The Silva Forest Foundation

The Forest Sustains Us, We Do Not Sustain the Forest

AN ECOSYSTEM-BASED APPROACH TO FOREST USE:

Definition and scientific rationale

September 1997

P.O. Box 9, Slocan Park, British Columbia, V0G 2E0
www.silvafor.org *silvafor@netidea.com*
Phone 250-226-7222 *Fax 250-226-7446*

AN ECOSYSTEM-BASED APPROACH TO FOREST USE:

Definition and scientific rationale

TABLE OF CONTENTS

LIST OF FIGURES

AN ECOSYSTEM-BASED APPROACH
TO
FOREST USE:

Definition and scientific rationale

1. INTRODUCTION

This paper provides a description of an ecosystem-based approach to planning and carrying out human activities. Understanding the relationships between ecosystems, human cultures, and economies is at the heart of an ecosystem-based approach. Both common sense and scientific knowledge lead us to the understanding that economies are subsets of human cultures, and human cultures are subsets of ecosystems. Therefore, if our activities protect the functioning of ecosystems, we will protect human cultures, and if we protect human cultures, we will protect or sustain our economies. These relationships are shown in Figure 1.

Throughout British Columbia, and in many parts of Canada and the world, the forest is the dominant ecosystem that includes people; therefore, ecosystem-based forest use is the specific application of an ecosystem-based approach to land use. While ecologically responsible forest use is the specific topic of this paper, scientific knowledge, principles, and concepts herein may be applied to any type of ecosystem.

Ecosystem-based planning and management can be defined as a way of relating to and using the ecosystems we are part of in ways that ensure the protection, maintenance, and, where necessary, restoration of biological diversity, from the genetic and species levels to the community and landscape levels. An ecosystem-based perspective works at all scales from the microscopic to the global.

An ecosystem-based approach to forest use protects forest functioning at all spatial scales through time as the first priority, and then seeks to sustain, within ecological limits, a diversity of human and non-human uses across the forest landscape. In other words, an ecosystem-based approach focuses first on what to leave and then on what can be taken without damage to ecosystem functioning.

In an ecosystem-based approach, forest composition, structures, and functioning are maintained, from the largest landscape to the smallest forest community, in both short and long terms.

An ecosystem-based approach recognizes that a forest ecosystem is a continuum in time and in space. In other words, over time, a forest ecosystem is not static and unchanging. Natural disturbances constantly modify forest ecosystems as time passes. However, unlike disturbances from integrated forest management and other forms of conventional management, natural disturbances serve to maintain forest functioning and provide biological legacies (e.g. dead trees) that connect one forest successional phase to another. In a natural forest ecosystem, the most frequent disturbance or agent of change is the death of an individual tree or small groups of trees.

A forest ecosystem is also a spatial continuum. In other words, forests are interconnected, interdependent clusters of ecosystems, from patches of different soil types within a 4 hectare (10 acre) forest stand to a watershed of 500,000 hectares (1.2 million acres) or more. Understanding that a forest ecosystem is a continuum through time and space reinforces the wisdom that what we do to one part of the forest, we do to all parts of the forest.

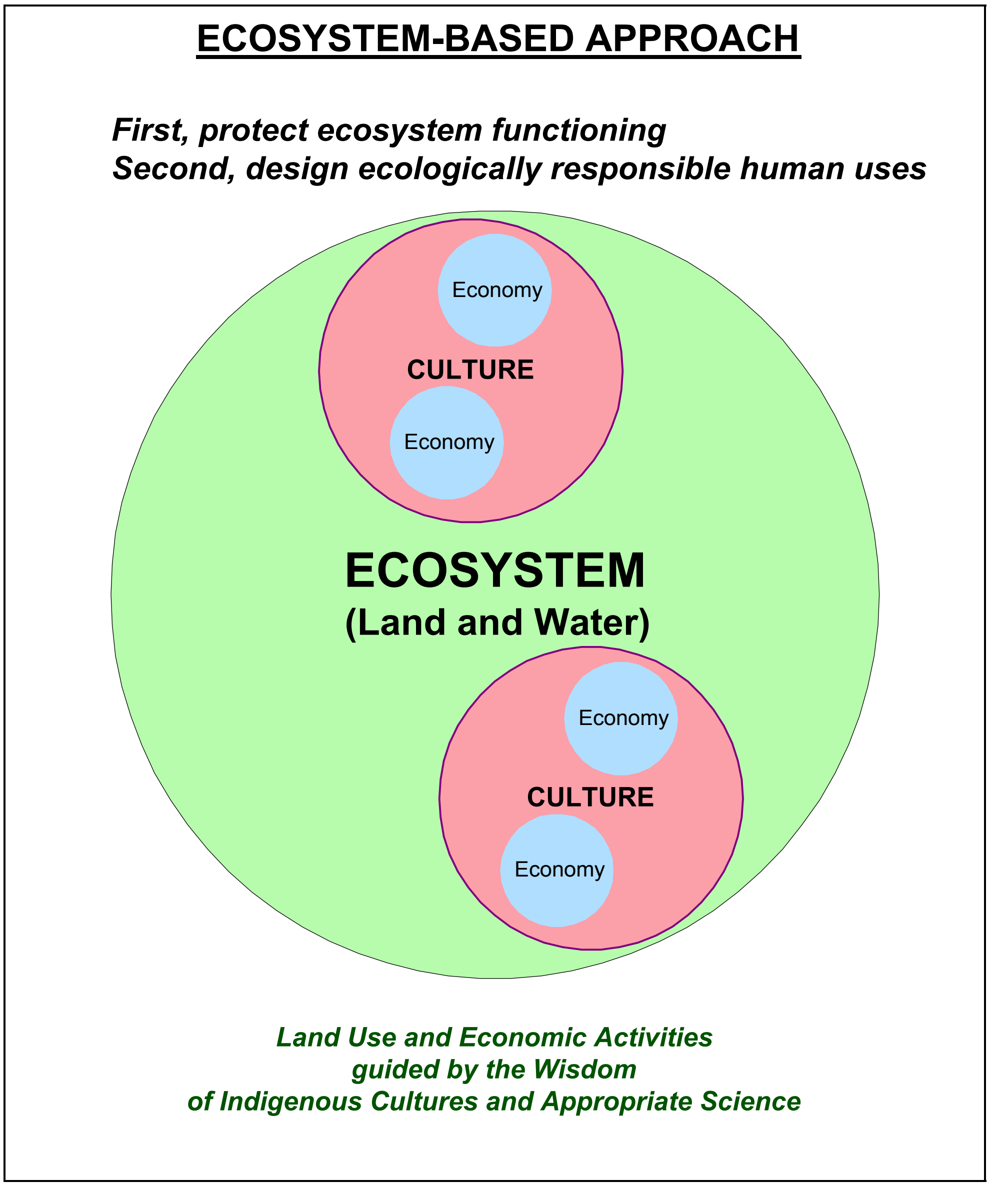

Figure 1: An ecosystem-based approach

2. ECOSYSTEM-BASED FOREST USE IN PRACTICE: LANDSCAPE ECOLOGY

Implementing ecosystem-based forest use does not begin in a stand of trees or an isolated forest patch--it begins with the forest landscape. In order to maintain fully functioning forests, the natural patterns and connections in the forest landscape must be protected and maintained, both during and following human activities. The concept of landscape used here does not refer to scenery, but rather to the matrix of ecosystem patterns and connections that exists across very large areas of land, often defined as large watersheds or drainage basins.

These patterns and connections exist in both time and space. Some of the temporal and spatial aspects of the forest landscape are difficult for people to understand because the scales involved are both much larger and much smaller than the scale of human life. The concept of space is probably the easier of the two for humans to understand, since we can use maps and air photos to obtain at least a second-hand appreciation of spatial patterns and connections. We need to remember, however, that a forest landscape functions at every spatial level, from the microscopic level up to the whole-watershed level and beyond.

Understanding the temporal patterns and connections in a forest landscape is a bigger challenge, since some forest parts—like rocks, old trees, and old-growth patches—function for 500, 1,000, 2,000 years or more, while others—equally significant in the forest web—live for only days or hours.

Many of the most serious errors in forest use have come about from our attempt to manage the forest on a human time scale--to plan timber cycles of 60 to 80 years, for example. Sixty to 80 years is a fairly normal human life cycle, but it is not a normal life cycle for most tree species. At the level of a whole forest, time cycles are often hard to identify because the forest is a continuum in time and space. Broad scale clearcut/plantation style timber management short-circuits the lifespan of trees and removes completely the future source of dead trees vital to forest functioning. Thus, conventional timber management fragments the forest continuum and breaks landscape connections in both time and space.

Maintaining the functioning of the forest landscape, indeed any landscape, means establishing two kinds of protected areas: 1) large protected reserves, and 2) protected landscape networks. Both of these protected areas accomplish the same primary goals: to maintain connectivity in the landscape and to protect the full range of biological diversity at all scales.

2.1 Large Protected Reserves

Large protected reserves constitute entire drainage basins or watersheds ranging in size from about 5,000 hectares upward. These areas are the storehouses of biological diversity necessary to maintain all of the forest, both that modified by human use and that which remains unmodified. The more severe and extensive the modifications of the landscape, the greater the need for large protected reserves.

Large protected reserves give us a way to protect the temporal aspect of landscape ecology. These reserves must be large enough to withstand natural disturbances and to retain their resiliency and integrity as a fully functioning forest landscape. How large is large enough? Scientists suggest that large protected reserves must be 50 to 200 times the size of the largest anticipated natural disturbance. Figure 2 is a conceptual diagram of a landscape that includes large protected reserves (labeled as “protected drainage basins”).

In order to maintain healthy landscapes, large protected reserves cannot exist as islands, regardless of their size. They must be connected across the landscape as shown in the diagram. Ideal connectors include riparian ecosystems and cross valley corridors.

Riparian ecosystems include the riparian zone (wet forest area along creeks, rivers, lakes, wetlands, and all water bodies) and the riparian zone of influence (the upland forest immediately adjacent to the riparian zone). Riparian zones are biological hotspots, concentrating the water, nutrients, and energy that drain into them and regulating their dispersal back into the landscape. As well, riparian ecosystems are travel corridors for animals and plants. Riparian ecosystems must be protected at all levels in the landscape.

Cross valley corridors consist of wide bands (ideally two to five kilometers in width) of forest that provide valley to valley connections between large protected reserves and across the whole landscape. Cross valley corridors need to be made up of representative ecosystems found in the landscape, and should not be blocked by land features such as cliffs and rock bluffs which obstruct the movement of large mammals.

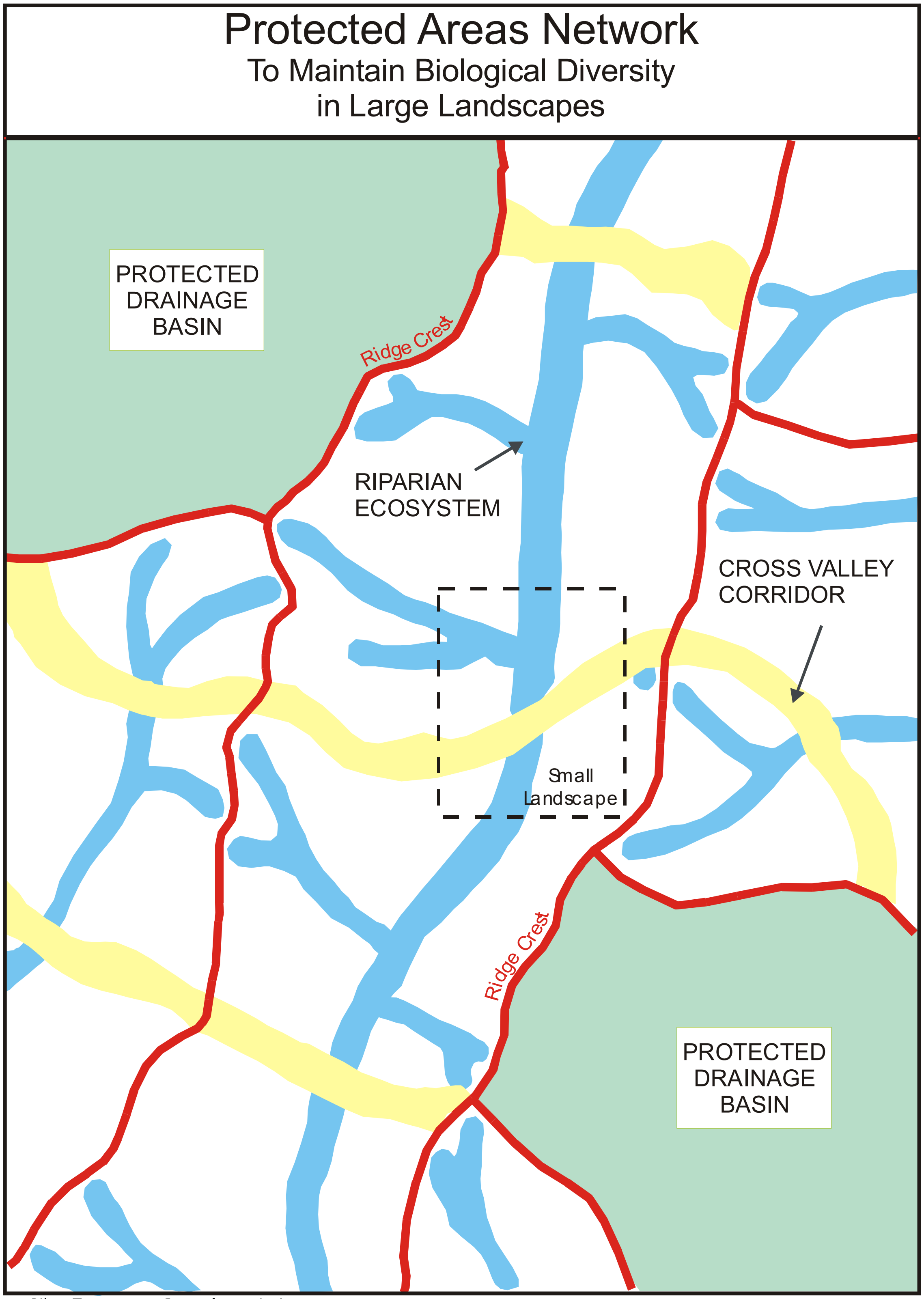

Figure 2: Protecting landscapes to maintain biological diversity.

2.2 Protected Landscape Networks

In the areas between large protected reserves, ecologically responsible human modification may occur. However, it is still necessary to maintain the landscape's framework in the areas outside of the large protected reserves. This is achieved through protected landscape networks. As shown in Figure 3, riparian ecosystems and cross valley corridors are also components in this level of landscape protection, along with other types of small protected areas.

The term "network" makes clear the idea of connectivity; however, we need to keep in mind that the corridors and protected clusters are not narrow strips, but broad areas encompassing entire ecosystem types. The overall area, seen from above, resembles a piece of Swiss cheese with wide connecting corridors of protected ecosystems interrupted by "holes." The protected landscape network forms the framework within which (in some of the holes of the Swiss cheese) various ecologically responsible human activities may occur. The complete set of components needed in a protected landscape network in order to maintain the landscape framework includes:

- *riparian ecosystems* . . . the backbone of the network. Riparian ecosystems range from small upland streams to large rivers, lakes, estuaries, and intertidal zones.
- *representative ecosystems* . . . small protected nodes of 400 hectares or more. Smaller protected nodes are established where an ecosystem type is strategically located, rare, or endangered. Old-growth or late successional forests are particularly important to include in the potential network.
- *sensitive ecosystems* . . . shallow soils, very wet and very dry areas, steep and/or broken terrain
- *cross valley corridors*

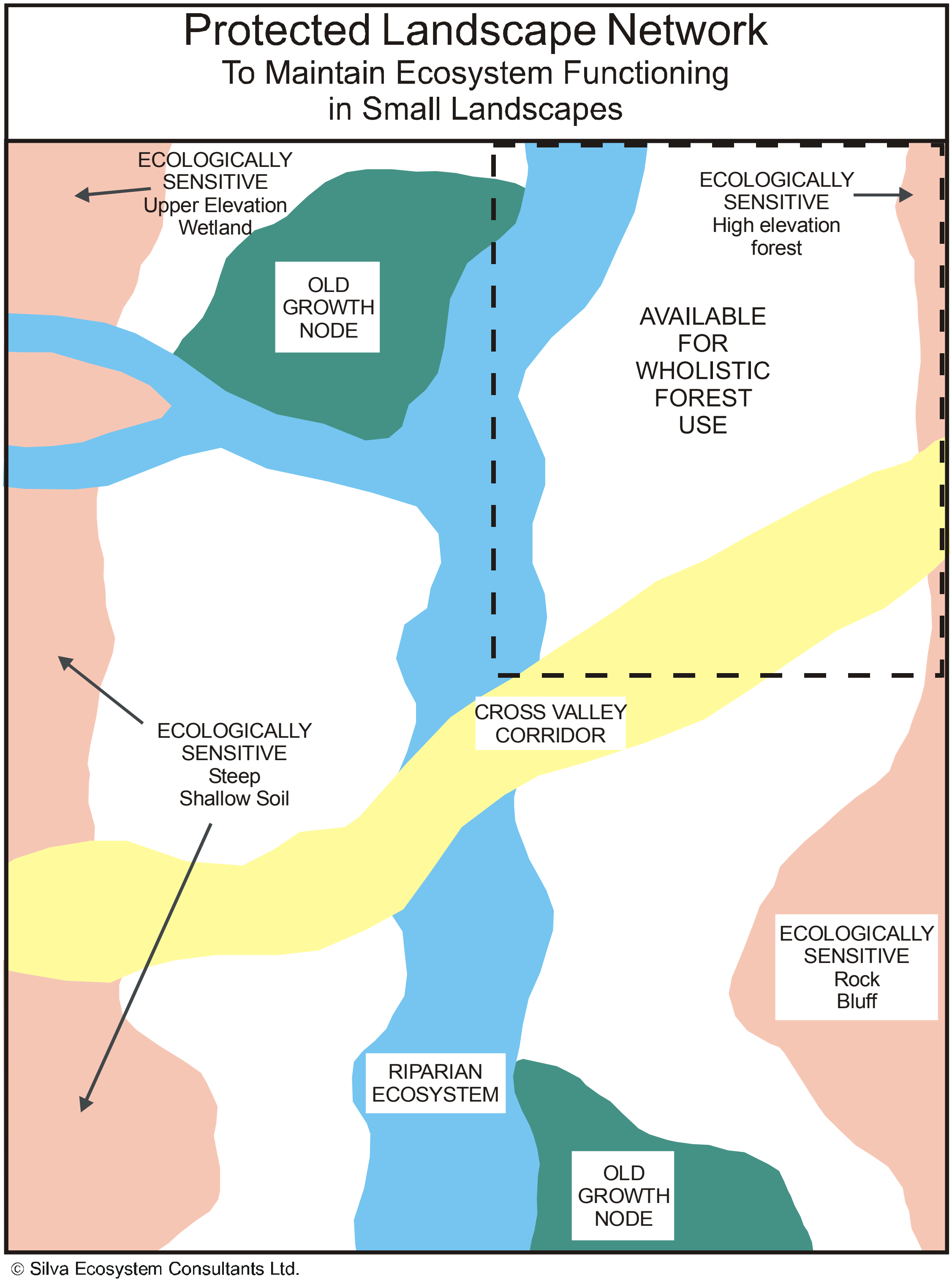

Figure 3: Protected landscape network—the foundation for wholistic forest use zones.

2.3 Human Needs—Human Impacts

In an ecosystem-based approach, human needs (not to be confused with wants) are included as part of the needs of ecosystems. In other words, people are included as an interconnected, interdependent part of whole forest ecosystems. However, an ecosystem-based approach also recognizes that modern human beings have inordinately large powers to modify and degrade ecosystems compared to any other living organism or natural disturbance.

We know that establishing large protected reserves and protected landscape networks will maintain the landscape ecology—the patterns and connections—of the forest. Within the framework provided by the protected landscape network, ecologically responsible and balanced human use is accomplished by establishing forest use zones.

The two priorities of forest use zones are:

- **Priority One:** *ecologically responsible* activities that maintain fully functioning forests, and
- **Priority Two:** *balanced use* that provides for a fair and protected land base for all forest users, both human and non-human.

Based on these priorities, forest use zones provide for a diversity of activities that not only protect forest functioning through time, but also furnish the foundation for diverse, sustainable community-based economies.

In establishing forest use zones, the most sensitive and easily damaged human uses are accommodated before allocating areas for more aggressive human uses. In order of their establishment, typical forest use zones include:

- **Culture** . . . areas which are culturally or historically important to local people
- **Ecologically Sensitive** . . . small sensitive areas not identified or protected in the protected landscape network
- **Fish and Wildlife Habitat**
- **Tourism**
- **Hunting, fishing, and trapping**
- **Timber Management**

Figure 4 shows forest use zones nested within the “holes” in the protected landscape network.

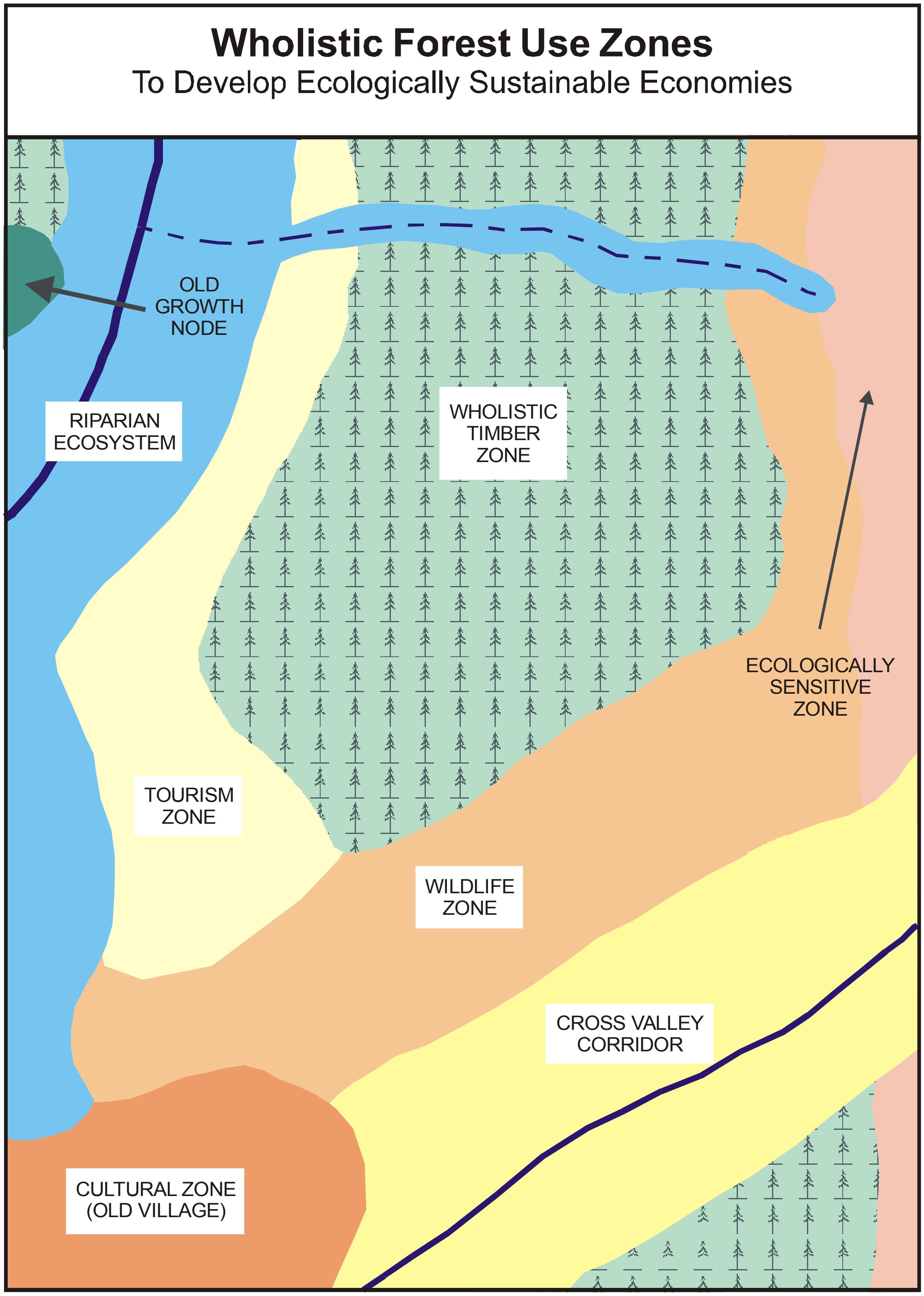

Figure 4: Portion of wholistic forest use zone map.

2.3.1 Human Examples: The Benefits of an Ecosystem-based Approach

An ecosystem-based approach attempts to avoid loss of forest functioning by maintaining forest composition and structures, from the smallest soil bacteria to the landscape patterns of a large forest watershed. We may not understand the functions of particular forest composition and structures; nevertheless, an ecosystem-based approach aims to protect all composition and structures. When parts of the forest are altered during activities such as ecologically responsible timber management or tourism, provisions for the replacement of forest composition and structures are built into ecosystem-based plans and activities.

Figure 5 illustrates how an ecosystem-based approach fosters the development of diverse, sustainable human economies while providing for the protection and maintenance of ecosystem functions. Because an ecosystem-based approach creates less modification to forest ecosystem composition and structures, it provides for a larger diversity of compatible forest uses. In other words, by maintaining trees on the sites where we practice timber management and by ensuring that ecologically viable old growth stands are found in each landscape, we provide an environment where the broadest spectrum of uses—from adventure tourism to timber extraction—can coexist. Such a range of activities is not possible where conventional timber management systems, such as clearcuts and tree plantations, are employed.

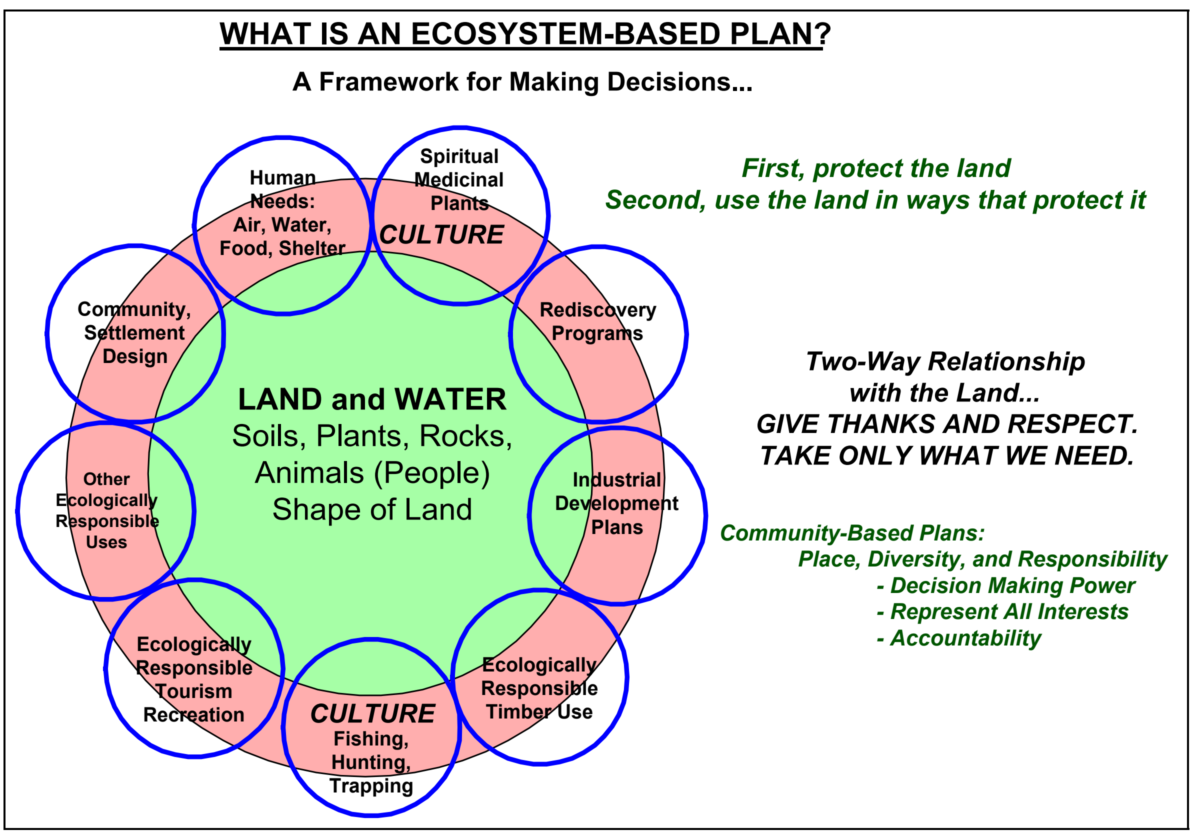

Figure 5: The development of sustainable human economies through an ecosystem-based approach.

The short-term scope of the current government and industry approach of "integrated management" is illustrated in Figure 6.

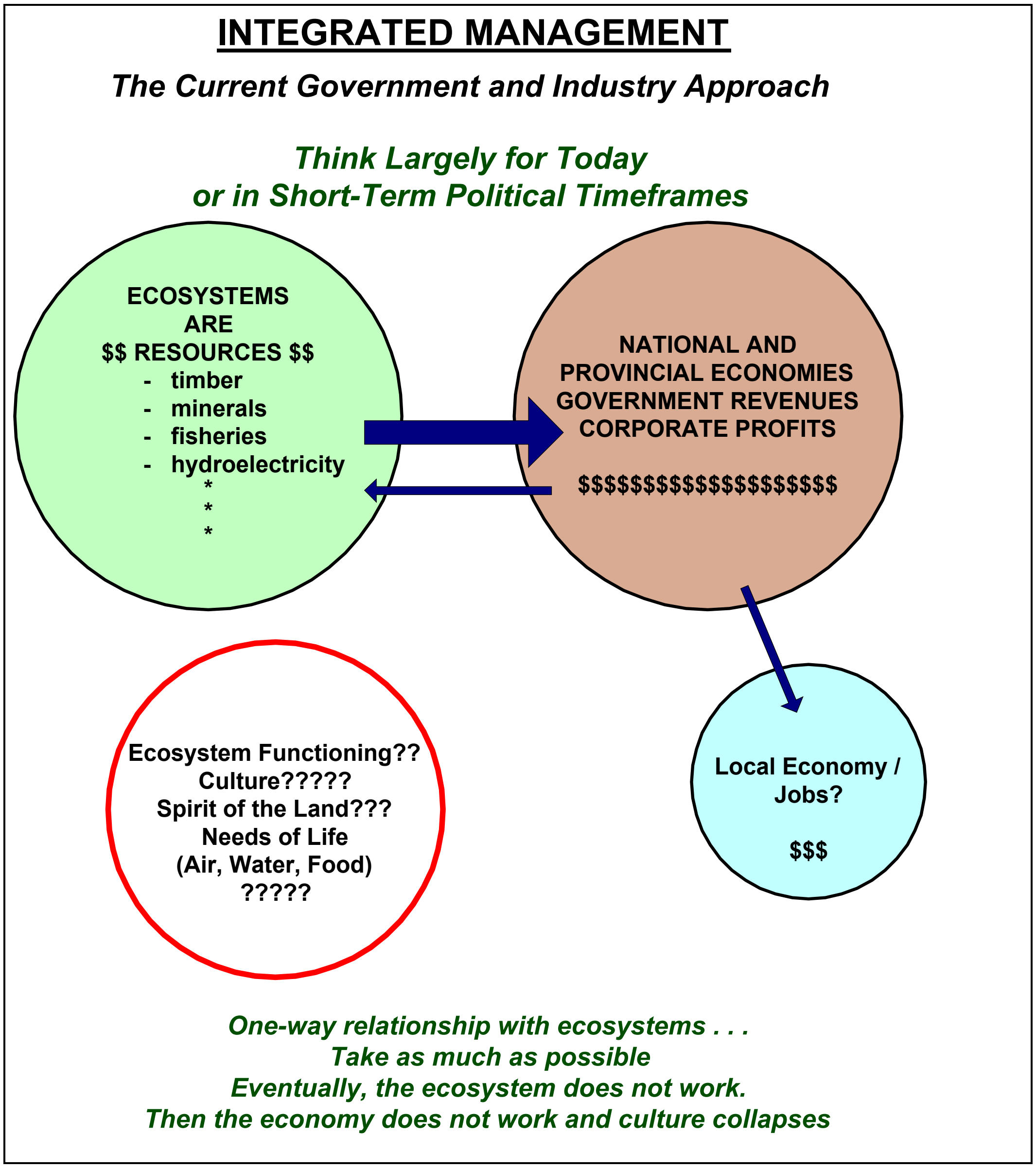

Figure 6: Current short-term approach to "integrated management"

Ecosystem-based planning and activities protect and maintain a complete range of plant and animal habitats across the landscape. The protected landscape network ensures that animal and plant populations can be sustained throughout the landscape as well as being used by humans for wildcrafting and hunting in the forest use zones.

In contrast to Figure 5, which illustrates how an ecosystem-based plan protects the forest while providing for an ecologically sustainable community economy, Figure 7 shows how timber cutting dominates the use of the forest under integrated forest management. Because timber cutting is given priority over all other uses in integrated forest management, the forest, First Nations' cultures, and community economies are seriously damaged by this approach.

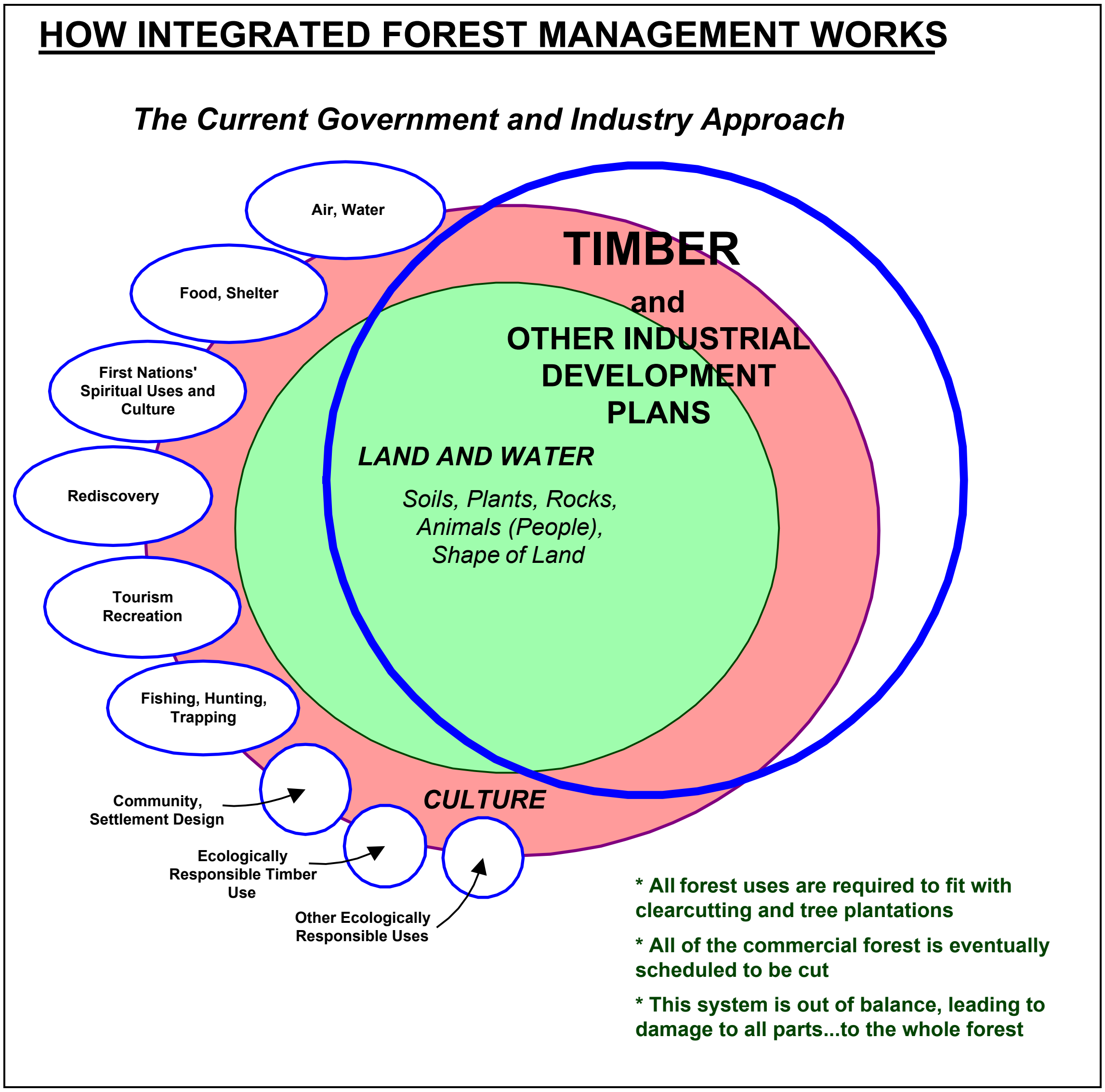

Figure 7: Dominance of timber in "integrated forest management"

From a timber standpoint, because ecologically responsible timber management produces steady supplies of mature wood, the long-term economic benefits exceed those of conventional timber management practices. Mature wood—long-fibred and strong—is superior for many uses, from structural materials and pulp to furniture and fine cabinets. In comparison, short-fibred, juvenile wood is not as strong and will warp and twist easily. Mature wood is produced when the cambium layer (the single layer of cells between the wood and the bark) divides around dead branches or no branches. Obviously, increasing amounts of mature wood are produced as a tree gets larger and older.

Research indicates that old growth Douglas-fir trees contain about 80% mature wood, while 60-year-old Douglas-fir trees contain only 10-20% mature wood. Under ecologically responsible timber management, trees grow for longer periods, not only to better maintain forest functioning, but also to produce steady supplies of high-value mature wood fibre. In contrast, conventional timber management is based on cutting cycles or rotations that provide primarily low-value juvenile wood. Thus, ecologically responsible timber management maintains supplies of high-quality mature wood similar to that provided by natural old growth forest ecosystems. This will ensure a healthy timber economy in perpetuity.

Growing high quality mature wood is particularly important for British Columbia's timber economy. Trees grow more slowly here than in many parts of the world. Therefore, we will not be able to compete well as fibre producers once old growth forests are gone. However, if forestry is based upon growing older trees, we will be able to sustain a timber economy based upon producing high quality mature wood.

2.4 The Guiding Principles of an Ecosystem-Based Approach

Ten principles, which are derived from both wisdom and science, guide an ecosystem-based approach to forest protection and use.

Principle #1: **Focus on what to leave, not on what to take.**

An ecosystem-based approach to forest use leaves fully functioning forests at all spatial scales through time. For example, ecologically responsible timber managers identify the parts of a forest stand and forest landscape that must be protected to maintain short- and long-term forest functioning, and these decisions determine what is possible to remove for wood products and other uses.

Principle #2: **Apply the precautionary principle to all plans and activities.**

The precautionary principle means that plans and activities must err on the side of protecting ecosystem functioning, as opposed to erring on the side of protecting short-term monetary profits or annual timber cutting quotas. In other words, if you are not sure that an activity will protect, maintain, or restore ecosystem functioning, do not do it.

Principle #3: **All plans and activities must include protection of forest functioning at all scales (time and space) and must define ecological limits of various forest ecosystem types to human disturbance.**

Temporal scales refer to the need to make *forest plans* considering timeframes of 500 years and beyond, as opposed to logging development plans of 1 to 20 years. Spatial scales refer to the need to define forest landscapes as, at a minimum, small watersheds of 200 hectares (500 acres) and larger. An ecosystem-based approach requires the development of forest landscape level plans for as large a landscape as is practical, given political and ownership constraints.

"Ecological limits" are physical and biological factors which indicate that various human uses may result in unacceptable levels of modification or degradation of forest ecosystem functioning. Common ecological limits include:

- **shallow soils** (less than 30 cm/12 inches deep)
- **very dry** or **very wet sites**
- **very steep slopes** (greater than 60% slope gradient)
- **broken slopes** (abrupt slope gradient changes occur regularly across a small landscape)
- **very dry climates** (less than 25 cm/10 inches of precipitation annually)
- **cold soils** that limit biological activity, particularly soil nutrient cycling
- **snow-dominated forests** characterized by open, canopied forest stands (i.e. park land forest ecosystems)
- **riparian ecosystems**, the wet forests adjacent to and the forests immediately upslope from creeks, rivers, ponds, lakes, wetlands, and the ocean.

Forest ecosystem types are relatively homogeneous forest areas delineated by their biological and physical characteristics, and by their ecological limits or lack of ecological limits. Stands or patches frequently contain several ecosystem types.

Describing a forest ecosystem type as having an ecological limit to human activities does not mean that such an ecosystem type will not grow trees following a human-induced disturbance such as logging. However, the existence of an ecological limit means that sustainable timber crops that have economically viable timber volumes and timber quality cannot be grown in reasonable periods of time. As well, both physical and biological problems, like landslides and poor regeneration of trees, result if ecological limits are not respected. If forest users attempt to ignore ecological limits, unacceptable levels of forest degradation will occur in both the short and long terms.

Principle #4: **All plans and activities must protect, maintain, and, where necessary, restore biological diversity (i.e. genetic, species, and community diversity).**

Maintenance and, where necessary, restoration of all types of biological diversity is necessary to sustain life as we know it in forest ecosystems. Maintaining genetic diversity means ensuring that viable natural gene pools, including the gene pools of trees logged from a site, remain on the site or, in the case of previously degraded forests, are restored (as much as possible) to the site following human use. Maintaining species diversity means that viable natural populations of plants, animals, and microorganisms must be maintained or restored, in previously degraded areas, throughout the various successional phases for each ecosystem type within a forest landscape. Maintaining community diversity means maintaining or restoring, in previously degraded areas, the variety of forest ecosystem types that result from natural disturbances at a variety of scales through short and long timeframes in a forest landscape. Protecting biological diversity must not be viewed as a frill or luxury. Instead, an ecosystem-based approach recognizes that maintaining natural biological diversity is a critical requirement to ensure maintaining fully functioning forests through time, and thereby sustaining human cultures and economies.

Principle #5: **Respect and maintain natural disturbance regimes through time and space in order to protect, maintain, and, where necessary, restore forest landscape patterns.**

Natural disturbances, from the death of individual trees to large fires or windstorms, are responsible for critical composition, structures, and ecosystem functioning necessary to maintain fully functioning forests. For example, the death of an individual tree sets off a process of change: it begins with a standing snag that provides habitat for cavity-nesting birds and ends with a fully decayed fallen tree that serves as Mother Nature's water storage and filtration system. At a landscape level, natural disturbances, large and small, are responsible for diversifying habitat patterns and, therefore, maintaining a natural diversity of plants and animals. Natural disturbance regimes are also critical to the maintenance of soil nutrient cycling and adequate levels of soil nutrients. Protecting, maintaining, and, where necessary, restoring natural disturbance regimes provides for natural composition, structures, and functioning at the forest landscape level.

Principle #6: **Protect, maintain, and, where necessary, restore composition, structures, and functions at the patch or stand level in all plans and activities.**

Composition refers to the parts of a natural, healthy forest ecosystem, including the topography, soil, water, plants, animals, and microorganisms. **Structures** are the arrangements of the parts in a forest ecosystem, including large old trees, large snags (i.e. standing dead trees), and large fallen trees. Forest **functioning** refers to how a forest works at a full range of scales over long timeframes. Natural composition and structures must be maintained in order to maintain fully functioning forests. Many compositions, structures, and functions are beneath the surface of the ground, within the soil where human beings cannot see while planning and carrying out forest uses. When implementing an ecosystem-based approach, we hope that by maintaining the forest composition, structures, and functions that we can see, we will also maintain the composition, structures, and functions that we cannot see.

Principle #7: **Protect, maintain, and, where necessary, restore forest ecosystem connectivity at all scales during planning and carrying out ecologically responsible forest use.**

Connectivity in forest ecosystems is maintained, in large part, by ensuring the protection of water movement patterns. This includes microscopic water movement patterns in the forest soil and in riparian ecosystems, from ephemeral streams and small wetlands to large river systems and wetland complexes. Connectivity is also maintained in forest ecosystems by protecting and, where necessary, restoring the full range of composition and structures from the large landscape level to the smallest stand or patch.

Principle #8: **Recognize that the concept of landscape is relative to the forest organism or process under consideration.**

Different forest organisms or forest processes operate at vastly different scales. What is a landscape to a salamander is only a small patch or small stand to a bear. Similarly, the landscape that results from a single tree falling over due to root decay and wind is much smaller than the landscape patterns created by a large fire. A forest landscape can exist at virtually any scale, depending on the organism or forest process that is used as the point of reference. Thus, applying the concept of a forest landscape, as much as possible, to all scales—from large landscape to small stand or patch level plans—is important to ensuring the maintenance and/or restoration of fully functioning forests.

***Principle #9:* Plan and carry out diverse, balanced activities to encourage ecological, social, and economic well-being.**

In planning for a diversity of human activities in a forest landscape or forest stand, we can use as a model the natural diversity that occurs in forest composition, structures, and functioning, from the smallest forest patch to the largest forest landscape. Diversity in forest composition, structures, and functioning maintains the integrity and resilience of forests. Diversity provides for both flexibility and stability in forest ecosystem functioning. Large natural disturbances, such as fire and insect attacks, that can dramatically alter the forest are simply processes of maintaining and restoring natural diversity, and, therefore, healthy functioning in the forest.

Because natural forests depend upon diversity, a diversity of ecologically responsible human activities is most likely to maintain natural forest diversity, and, therefore, to maintain fully functioning forests. At the same time, diverse human activities best meet the needs of all interests in human society, and provide for the most stable, sustainable human economies.

Diverse forest uses also need to be *balanced* in ways that establish equitable, protected land bases for all forest users, both human and non-human. This goal is accomplished by defining forest use zones within the forest landscape.

Currently, in most forests around the world, the most aggressive and consumptive forest uses are expanding, namely logging and the manufacture of a few wood products such as pulp and 2x4's. Continuing this growth of consumption is not sustainable, either biologically or economically. Ecologically responsible timber management does not intend to continue the same level of cutting as that practiced by conventional timber management. Instead, ecologically responsible timber management requires the reduction of timber cutting levels, and, therefore, a reduction in the overall use of wood. A high priority is placed upon developing and marketing recycled wood products, including paper, 2x4's, siding, paneling, windows, and doors. Reducing consumption and recycling all wood products is a first priority in ecologically responsible forest use.

As well as ensuring that timber cutting and the manufacture of wood products stays within ecological limits, an ecosystem-based approach will also limit the number and scale of such activities as tourism and ranching within forest landscapes in order to maintain fully functioning forests.

***Principle #10:* Evaluate the success of all forest use activities at meeting the requirements of ecological responsibility.**

Important questions to ask during an evaluation include:

- Are natural landscape patterns maintained or restored?
- Are natural stand or patch composition and structures maintained or restored?
- Are water quality, quantity, and timing of flow, at all scales, unaltered?
- Are soil structures and soil processes unaltered?
- Have natural disturbance regimes, from the landscape to the stand or patch level, been protected and/or restored?

- Do all ecologically responsible forest users, both human and non-human, have a fair and protected landbase?

Evaluation—asking how we did—is an absolutely essential part of an ecosystem-based approach. By evaluating our plans and activities, we learn and are able to improve our relationship with forests and with each other. The questions posed above are inclusive of all aspects of forest functioning as it relates to a variety of human uses.

Evaluation is the basis for adaptive planning and management, where new knowledge about the results of our activities is used to change management practices.

3. SCIENTIFIC RATIONALE

An ecosystem-based approach relies on scientific concepts developed by leading-edge researchers and practitioners. Forest ecology, conservation biology, landscape ecology, and ecological economics are synthesized in designing the methodology and products of an ecosystem-based plan. Some of the scientific concepts underlining an ecosystem-based approach are summarized below.

3.1 Scientific Panel for Clayoquot Sound

The Silva Forest Foundation's ecosystem-based approach is consistent with the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound (1994) definition of sustainable ecosystem management:

> *The Panel believes that forests should be managed as ecosystems, rather than as potential products, and that forest practices should not put at risk the long-term health of forest ecosystems. Sustainable ecosystem management is characterized by resource management practices that are scientifically based, ecologically sound, and socially responsible...*
>
> *The goal of sustainable ecosystem management is to maintain the integrity of ecosystems. Achieving this goal requires maintaining ecosystem components and ecological processes that enable the land, water, and air to sustain life, be productive, and adapt to change.*
>
> *The objectives of sustainable ecosystem management include: maintaining soil formation, stability, and productivity; maintaining water quality, flow, and channel integrity; and maintaining biodiversity. Failure to maintain these processes and states may lead to failure to sustain a flow of products from the forest and failure to protect cultural, scenic, recreation, and tourism values.*
>
> *Human needs are one of many considerations in designing management activities. The needs of current generations should not supersede the needs of future ones. The protection of ecosystem components and maintenance of ecosystem processes and productivity must take precedence over all other management objectives.*

> *In the long term, managing forests as ecosystems is the best way to secure a supply of timber and other products from the forest, and to sustain British Columbia's multitude of other forest values.*

The Scientific Panel notes that at each level of planning, sustaining ecosystem productivity and biodiversity must take precedence over specific product outputs. Levels of resource extraction must be determined within the limits prescribed by ecosystems.

One of the primary goals of SFF's ecosystem-based approach is to protect biodiversity. The Scientific Panel states: "Conserving biodiversity is a prerequisite to sustaining ecosystem integrity, which depends on interactions among a broad range of the ecosystem's component species, both known and unknown." The Panel stresses the need to establish a system of protected areas as well as sustainable ecosystem management outside protected areas. Thus, one of the goals recommended by the Panel is "to maintain the functional integrity of ecosystems, recognizing the connections between terrestrial, freshwater, and marine ecosystems."

3.2 Landscape Ecology and Conservation Biology

An ecosystem-based approach represents the practical application of concepts and findings in the sciences of landscape ecology and conservation biology.

Landscape ecology is concerned with the connections and interactions between forest stands across the landscape, and with the effects of both natural and human disturbances on the landscape. The scientific discipline of landscape ecology originated as an attempt to integrate the spatial concerns of geography with the time and scale concerns of ecology. The following important principles of landscape ecology are incorporated in an ecosystem-based plan:

Time and Space: Forest ecosystems are connected in time and space across the landscape. Risser (1987) summarized the interrelation of time and space over the landscape:

> *Thus, the landscape is heterogeneous, that is, consists of dissimilar or diverse components or elements. In addition to the rather obvious spatial heterogeneity, the landscape is temporally heterogeneous. Ecological processes operate at different time scales. For example, forest trees have life spans of decades, annual crops grow for less than a year, and individual stream insects may last only a few days. It is this mixture of processes consisting of different spatial and temporal scales, all operating as a system, that leads to ideas of landscape ecology.*

Heterogeneity: Landscape heterogeneity, or diversity, is essential to forest landscapes. Diversity contributes to redundancy, or the ability of ecosystems to perform important functions in more than one way. For example, after disturbance on a forest site, mycorrhizae essential to the nutrient needs of young conifers can persist in the decaying wood of fallen trees, or through association with surviving conifers, or by colonizing compatible successional plant species. This type of redundancy, maintained by landscape diversity, is a vital function which allows ecosystems to survive stress (Bormann 1987, Franklin et al 1989) and helps organisms survive through catastrophic disturbances over time (Perry et al 1989, Amaranthus et al 1989).

Extreme diversity can result in negative effects if habitat areas become too small to be effective. As with many aspects of forest functioning, a balance is required between heterogeneity and homogeneity.

Connectivity: Within a forest landscape, connectivity is provided by movement corridors, which are frequently riparian ecosystems (see Principle 3 above). Riparian ecosystems serve as movement corridors for many species of plants and animals, as well as for nutrients and energy. Riparian ecosystems are connected from valley to valley by treed forest corridors (i.e. cross valley corridors) that run up and down forest slopes. Groundwater is another landscape connector that transports nutrients and energy both within forest patches and throughout the forest landscape. Riparian ecosystems, cross valley corridors, and groundwater provide connectivity in space. The importance of these connections within forested ecosystems has been articulated by Noss (1991). Connectivity in time is represented by the various stages that a forest goes through. From the shrub/herb phase through the young and mature forest phases to old growth, each stage plays important roles in maintaining a healthy and diverse forest landscape.

Human or natural impacts that reduce or break natural landscape connectors will have direct impacts on animal, plant, energy, nutrient, and water movements (Forman 1987, Forman and Godron 1983, Noss 1987).

Conservation biology has been defined by Grumbine (1992):

> *Conservation biology is the science that studies biodiversity and the dynamics of extinction. Much of this work focuses on how genes, species, ecosystems, and landscapes interact, and how human activities affect changes in ecosystem components, patterns, and processes... Conservation biologists consider the entire biodiversity hierarchy at diverse scales of space and time...*

Maintaining natural forest diversity is a primary goal of ecosystem-based planning. Both landscape ecology and conservation biology study ecosystem interconnections and propose management that maintains the biodiversity within ecosystems. Numerous scientists have stressed the need to maintain the natural diversity of the forest landscape when implementing management activities (Amaranthus et al 1989, Bormann 1987, Franklin et al 1989, Harris 1984, Marcot et al 1989, Maser 1988, Perry 1988, Perry et al 1989, Schowalter 1989, Wilcove 1988).

3.3 Silviculture Systems

Ecologically responsible timber management differs significantly from conventional practices. In his book, *Forest Ecology,* Dave Perry defines the goals of ecologically responsible silviculture systems:

> *To maintain biological diversity (and along with it the health and integrity of entire ecosystems), silviculture must do two things: (a) protect species and habitats that have no market value, and (b) mimic (to the degree possible)*

> *natural disturbance and successional patterns at the scale of both stands and landscapes. Intensive forest management does rather poorly on both scores. A more ecologically based management will focus on what it leaves behind rather than on what it takes. Biological legacies will be protected and habitat imbalances redressed by restoring forested landscapes to a higher proportion of old growth. Early and mid-successional communities will exist as islands within an old-growth matrix rather than vice versa, producing the shifting mosaic that characterized many natural forest landscapes. Silvicultural techniques for achieving this include partial harvesting, density management, and long rotations. Ultimately, a sustainable future will only be achieved by considering the Earth and all of its inhabitants as an integrated, interdependent whole.*

3.4 Ecological Economics

Ecological economics is a transdisciplinary field of study that addresses the relationships between ecosystems and economic systems in the broadest sense, attempting to integrate and synthesize many different disciplinary perspectives (Costanza et al 1991). Ecological economics points out the need to protect the integrity of ecological systems (Norton 1991). The connections between ecosystems and economics is summarized by Costanza (1991):

> *Ecological systems play a fundamental role in supporting life on earth at all hierarchical scales. They form the life-support system without which economic activity would be impossible. They are essential in global material cycles like the carbon and water cycles. They provide raw materials, food, water, recreational opportunities, and microclimate control for the entire human population. In the long run, a healthy economy can only exist in symbiosis with a healthy ecology.*

Ecological economics also recognizes the need to assign value to ecological goods and services (Costanza 1991) so that humans do not consider these to be "free." Thomas Power (1988) has studied the non-commercial qualities that contribute to a healthy economy. In examining what makes a local or community economy healthy and stable, Power discovered that people valued the quality of life in an area and would accept lower wages and a certain level of reduced services if their quality of life needs were met.

4. CONCLUSION—ECOSYSTEM-BASED APPROACH: THE FOUNDATION FOR SUSTAINABILITY

As noted above, an ecosystem-based approach is supported by such formerly divergent disciplines as ecology and economics. Leading thinkers in ecological economics, conservation biology, landscape ecology, and forest ecology are all telling us that maintaining fully functioning ecosystems at all scales must be our priority if we are to develop and sustain human cultures and the economies that make up human cultures.

5. LITERATURE CITED

Amaranthus, M., J. Trappe, R. Molina. 1989. *Long-term forest productivity and the living soil*. Chapter 3 *in*: Perry et al (eds.), Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Timber Press, Portland.

Bormann, F. 1987. *Landscape ecology and air pollution*. Chapter 3 *in* M. Goigel Turner (ed.), Landscape heterogeneity and disturbance. Springer-Verlag, New York.

Costanza, R. 1991. *Assuring sustainability of ecological economic systems.* Chapter 21 *in* R. Costanza (ed.), Ecological economics: the science and management of sustainability. Columbia University Press, New York. pp. 331-343.

Costanza R., H. Daly, J. Bartholomew. 1991. *Goals, agenda, and policy recommendations for ecological economics*. Chapter 1 *in* R. Costanza (ed.), Ecological economics: the science and management of sustainability. Columbia University Press, New York. pp. 1-21.

Forman, R. 1987. *Corridors in a landscape: their ecological structure and function.* Ekologiya (CSSR) 2:375-387.

Forman, R. and M. Godron. 1986. *Landscape ecology*. John Wiley & Sons, New York. 619 pp.

Franklin, J.F., D. Perry, To. Schowalter, M. Harmon, A. McKee, T. Spies. 1989. *Importance of ecological diversity in maintaining long-term site productivity.* Chapter 6 *in* Perry et al (eds.), Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Timber Press, Portland.

Grumbine, R. 1992. *Ghost bears: exploring the biodiversity crisis*. Island Press, Washington, D.C. 290 pp.

Harris, L. 1984. *The fragmented forest*. University of Chicago Press, Chicago.

Marcot, B., R. Holthausen, J. Tepley, W. Carrier. 1989. *Old-growth inventories in the Pacific Northwest: definitions, status, and visions for the future.* Final draft for: Old-growth Douglas-fir forests, wildlife communities and habitat relationships.

Maser, C. 1988. *The redesigned forest*. R. & E. Miles, San Pedro, CA. 234 pp.

Norton, B. 1991. *Ecological health and sustainable resource management*. Chapter 8 *in* R. Costanza (ed.), Ecological economics: the science and management of sustainability. Columbia University Press, New York. pp. 102-117.

Noss, R. 1991. *Landscape connectivity: different functions at different scales*. Chapter 2 *in* W. Hudson (ed.), Landscape linkages and biodiversity. Island Press, Washington, DC, pp. 27-39.

Noss, R. 1987. *Corridors in real landscapes: a reply to Simberloff and Cox*. Conserv. Biol. 1:159-164.

Perry, D. 1994. *Forest Ecosystems.* Johns Hopkins University Press, Baltimore. 649 pp.

Perry, D. 1988. *Landscape pattern and forest pests.* Northwest Environmental Journal 4:213-228.

Perry, D., M. Amaranthus, J. Borchers, S. Borchers, R. Brainerd. 1989. *Bootstrapping in ecosystems*. BioScience (39)4.

Power, T. 1988. *The economic pursuit of quality*. M.E. Sharpe, New York. 218 pp.

Risser, P.G. 1987. *Landscape ecology: state of the art*. Chapter 1 *in* M. Goigel Turner (ed.), Landscape heterogeneity and disturbance. Springer-Verlag, New York. 239 pp.

Schowalter, T. 1989. *Insects and old growth*. Presentation at Old Growth Conference, August 1988, Oregon State University, Corvallis, OR.

Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. 1994. *Progress Report 2: Review of Current Forest Practice Standards in Clayoquot Sound*. Cortex Consultants Inc., Victoria.

Wilcove, D. 1988. *National forests: policies for the future. Vol. 2: Protecting biological diversity.* The Wilderness Society, Washington, D.C.