladed trail used by track or rubber-tired skidders to drag logs from the felling site to a landing.

Skid trail: a pathway travelled by ground skidding equipment while moving trees or logs to a landing. A skid trail differs from a skid road in that stumps are cut very low and the ground surface is mainly untouched by the blades of earth-moving machines.

Skidder: a wheeled or tracked vehicle used for sliding and dragging logs from the stump to a landing.

Skidding: the process of sliding and dragging logs from the stump to a landing, usually applied to ground-based yarding operations.

Slash: the wood residue left after harvesting operations, stand tending, breakage, mortality, or other natural phenomenon. Slash includes material such as logs, splinters or chips, tree branches and tops, uprooted stumps, and broken or uprooted trees and shrubs.

Slide: a mass movement process in which slope failure occurs along one or more slip surfaces and in which the unit generally disintegrates into a jumbled mass en route to its depositional site. A debris flow or debris torrent may occur if enough water is present in the mass.

Slope processes: mass movement processes, such as debris slides, and surface wash whereby fine sediments are transported downslope by overland flow.

Slope stability: pertains to the susceptibility of slope to landslides and the likelihood of slope failure.

Slump: a mass movement process in which slope failure occurs on a usually curved slip surface and the unit moves downslope as an intact block, frequently rotating outward. Slumps appear as discrete block movements, often in place, whereas slides usually break up and travel downslope.

Small Business Forest Enterprise Program (SBFEP): this program permits the B.C. Ministry of Forests to sell Crown timber competitively to individuals and corporations who are registered in the SBFEP. Approximately 10% of the province’s timber allocation is directed towards this program.

Smolt: a young salmonid migrating to the sea for the first time; commonly applied to steelhead, cutthroat, coho, chinook, and sockeye at one or two years of age. The name implies that the fish has undergone a major physiological change that enables it to go from a freshwater to saltwater environment.

Snag: a standing dead tree or part of a dead tree.

Soil creep: slow (imperceptible) downslope movement of soil.

Soil horizon: a zone in the soil that is generally parallel to the land surface and distinguished from zones above and below by characteristic physical properties, such as colour, structure and texture, and soil chemistry.

Soil productivity: the capacity of a soil, in its normal environment, to support plant growth.

Spacing: the removal of undesirable trees within a young stand to control stocking, to maintain or improve growth, to increase wood quality and value, or to achieve other resource management objectives.

Species richness: the numbers of species in an area.

Stand: a community of trees sufficiently uniform in species composition, age, arrangement, and condition to be distinguishable as a group from the forest or other growth on the adjoining area, and thus forming a silviculture or management entity.

Stand development: changes in forest structure over time, during and after disturbances.

Stand dynamics: the study of changes in forest stand structure with time, including stand behaviour during and after disturbances.

Stand structure: the distribution of trees in a stand, which can be described by species, vertical or horizontal spatial patterns, size of trees or tree parts, age, or a combination of these.

Stand tending: a variety of forest management treatments, including spacing, fertilization, pruning, and commercial thinning, carried out at different stages during a stand’s development.

Stocking: a measure of the area occupied by trees, usually measured in terms of well-spaced trees per hectare, or basal area per hectare, relative to an optimum or desired level.

Stream audit: measurements of stream characteristics, possibly including length of channel cut to streambank, length of bank with active erosion, amount and distribution of large organic debris, length of pool, riffle and glide habitat, and evidence of scour or sedimentation.

Stream class: as set out in the *British Columbia Coastal Fisheries/Forestry Guidelines*, Class A includes streams or portions of streams that are frequented by anadromous salmonids and/or resident sport fish or regionally significant fish species, or streams identified for fishery enhancement in an approved fishery management plan; stream gradient is usually less than 12%. Stream Class B includes streams or portions of streams populated by resident fish not currently designated as sport fish or regionally significant fish; stream gradient is usually 8–20%. Stream Class C includes streams or portions of streams not frequented by fish; stream gradient is usually greater than 20%.

Stream morphology: the characteristics of a stream including pool and riffle sequences and bank characteristics.

Stumpage (assessment): the price paid to the provincial government for timber harvested on Crown land. The market value of timber on an area of Crown land scheduled for harvesting is assessed, and the difference between the timber's market value and the operating costs necessary to get it to an acceptable market condition is determined. This difference is the stumpage value.

Subglacial till: material that accumulates directly from melting ice at the base of a glacier; includes basal till and lodgement till.

Subgrade: the material placed to construct the roadway, excluding surfacing.

Subregional planning level: a planning level that includes large areas made up of aggregations of watersheds.

Subtidal zone: the area between the low tide line and the outer limit of the littoral zone.

Surficial deposits (materials): relatively young, non-lithified sediments, usually of Quaternary age; usually classified as to their genesis, hence fluvial sediments, colluvium, glaciolacustrine sediments, etc.

Suspended sediment: sediments suspended in water.

Suspension (full, partial, or ground lead): describing the lifting of logs during yarding. During full suspension logs are entirely off the ground during yarding operations; partial suspension indicates that one end of the log contacts the ground during yarding; ground lead exerts no lift on the logs, resulting in little or no clearance of the log from the ground.

Sustainability: the concept of producing a biological resource under management practices that ensure replacement of the part harvested, by regrowth or reproduction, before another harvest occurs.

Swamp: is a wooded mineral wetland or a wooded peatland with standing or gently flowing water in pools and channels. The water table is usually at or very near the surface. Waters are nutrient-rich. Vegetation is a dense cover of deciduous or coniferous trees or shrubs, herbs, and some mosses.

Swing yarder: a yarder that has a slackpulling carriage that provides lateral yarding capability.

Talus: angular rock fragments accumulated at the foot of a steep rock slope and being the product of successive rock falls; a type of colluvium.

Tenure: the holding, particularly as to manner or term (i.e., period of time), of a property. Land tenure may be broadly categorized into private lands, federal lands, and provincial Crown lands. The *Forest Act* defines many forestry tenures by which the cutting of timber and other user rights to provincial Crown land are assigned.

Terrain: (i) a comprehensive term to describe a tract of landscape being studied with respect to its natural features; (ii) pertains to maps showing surficial materials, material texture, surface expression, present day geomorphological (geological) processes, and related features.

Terrain analysis: the process of terrain mapping and interpretation or assessment of terrain conditions for a specific purpose such as construction of logging roads or urban expansion.

Thermal regimes: the pattern of heat building up and cooling over a period of time in an area.

Thinning: see *Commercial thinning*, *Spacing*.

Threatened species: see *Red-listed species.*

Till: unstratified glacial drift deposited directly by the ice and consisting of clay, sand, gravel, and boulders intermingled in any proportion.

Timber supply area (TSA): the revised and consolidated former Public Sustained Yield Units within which the forest companies manage the timber resource according to strategic resource management plans prepared by the Ministry of Forests. Land is designated as a TSA under Part 3, Division (4) of the *Forest Act*.

Total resource plan: a plan for long-term forest management over an entire area, such as a watershed. The plan identifies known resource values, capabilities, and sensitivities; confirms or refines management objectives for those values; and establishes detailed management guidelines by which to achieve those objectives on the ground.

Tree farm licence (TFL): a licence entered into under Part 3, Division (2) or (5) of the *Forest Act*. The TFL is a stewardship agreement over a sustained yield management unit. This includes the right to harvest a specified volume of timber annually and the obligation to carry out all phases of forest management on behalf of the Ministry of Forests. The licence has a term of 25 years and is replaceable every 10 years.

Trophic processes: the processes (photosynthesis, herbivory, predation, scavenging, etc.) that link levels in the food chain.

Understory: any plants growing under the canopy formed by others, particularly herbaceous and shrub vegetation under a tree canopy.

Uneven-aged silvicultural systems: silvicultural systems that maintain or create stands with a wide range of tree ages and sizes. See *Selection silvicultural system.*

Unmerchantable: timber that is not economical to harvest due to size and quality constraints.

Utilization standards: the dimensions (stump height, top diameter, base diameter, and length) and quality of trees that must be cut and removed from Crown land during harvesting operations. Utilization standards can vary by species and timber supply areas (or supply blocks in TSAs).

Vascular plants: plants having cells for transferring water and nutrients up from the roots. Includes flowering plants and ferns.

Vertebrates: organisms with backbones.

Visual absorption capability (VAC): the landscape's capacity to absorb human-induced changes without reducing its visual qualities or integrity.

Visual green-up: the mix of herbaceous growth and deciduous and coniferous trees which acts to blend the cutblock into the surrounding forested landscape, making the cutblock less obvious.

Visual landscape management: the identification, assessment, design, and manipulation of the visual features or values of a landscape, and the consideration of these values in the integrated management of provincial forest lands.

Visual quality objective (VQO): an approved resource management objective that reflects a desired level of visual quality based on the physical and sociological characteristics of the area; refers to the degree of acceptable human alteration to the characteristic landscape.

Visual quality: the character, condition, and quality of a scenic landscape or other visual resource and how it is perceived, preferred, or otherwise valued by the public.

Visually sensitive areas: viewsheds that are visible from communities, public use areas, travel corridors—including roads and waterways—and any other viewpoint so identified through referral or planning processes.

Vulnerable species: see *Blue-listed species.*

Wall-base channels: small channels that originate at the base of valley walls and may run parallel to them. These are fed by groundwater from floodplain and adjacent valley slopes, and drain into the main stem of streams.

Water stage: the level of water (in a stream channel, lake, or the sea) measured relative to a fixed datum (which may be arbitrary). Stage establishes a consistent basis for measuring the variation in water level at a place.

Water table: the upper surface of groundwater (of the zone of saturation) in rocks or surficial materials.

Water-sorting: sorting logs by species and size in the water.

Watering bundles: the placing of bundles of logs (usually from a dryland sort or directly from a logging truck) into the water (ocean, lake). Bundles are usually pushed down inclined skids into the water.

Watershed: total region draining into a given waterway, lake, or reservoir; a drainage basin.

Watershed planning level: a planning area consisting of a specific watershed or groups of small watersheds, generally under 35 000 ha in area.

Watershed sensitivity analysis: in general, a procedure designed to determine whether, and in what degree, land use or land development will affect the flows of water and/or sediment in a watershed. See *Watershed Assessment Procedure (Interim Methods)* for specific procedures (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1994).

Wetland: land that is saturated with water long enough to promote wetland or aquatic processes; indicated by poorly drained soils, hydrophilic vegetation, and biological activity that is adapted to a wet environment. Includes fens, swamps, marshes, and bogs.

Wilderness: an area of land generally greater than 1000 ha that predominantly retains its natural character and on which the human impact is transitory and, in the long run, substantially unnoticeable.

Wildlife trees: dead, decaying, deteriorating, or other designated trees that provide present or future critical habitat for the maintenance or enhancement of wildlife.

Yarding (yarding methods): in logging, the hauling of felled timber to the landing or temporary storage site from where trucks (usually) transport them to the mill site. Yarding methods include cable yarding, ground skidding, and aerial methods such as helicopter and balloon yarding.

Yarding corridors (yarding roads): the roughly linear paths that logs travel as they are pulled by cables (lines) from where they are felled and bucked to a landing or roadside. Depending on the yarding system, corridors may be parallel to one another or radiate from a central landing. In the latter case, the area logged is fan-shaped to roughly circular.

Appendix V

Members of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound

Co-Chair	**Dr. Fred Bunnell**, Professor of Forest Wildlife Ecology and Management; and Director of the Centre for Applied Conservation Biology, University of British Columbia, Vancouver
Co-Chair	**Dr. Richard Atleo**, Hereditary Chief UMEEK; Instructor, Malaspina University-College; and Researcher, Consultant, Indigenous Human Resources, Nanaimo

Other members of the Scientific Panel, by area of expertise:

Biodiversity	**Dr. Ken Lertzman**, Assistant Professor, Forest Ecology, Simon Fraser University, Burnaby
	Dr. Chris Pielou, Ecologist, Denman Island
	Laurie Kremsater, Consultant, Forest Management and Wildlife Biology, Vancouver
Ethnobotany	**Dr. Nancy Turner,** Professor, Environmental Studies, University of Victoria, Victoria
First Nations	**Ernest Lawrence Paul**, Hesquiaht Elder; expert in Hesquiaht history, culture, traditional resource use and language, Hesquiat
	Roy Haiyupis, Ahousaht Elder; expert in Ahousaht history, culture, language and traditional use of resources, Lillooet
	Stanley Sam, Ahousaht/Tla-o-qui-aht First Nations Elder; expert in First Nations history, language, culture, and traditional resource use, Ahousat
Fisheries	**Dr. Gordon Hartman**, Consultant, Fisheries Biology, Nanaimo
Forest Harvest Planning	**Keith Moore**, Registered Professional Forester; Consultant, Environmental Forestry, Queen Charlotte City *(resigned from Panel December 16, 1994 when assumed position as Chair, Forest Practices Board, Victoria)*
Hydrology	**Dr. Mike Church**, Registered Professional Geologist (B.C.); Professor, Fluvial Geomorphology, Department of Geography, University of British Columbia, Vancouver

Roads and Engineering	**Dr. Peter Schiess**, Professor and Head of Forest Engineering, University of Washington, College of Forest Resources, Seattle
Scenic Resources, Recreation, and Tourism	**Catherine Berris,** Consultant, Landscape Architecture and Land Use Planning, Vancouver
Silvicultural Systems	**Dr. Jerry Franklin**, Professor, University of Washington, College of Forest Resources, Seattle
Slope Stability	**Dr. June Ryder**, Consultant, Terrain Analysis, Vancouver
Soils	**Dr. Terry Lewis**, Consultant, Soils and Land Use, Courtenay
Wildlife	**Dr. Alton Harestad**, Associate Professor, Wildlife, Simon Fraser University, Burnaby
Worker Safety	**Jim Allman**, Regional Manager, Workers' Compensation Board, Victoria *(resigned from Panel February 24, 1995 when assumed position as Manager of Occupational Health and Safety, B.C. Ministry of Forests, Victoria)*
Secretariat to the Panel	**Melissa Hadley**, Registered Professional Forester, Cortex Consultants Inc., Halfmoon Bay

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