The Silva Forest Foundation

ECOSYSTEM-BASED LANDSCAPE ANALYSIS OF THE FRASER HEADWATERS: HORSEY CREEK LANDSCAPE

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prepared by

The Silva Forest Foundation.

P.O. Box 9, Slocan Park, British Columbia   Phone 250-226-7222 Fax 250-226-7446

www.silvafor.org

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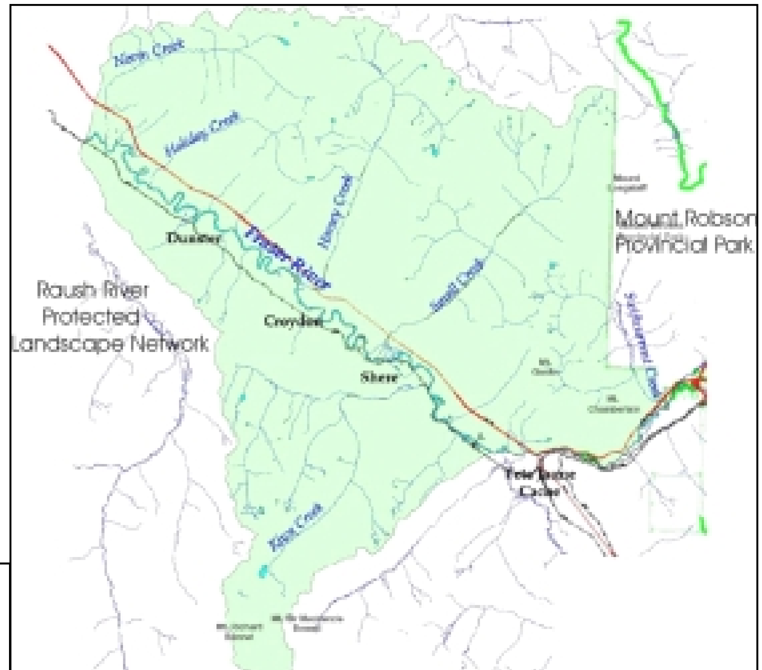
[1] Maps in this report lack some detail and are included for illustration purposes. For detailed viewing see the accompanying full-size planning maps.

INTRODUCTION

This report summarizes the results of an ecosystem-based analysis of the Horsey Creek Landscape surrounding Dunster, BC. The Silva Forest Foundation conducted the analysis for the Dunster Community Association and the Fraser Headwaters Alliance. The goal of the analysis, and the purpose of this report and the accompanying full size maps, is to provide practical information to local residents and groups who wish to protect, maintain, and plan for the ecologically sustainable use of the forests and waters that occupy this part of the Fraser River Headwaters. The analysis is part of an ongoing project to develop and implement ecosystem-based mapping for the entire Robson Valley. The first phase of the project, an ecosystem-based analysis of the Raush River Watershed, was completed in 1998.



Landscape and ecosystem diversity in the Horsey Creek Landscape – a beaver pond, large fallen tree, multi-aged subalpine fir forests, and mountains in the Small Creek watershed

The main objectives of this ecosystem-based analysis of the Horsey Creek Landscape were to:

- identify important landscape and ecosystem characteristics, assess ecological sensitivity, and determine where and how these factors limit human use
- assess how past and present human use has affected the ecological condition of the landscape, and
- develop recommendations to guide the protection, maintenance,

restoration, and sustainable use of the Horsey Creek Landscape.

This analysis is preliminary—the conclusions and recommendations in this report, and the work on which it is based, are initial estimates. Terrain interpretations and landscape analyses are based largely on air photo interpretation and GIS analysis of Ministry of Forests (MoF) forest cover and Ministry of Environment, Lands and Parks (MoELP) terrain and resource information (TRIM) topographic data, supplemented by 15 crew days of reconnaissance-level field work. We believe the landbase, terrain sensitivity, stream geometry, and other estimates are realistic, but further field assessment and data analysis are required to verify and improve the accuracy of the results and to develop operational plans.

Implementing the recommendations described in this report will require community commitment and involvement, additional site-level field study, total-cost economic assessment, and long-term strategic and operational planning. The result will be a set of detailed plans to direct human use and restoration of the ecosystems in the Horsey Creek Landscape, and a framework for monitoring to evaluate and learn from the consequences of those activities.

The Brainerd Foundation, Lazar Foundation, and W. Alton Jones Foundation gave generous funding for this project. Silva Forest Foundation, the Dunster Community Association, and the Fraser Headwaters Alliance are also grateful to the MoF Robson Valley District Office and to the MoELP for providing forest cover and TRIM digital data.

Silva Forest Foundation, the Dunster Community Association, and the Fraser Headwaters Alliance acknowledge that the Horsey Creek Landscape lies within the territory traditionally used by the Lheidli T'enneh and Secwepemc peoples. We hope constructive partnerships can be formed between the Lheit-Lit'en and Secwepemc First Nations, the Dunster Community Association, and the Fraser Headwaters Alliance to develop and implement ecosystem-based planning throughout the Robson Valley.

RATIONALE AND OVERVIEW

There is growing awareness that to sustain human uses of a landscape, the landscape, its ecosystems, and the plants and animals that naturally live in those ecosystems, must be protected and maintained. This awareness is based on the understanding that sustainable human communities and their economies depend on the benefits and services that flow from healthy ecosystems (Figure 2). Sustaining flows of benefits and services such as high-quality wood, clean water, and quality backcountry recreation in the Horsey Creek Landscape means developing plans and carrying out activities that protect, maintain, or where necessary restore natural landscape patterns, quality and quantity of stream flows, native plant and animal species, and long-term ecological productivity.

Figure 1. Reconciling human use of the landscape with the need to protect and maintain the ecological systems and processes that support those uses. Settlement and agriculture depend on productive soils and the clean, abundant water produced by healthy forests and streams.

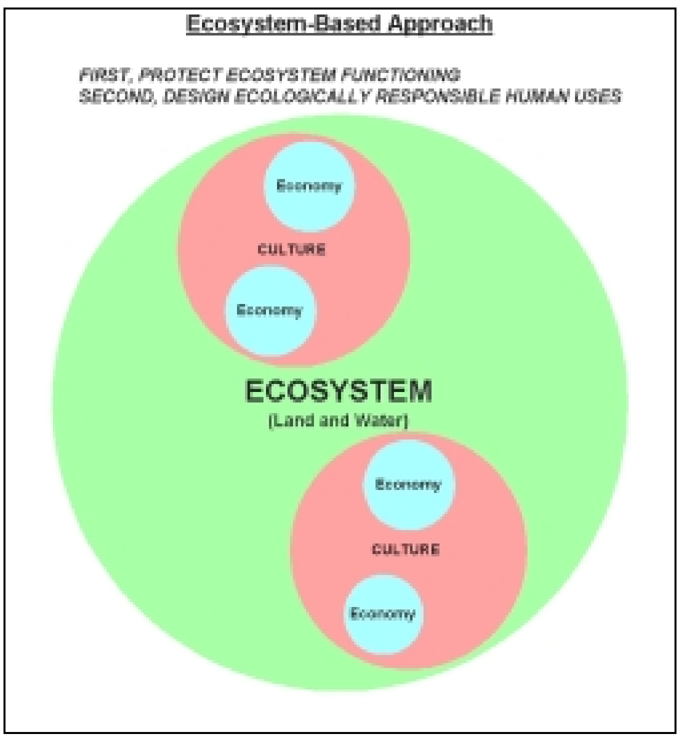


Figure 2. Human communities and economies develop within, and depend upon, ecological systems

Current arrangements for land and natural resource planning in the Horsey Creek Landscape make this goal often difficult if not impossible. Natural resource licences and tenures limit balanced access to, and use of, forest and water resources. A multitude of government ministries, resource sectors, and land use interests typically have competing objectives and produce contradictory, fragmented information. Conflicting federal, provincial, regional, and municipal jurisdictions and poorly integrated legislation only adds further difficulty.

This ineffective framework for landscape and forest use planning typically results in management goals and operational activities that focus on producing a single resource output such as cubic metres of wood fibre, on maximizing a mix of outputs and uses such as timber production, grazing, and recreation, or on achieving a balance among competing land uses and resource interests (Figure 3). The emphasis in all of these cases is almost always on satisfying a limited and often unsustainable range of human demands or wants, rather than on respecting the limits of the ecological functions and processes that sustain healthy households and communities.

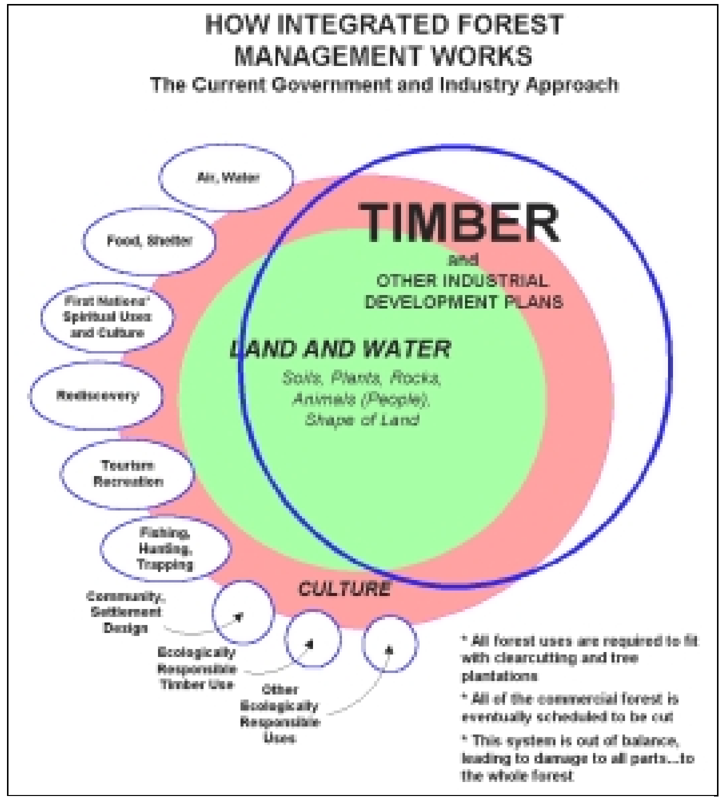


Figure 3. Tenure arrangements in the Horsey Creek Landscape promote industrial resource management rather than balanced and sustainable forest use

An ecosystem-based approach offers a more comprehensive, precautionary, and therefore sustainable framework for landscape-level analysis and planning (Figure 4). Ecosystem-based analysis is comprehensive because it seeks to understand, protect, and maintain the broad range of ecosystems and ecological processes that support human communities and economies. It is precautionary because it acknowledges the gaps in current understanding of ecology, and responds with a planning approach that errs on the side of sustaining ecosystem function, rather than on the side of maintaining short-term financial profits and economic opportunities. Finally, it is sustainable because it focuses on achieving balanced human and non-human use of

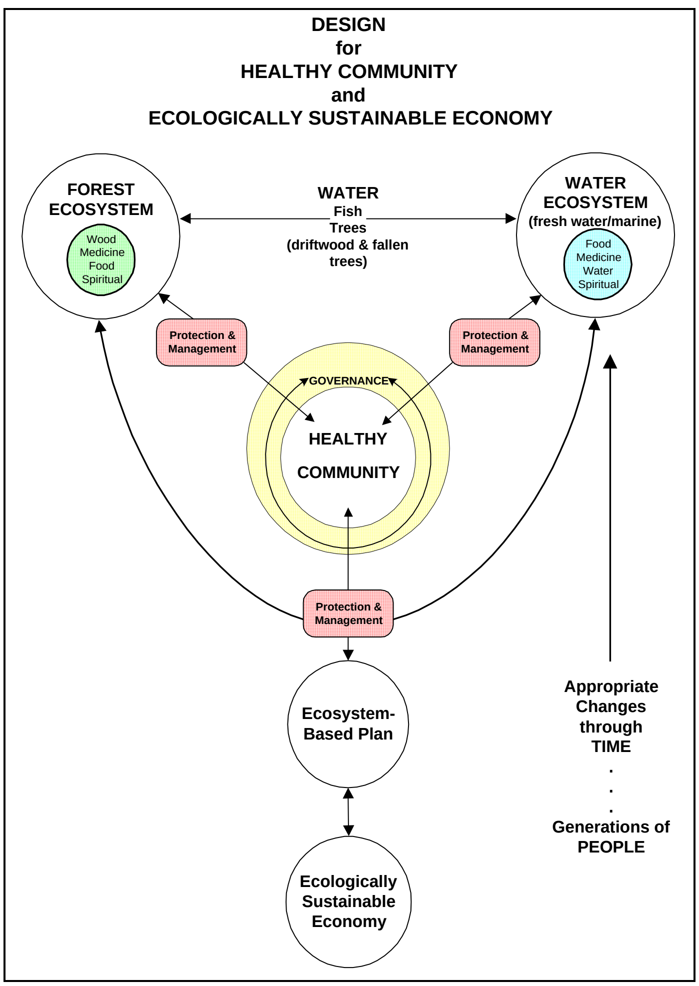


Figure 4. Ecosystem-based planning process for achieving ecologically sustainable communities and economies

the land to provide for long-term household and community well-being, rather than on providing resources to meet the short-term priorities of powerful natural resource stakeholders.

Developing the ecosystem-based analysis results and recommendations described in this report involved assessing landscape and ecosystem characteristics and conditions, analyzing and synthesizing information, and preparing maps to guide the protection, maintenance, and where necessary restoration of the forests and waters that occupy the Horsey Creek Landscape.

Preparing a complete ecosystem-based plan for the Horsey Creek Landscape will involve identifying and planning where, when, and how a diverse range of human uses can occur within those ecological constraints. These uses must respect the limits of ecological functioning within the Horsey Creek Landscape, and provide a healthy and balanced range of benefits that encourage ecological, social, and economic well-being. The rights and values of all forest users, human and non-human, must be respected.

Principles of Ecosystem-Based Planning

1. Focus on what to leave, not what to take.
2. Adopt a precautionary approach to all plans and activities.
3. Respect the limits of landscape and ecosystem function.
4. Ensure that all plans and activities, protect, maintain, and where necessary restore biodiversity, natural composition and structure, and ecosystem connectivity.
5. Apply the concept of the landscape to the forest, organism, or process under consideration.
6. Plan and carry out diverse activities to encourage ecological, social, and economic well-being.
7. Ensure that First Nations rights and values are protected and maintained
8. Evaluate the success of all land, water, and forest use activities in meeting the requirements and goals of ecological responsibility.

PROJECT METHODS

The ecosystem-based analysis and planning process involves several stages, each of which uses a variety of information sources, field methods, and data analysis tools.[2] Preliminary information collection and research focused on developing a basic understanding of the ecological characteristics and conditions in the Horsey Creek Landscape. This initial work, conducted during May - June 1998, involved:

- reviewing background material and literature to develop a historical overview of the project area, and to develop tentative project goals and objectives,
- collecting and evaluating reference information to gain knowledge of the project area's ecological and social characteristics and conditions, and to identify information gaps and prepare field work plans, and
- visually interpreting air photos, topographic maps, and forest cover maps to develop an initial assessment of landscape character and to assign initial ecological sensitivity to disturbance ratings.

The preliminary assessment was followed with ten days of reconnaissance level field work conducted during July 7 - 17, 1998. The field work involved meetings, interviews, visual field observation, and field data collection.[3] Specific tasks included:

- meeting with Dunster community members to clarify goals and objectives and to obtain local knowledge
- visually ground-truthing preliminary air photo and map interpretations of ecosystem character, condition, and ecological sensitivity to disturbance
- visually ground-truthing MoF forest cover data, and
- collecting reconnaissance-level baseline information on forest stand and stream channel characteristics and conditions.

Subsequent analysis focused on preparing initial components of an ecosystem-based forest use plan for the study area. ArcInfo geographic information system (GIS) software was used during this phase of the project to analyze digital data sets, to design a protected landscape network, and to prepare draft maps. This broad synthesis portion of the study involved:

- refining preliminary air photo interpretations
- digitizing ecological sensitivity ratings

[2] For a list of the information collected, developed, and used see Appendix I.
[3] For a more detailed description of field methods see Appendix III

- analyzing TRIM data to identify and classify streams, slopes, aspect, and elevation
- analyzing forest cover data to identify the distribution of tree species, stand age classes, and vegetative communities
- digitizing information describing community forest uses, and
- synthesizing digital information to produce project maps.

Final work focused on developing and writing the observations, estimates, interpretations, maps, and recommendations contained in this report, and to produce a final set of full-size maps for use in planning. Map production was an interactive process between Silva and members of the Dunster Community Association. Association members contributed local knowledge about the location and distribution of undocumented ecological features and current human uses in the Horsey Creek Landscape. The planning maps describe:

- Ecological Sensitivity to Disturbance
- Landbase Unsuitable for Development
- Past and Planned Logging
- Old Growth Forests
- Non-Timber and Community Forest Use
- Protected Landscape Network
- Potential Timber Management

LANDSCAPE CHARACTERISTICS AND SENSITIVITY

The term **landscape characteristics** refers to the biophysical structure and ecological composition of the Horsey Creek Landscape and its ecosystems, and to the processes that allow that landscape to function ecologically over space and time. Important

Figure 5. Varied climate, geological, and topographic characteristics in the Horsey Creek Landscape create a diverse range of sites and habitats. Outwash floodplains, alluvial fans, and rich valley bottom soils in the Kiwa Creek watershed, for example, provide the foundation for a wide range of ecosystem types, plant communities, and habitats for mammal, bird, reptile, amphibian, and invertebrate species.

structure and composition includes the geology and the topography, and the pattern of streams, lakes, forest stands, and terrestrial ecosystems that occur in the landscape. Important processes include the water, energy, and nutrient flows; the growth and dispersion of plants, trees, and wildlife; and the natural disturbances such as fire, flooding, and insect attacks that act to renew ecological processes and to maintain a diverse range of ecosystems and habitats. Knowledge of landscape character is the basis for understanding how a landscape functions ecologically, and for determining the sensitivity of the ecosystems within that landscape to human disturbance.

Biophysical Characteristics

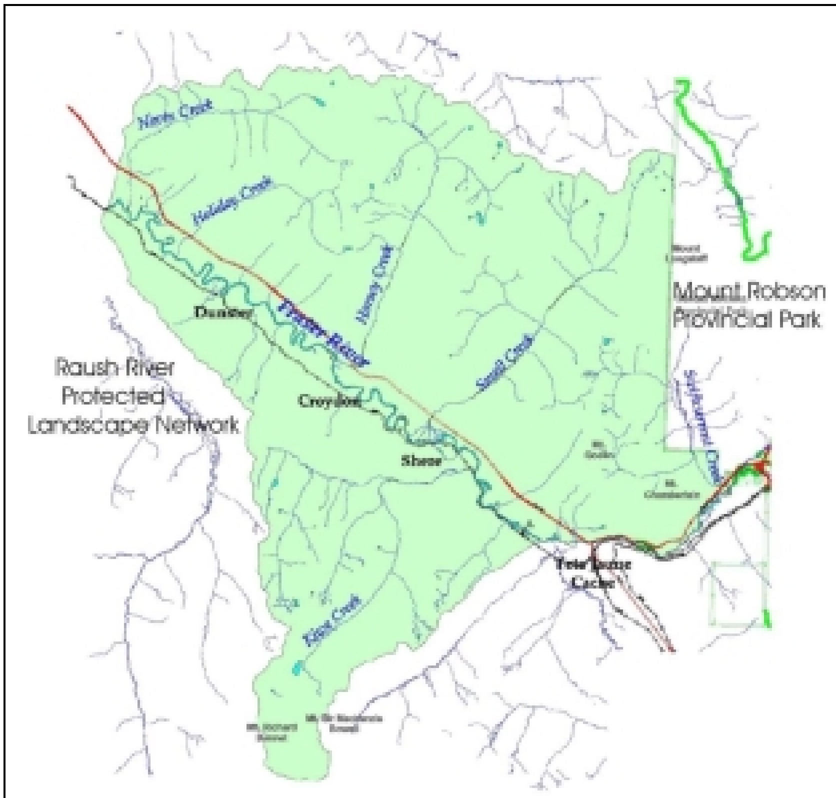


Figure 6. Horsey Creek Landscape study area.

The project area, approximately 150,000 hectares, includes the wide floodplain, terraces, and slopes rising on either side of the Fraser River near Dunster, BC, and the steep, rugged terrain in several tributary watersheds including Kiwa Creek on the west side, and Nevin, Holliday, Horsey, Small, Spittal, and Swiftcurrent Creek watersheds on the east side (Figure 6). Elevation in the landscape ranges from 730 meters on lower floodplains, to slightly more than 3500 meters at the high peaks in the upper Kiwa Creek watershed. Terrain ruggedness and the harsh climatic conditions in higher elevations of the tributary watersheds are highlighted by the fact that alpine tundra occupies more than 40% of the total study area.

Local climate variation is the basis of high ecological productivity in some sites, and very low productivity in others. Temperatures for the landscape as a whole range from a mean daily maximum of 24^{o} C in July to a mean daily minimum of -14^{o} C in January. Extremes can range from 37^{o} C to -46^{o} C, but constant colder temperatures in higher elevations limit plant growth and produces isolated patches of permafrost. The high mean annual precipitation of 700 mm to 800 mm in lower elevations is a major factor contributing to the productive "interior rainforest" ecology of the ecosystems occupying lower portions of the trench and adjacent tributaries. Less productive ecosystems in higher elevations are adapted to a shorter growing season and annual snow accumulations of up to 5 meters during October to May.[4]

Geology in the Horsey Creek Landscape is also highly variable. Bedrock geology consists of uplifted sedimentary and metamorphic strata. Advancing continental ice streams carved the wide trench, and in retreat deposited deep layers of

[4] These figures are based on local knowledge and Canadian Climate Normals 1960-1990 collected in Quesnel and Prince George.

unconsolidated sands, gravels, cobbles, and boulders on the terraces and floodplains adjacent to the Fraser River. Smaller glacial and meltwater outflows originating from higher mountain slopes on either side of the trench cut the narrow, steep tributary watersheds, leaving a mixture of glacial and fluvial deposits on benches, lower slopes, and valley bottoms. Subsequent weathering, erosion, and deposition have produced a complex mix of surficial features ranging from the rich, sandy sediments and organic accumulations located in the valley bottoms, to the thin coarse soils, fallen rock, and rock outcrops on higher slopes.

Soils on sandy floodplains and lower slopes consist mostly of productive, clayey soils referred to as Gray Luvisols, and another equally productive soil type known as Humo-Ferric Podzols that develop on coarser morainal deposits. Poorly-drained, sensitive organic soils known as Gleysols and Mesisols occupy soils in moist depressions and wetlands. Mid and upper slopes in the trench and tributary watersheds also contain moderately productive Humo-Ferric Podzols that have developed on colluvial, morainal, and fluvioglacial deposits. Higher elevations contain poorly-developed regasols consisting mostly of fine, weathered rock fragments which have developed *in situ* or fallen from nearby rock outcrops and cliffs.

Ecological Characteristics

The highly variable biophysical characteristics of the Horsey Creek Landscape result in a diversity of ecological patterns, gradients, and site conditions. Landscape patterns reflect underlying geology and landforming processes, with the wide valley trench a product of the northwest-southeast movement of continental ice streams, and the northeast-southwest oriented tributary watersheds a function of smaller valley ice and stream flows. Overlying this pattern is a clear difference in soil-plant community relationships, with the ecosystems on the northeast side of the trench being adapted to slightly colder and drier conditions than those on the southwest side.

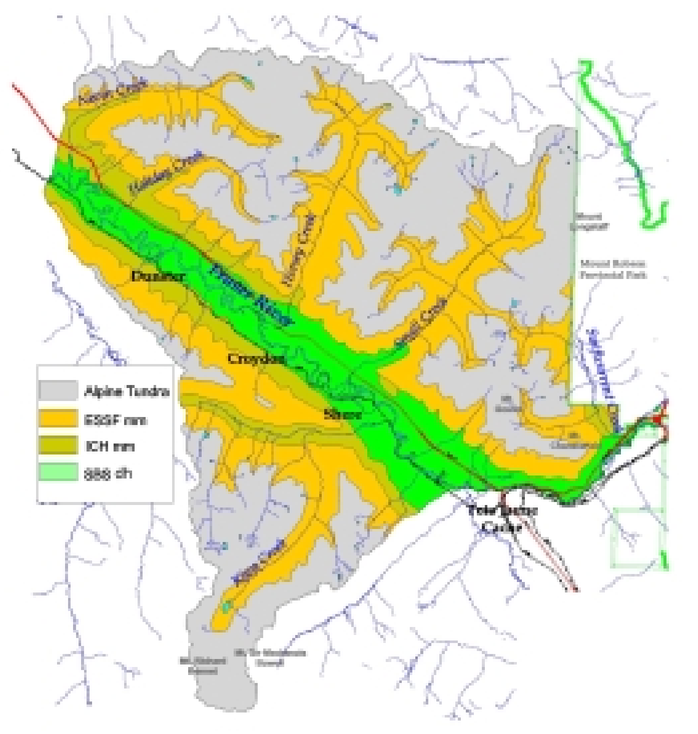


Figure 7. Biogeoclimatic subzones in the Horsey Creek Landscape.

At a finer scale the biophysical variability results in a gradient of ecological associations that change with elevation from the valley floor to alpine slopes and meadows (Figure 7). The relatively dry and warm floodplain terraces, benches and lower slopes on both sides of the Fraser River, for example, contain a productive ecosystem type known as the Dry Hot Sub-Boreal Spruce subzone (SBSdh). This subzone historically contained scattered, even-aged stands of younger lodgepole pine and Douglas-fir ranging up to hundreds of hectares in size. These stands were interspersed within an older and more structurally complex mosaic of forests containing white spruce, subalpine fire, and the occasional veteran or patch of old-growth Douglas-fir. Relatively frequent, small-scale, and intense stand-initiating wildfires that occurred in different areas of the landscape roughly every 125 to 150 years maintained a younger overall forest age structure.

Slightly higher slopes on both sides of the trench north of Dunster, and on the western side of the trench south of Dunster, contain another productive ecosystem type referred to as the Moist Mild Interior Cedar-Hemlock (ICHmm) subzone. The slightly colder climate and thinner soils in these areas historically resulted in a mosaic of older, complexly structured forests dominated by an overstory of western redcedar and western hemlock, with minor components of white spruce and subalpine fir. Under natural conditions, infrequent, localized, and intense stand-replacing fires created a patchwork of smaller seral stands containing Douglas-fir, lodgepole pine and trembling aspen.

Middle and upper elevations in the trench and in the tributary watersheds contain wetter, colder ecosystems referred to as the Moist Mild Engelmann Spruce-Subalpine Fir variant (ESSFmm1)(Figure 8). Subalpine fir and Engelmann spruce are dominant in these forests, growing in multi-aged stands following very infrequent stand-initiating fires. Seral stands of lodgepole pine are common on drier sites, with stands of western hemlock, Douglas-fir, and western redcedar occurring in lower elevations.

Figure 8. Structural and compositional diversity of undisturbed Engelmann spruce-subalpine fir forests in West Kiwa Creek. Each stand contains a wide range of height and age classes, with a rich and diverse shrub and herb understory.

Hydrological Characteristics

Cold winter temperatures and relatively high annual precipitation at higher elevations combine to create a cold continental hydrological regime (Figure 9).[5] Cold temperatures during October to April store available precipitation in ice and snow pack resulting in low winter streamflows. Spring warming releases an increasing amount of meltwater, with peak flows occurring during late June, July, and early August. Streamflows gradually recede through late summer and fall as water retained in ice, snow, fluvial deposits, and soils dries up and temperatures begin to cool.

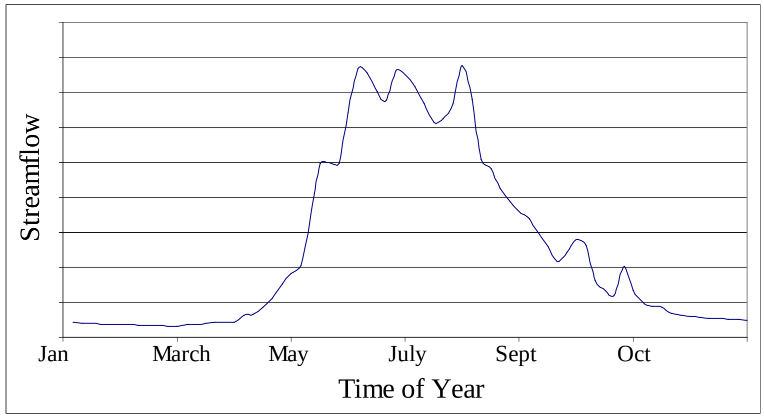


Figure 9. Annual flow regime of streams in the Horsey Creek Landscape. Cold winter temperatures store available precipitation in ice and snow during winter. Delayed snowmelt and summer rains produce peak flows from mid June to mid August.

Streamflow in the Fraser River ranges from a low of 30 cubic meters per second (m^2/s) in mid-winter to a high of more than 700 m^2/s during mid-summer. The relatively uniform flow in the channel proper carves well-developed meanders through the wide, alluvial Fraser floodplain. Side-channels and local flow conditions along the banks of certain reaches provide important rearing and spawning habitat for chinook salmon, and for rainbow trout, bull trout, and other resident freshwater species.

[5] Streamflow regime analysis based on Water Survey of Canada hydrological summary data for Dore and Canoe Rivers, 1990-1995, located just north and south of the study area, and for the Fraser River near McBride BC.


Figure 10. Upper Kiwa Creek winding through outwash floodplain.

The characteristics of tributary rivers and streams are highly variable depending on local geology, topography, and channel gradient. West Kiwa Creek, for example, begins as a relatively uniform flow, low-gradient stream meandering though a floodplain of fine glacial outwash material (Figure 10). The stream soon changes to a highly turbulent flow that cascades among the large cobbles and boulders that have accumulated in the steeper gradients found in middle reaches. Lower reaches of Kiwa Creek are more moderate but still reflect the highly variable channel morphology referred to as "step-pool" that is characteristic of other streams in the study area. The diverse flow conditions and channel morphologies that occur in these streams provides a diverse range of habitat for resident fish and aquatic invertebrates.

Biodiversity

The term **biodiversity** refers to the diversity of ecosystem types, plants, animals, and other living organisms that live in an area, and to the evolutionary and functional processes that links those ecosystems, plants, animals, and organisms together and allows them to adapt to changing biophysical and ecological conditions over time. As a general rule, landscapes with highly varied biophysical characteristics support a higher level of biodiversity than more uniform landscapes.

The highly varied biophysical characteristics of the Horsey Creek Landscape do provide a wide range of habitats for plants, wildlife, fish, and other living organisms. Forests in lower elevations, for example, may contain lodgepole pine, trembling aspen, black cottonwood, and white spruce in the overstory, a variety of shrubs such as velvet-leaved blueberry, soopoallie, birch-leaved spirea, and red-osier dogwood in the understory, and kinnikinnick, pinegrass, and twinflower in the herb layer. Cooler mid slopes may contain Engelmann spruce, subalpine fir, Douglas-fir, western hemlock, and western redcedar, with saskatoon, black huckleberry, white flowered rhododendron, and false azalea in the shrub layer, and bunchberry, five-leaved bramble, oak fern, and red-stemmed feathermoss as ground cover.

Several rare plant associations plants may occur in the Horsey Creek Landscape (Table 1). Rare associations that may be found on lower slopes of the trench will occur in wet, poorly drained depressions with rich organic soils and a variable

Plant Association	Habitat Requirement	Possible Location
western redcedar/white spruce – devil's club – sphagnum	ICHmm/06	fertile, wet sites in lower slopes adjacent to the floodplain
western redcedar/white spruce – skunk cabbage – horsetail	ICHmm/08	fertile, wet sites on lower slopes adjacent to the floodplain
lodgepole pine – velvet leaved blueberry – cladonia	SBSdh/02	steep, dry, nutrient-poor sites on the floodplain
black spruce – labrador tea – velvet-leaved blueberry	SBSdh/05	steep, dry, nutrient-poor sites on the floodplain
black spruce – sedge – feathermoss	SBSdh/05	steep, dry, nutrient-poor sites on the floodplain

Table 1. Communities listed as rare in the Robson Valley Forest District that may occur in Horsey Creek Landscape.

canopy of western redcedar, western hemlock, and white spruce. These communities are marginally productive from a timber management point of view, and provide important wildlife habitat. Rare associations such as the black spruce – sedge – feathermoss plant community that may be found on the Fraser River floodplain will occur in steeper, very dry sites with coarse, nutrient-deficient soils and a thin canopy of lodgepole pine. These site and soil conditions result in very low productivity. Numerous plants listed as rare, threatened, or endangered in the Robson Valley Forest District, may also occur in the project area (Table 2).[6] Most of these plants likely occur in the dry forests found in lower portions of the trench.

[6] Information supplied by the Conservation Data Centre, September 1998. Species listed as red are considered to be extinct, endangered, or threatened in B.C. Endangered means facing imminent extinction; threatened means the plant or animal is likely to become endangered if current conditions persist. Species listed as blue are considered to be at risk, and are particularly sensitive to human or natural disturbance.

More than 50 mammal species occur in the Horsey Creek Landscape, including four that are considered to be at risk due to human disturbance (Table 3). Large ungulates using the landscape include moose, white-tailed deer, mule deer, elk, mountain goat, and migrating caribou. Black bears are common, and a small number of grizzly bears and wolverine also live in the area. Common small mammals include beaver, coyote, fox, mink, weasel, and red squirrels. The number and distribution of most wildlife species are limited by steep valley walls, heavy winter snow accumulations, and loss of habitat due to settlement and agricultural development. Habitat restoration and maintenance of movement and travel corridors will likely be critical to the long-term persistence of many species within the study area.

Plant Common Name	Provincial Listing
rusty cliff fern	blue
three-lobed daisy	red
arctic eyebright	blue
gray-leaved draba	blue
Canada anemone	blue
slender paintbrush	blue
purple-leaved willowherb	blue
Hornemann's willowherb	blue
wooly daisy	blue
rocky mountain sandwort	blue
meadow willow	blue
plains butterweed	blue
bald sedge	blue
little fescue	blue
sheathed cotton-grass	blue
small deer-grass	blue

Table 2. Plants that are endangered or at risk in the Robson Valley Forest District that are known to or may occur in the Horsey Creek Landscape.

Common Name	Status
grizzly bear	blue
wolverine	blue
rocky mountain bighorn sheep	blue
fisher	blue
northern long-eared mytotis	red
American bittern	blue
short-eared owl	blue
bull trout	blue

Table 3. Wildlife, birds, and fish that are endangered or at risk in the Robson Valley Forest District that are known to or may occur in the Horsey Creek Landscape

The Horsey Creek landscape and surrounding Robson Valley support over 200 of British Columbia's 430 bird species. Common waterfowl include Canada goose, mallard, common merganser, and loons. Common bird species include bald eagle, white-crowned sparrow, yellow-rumped warbler, Black-capped chickadee, ruffed grouse, eagle, and osprey. Two bird species, the American bittern and short-eared owl, are listed by the Conservation Data Centre as being at risk in the Robson Valley Forest District because of habitat loss.

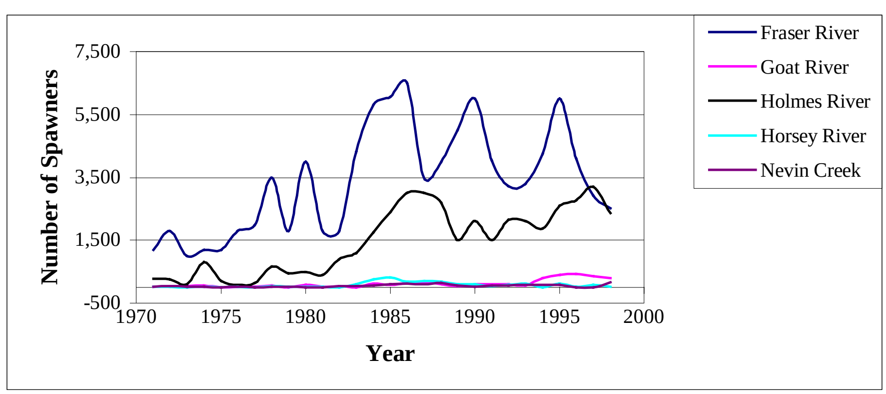


Figure 11. Chinook spawning escapements in the Fraser Headwaters, 1971-1998

Streams in the Horsey Creek Landscape support a variety of anadromous and freshwater fish populations including: chinook salmon; rainbow, cutthroat, and bull trout; and mountain whitefish. Regional data suggests chinook spawning escapements have been slowly increasing over the last 25 years, although recent years show a sharp decline (Figure 11).[7] Bull trout, a species which relies on highly varied mid- and upper-steam habitat, are listed by the Conservation Data Centre as being at risk. Much of the Fraser River and most lower reaches of tributary streams have been designated as class “A” fish habitat. Protection and maintenance of riparian ecosystems, instream habitat, side-channels, and natural streamflows is necessary to sustain resident fish populations in these river and stream reaches.

Ecological Sensitivity

The forest stands in the Horsey Creek Landscape which have thin, poorly-developed soils, and the plant and animal populations which are susceptible to serious decline or extinction, can be described as being **sensitive to disturbance.** The soils and plant communities growing on steep, wet slopes in tributary watersheds, for example, are sensitive to timber cutting or road building disturbance because they are likely to slump or slide, resulting in erosion and stream siltation. Wildlife, plant, or fish populations that occupy the landscape are sensitive to habitat loss or excessive harvesting if their numbers are unnaturally low, or if they have specific seasonal or life-stage habitat requirements.

Figure 12. Sensitive ecosystems in the Small River watershed. Stunted trees and avalanche chutes in the background indicate steep, unstable slopes, cold climate, and low ecological productivity. These ecosystems are highly sensitive to disturbance.

Ecosystems, plant communities, and animal populations in the Horsey Creek Landscape which are sensitive to disturbance have thresholds, and long-term loss of ecological function or biodiversity can occur if people ignore these **ecological limits**. Many limiting factors such as steep, unstable slopes are easy to identify. Others such as the point at which habitat loss seriously threatens resident wildlife or fish populations can be difficult to determine or assess. Different forest and water uses also vary in their impacts. Also, the **resilience,** or ability of ecosystems or plant and animal populations to recover from disturbance, varies over space and time. Soils, for example, differ in temperature, texture, moisture content, thickness, and consequently stability and ability to regenerate from place to place. Plant and

[7] Data provided by Department of Fisheries and Oceans, Clearwater Office.

animal populations have different dynamics, and, as a result vary, in their ability to recover from excessive harvesting and hunting, or in their ability to adapt to changing habitat conditions.

Figure 13. Road construction on steep, unstable glaciofluvial deposits n Kiwa Creek results in debris flows and soil erosion.

A precautionary, ecosystem-based approach to landscape analysis acknowledges our inability to accurately predict the consequences of many activities, and seeks to avoid or minimize negative impacts by identifying key biophysical and ecological characteristics that indicate high ecological sensitivity. Areas with these characteristics are initially reserved from the development landbase until detailed site assessments have been carried out to determine whether or not proposed activities pose little or no risk. Important biophysical characteristics include: cold, dry climate; steep slopes; complex or broken terrain; very wet or dry moisture regime; and thin or poorly-developed soils. Important ecological characteristics include ecosystem rarity, and plant or animal population vulnerability or endangerment.

The indicators used in this analysis to determine high or extreme ecological sensitivity to disturbance (ESD) in the Horsey Creek Landscape include:

- proximity to rivers, lakes, streams, and wetlands (20 to 50 meters)
- slopes in excess of 60% and steep avalanche zones
- complex, highly variable terrain containing more than 50% rock outcrops, steep gullies, slides, and fallen rock
- thin, poorly-developed soils that cover bedrock, fallen rock, and coarse glacial materials
- very wet or very dry site moisture conditions, and
- high elevations or cold temperatures that reduce productivity[8]

[8] See Appendix VII for a detailed description of the Silva ESD classification system

These criteria were used to identify the following ESD classes in the Horsey Creek Landscape study area:

- **Riparian Ecosystems and Wetlands**—riparian ecosystems include the riparian zone and the riparian zone of influence. These are areas adjacent to streams, rivers, and lakes. Wetlands are fen, bog, and swamp ecosystems situated in local depressions and in valley bottoms. These ecosystems typically contain a high level of biodiversity, and play a crucial role in regulating water flows.
- **Alpine**—a very sensitive ESD class containing high elevation ecosystems which are limited by cold temperatures. Soils typically form a thin, poorly-developed layer over glacial deposits, fallen rock, and bedrock. Trees, vegetation, wildlife, and other living organisms are adapted to cold climate conditions, heavy snow accumulations, and a short growing season.
- **Avalanche Terrain**—consists of steep, narrow chutes which experience frequent snow avalanches. Vegetation is typically dominated by a hardy shrub layer that is adapted to withstanding constant snow, soil, and rockfall disturbance.
- **Complex Terrain**—contains highly variable topography containing ridges, steep gullies, rocky outcrops, and depressions. Micro slopes typically exceed of 60%. Thin soils and poor water storage capacity on ridges or upper slopes, or poor drainage and acidic soil conditions in depressions, limit site productivity.
- **Steep Terrain—**contains areas with slopes greater than 60% that are unstable and prone to landslides and erosion, particularly after logging and road construction. Steep slopes can be economically logged with modern equipment, but they are too ecologically sensitive to be sustainable timber management sites. Steep slopes are common in the Horsey Creek Landscape, particularly in the tributary watersheds.
- **Moderately Stable Terrain—**consists of areas with an average slope of between 30% and 60%. Small areas with rocky knolls, steep slopes, or wetland depressions may occupy up to 50% of the terrain, but overall slopes are moderate and contain relatively well-developed, productive soils. 50% of the area within moderately stable terrain is removed from the potential timber management landbase.
- **Stable Terrain—**consists of areas with an average slope of between 0– 30%, and well-drained, productive soils. 100% of the forested area within stable terrain is included in the timber management landbase.

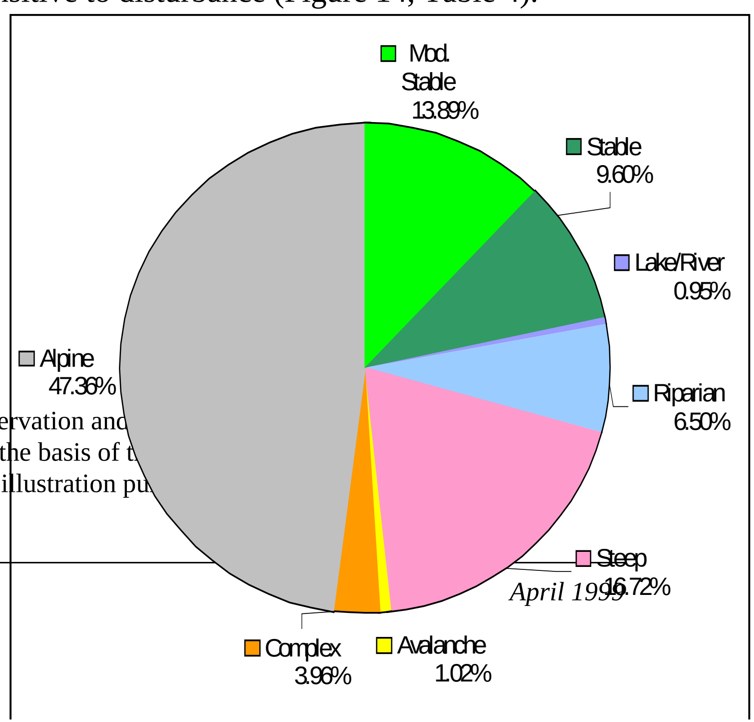
The distribution of these classes in the Horsey Creek Landscape was identified through a combination of air photo interpretation, field reconnaissance, interpretation and analysis of forest cover and TRIM data, and GIS modeling. A preliminary ESD classification was developed prior to going into the field using 1:60,000 air photos, 1:50,000 topographic maps, and 1:20,000 forest cover maps. Interpretations focused on stratifying the Horsey Creek Landscape into broad classes using a variety of criteria such as slope, site moisture, forest cover, and terrain complexity.

A reconnaissance level field check of the photo-interpreted sensitivity to disturbance classification was carried out over 8 days during the June 15-23 field trip. Field checking was limited to areas accessible by four-wheel drive vehicle, quad, and hiking distances of approximately 2 kilometres. The field crew visually assessed terrain and forest cover.[9] Field observations were used to revise and improve the initial ESD interpretations.

Initial ESD linework was then digitized into a GIS database. Classification boundaries were verified and refined using a variety of techniques:

- All classification boundaries were verified by comparison with field notes and photographs, air photos, and MoF forest cover data.
- Boundaries of stable and moderately stable terrain were verified using TRIM data and Arcview 3D Analyst software.[10] The software was used to stratify the Horsey Creek Landscape into three broad slope classes:
  - stable terrain less than 30% slope
  - moderately stable terrain with slopes between 30% and 60%
  - steep terrain with slopes greater than 60%.
- Riparian ecosystems and the zone of riparian influence were either identified on air photos and verified in field, or modeled using GIS. Riparian zones around the Fraser River were modeled by identifying the boundary of the first floodplain terrace and adding an additional 15 meter buffer. Riparian zones and the zone of riparian influence around tributary streams were modeled by creating a 60 meter wide buffer around water features and main channels, and a 40 meter wide buffer around all smaller streams.

When these characteristics are identified in the study area (Map 1),[11] it is clear that the Horsey Creek Landscape is highly sensitive to disturbance (Figure 14, Table 4). High elevation alpine occupies slightly more than 47% of the landscape, and most forests adjacent to these alpine areas are slow-growing transitional forests. Most mid and upper slopes are steep and complex, with numerous avalanche chutes, slides, and rock outcrops. Lower slopes in the tributary watersheds contain abundant rock



[9] See Appendix III – Fraser Headwaters field observation and
[10] A minimum polygon size of 5 hectares formed the basis of t
[11] The maps in this report have been included for illustration pu
planning maps that accompany this report.

fallen from upper slopes, the valley bottoms are often narrow gorges that climb steeply away from streams and narrow riparian forests. Lower slopes and benches on and adjacent to the Fraser River are much more stable and productive, but rare wetlands and sensitive riparian ecosystems occupy more than 7% of the Horsey Creek Landscape that does lie with the trench proper. As the section reviewing the current ecological condition of the Horsey Creek Landscape describes (section 5), much of this productive forest land has been negatively impacted by fires and development that occurred in the early part of the century.

Figure 14. Summary of ecological sensitivity classification

Silva Ecological Sensitivity to Disturbance Class	Area (ha)	Percent of Total
Aquatic Ecosystems		
Lakes and Swamps	301.9	0.20%
Rivers and Streams	1,111.4	0.75%
Subtotal	1,413.3	0.95%
Ecologically Sensitive Areas and Sites		
Alpine Tundra	70,355.6	47.36%
Riparian Ecosystems	9,657.5	6.50%
Steep Terrain	24,835.8	16.72%
Avalanche Terrain	1,514.7	1.02%
Complex Terrain	5,882.8	3.96%
Subtotal:	112,246.4	75.54%
Stable and Moderately Stable Areas and Sites		
Moderately Stable Terrain	20,628.2	13.89%
Stable Terrain	14,260.4	9.60%
Subtotal:	34888.6	23.51%
Total:	148,548.3	100%

Table 4. Summary of Ecological Sensitivity to Disturbance Classification

Map 1. Insert map of ecological sensitivity

Landbase Unsuitable for Development

The term **landbase unsuitable** refers to areas and sites within the valley where timber management and other industrial activities are inappropriate either because those areas and sites contain ecosystems which do not support forest vegetation (*e.g.* alpine parkland, avalanche zones, and wetlands), or because they are highly sensitive to disturbance (*e.g.* steep unstable slopes, rare habitat, unproductive soils). Classifying areas as unsuitable for development does not mean they are off limits to all uses and activities—less obtrusive activities such as carefully planned backcountry recreation, guide-outfitting for nature interpretation, and botanical forest product harvesting may be possible. Each area initially classed as unsuitable for development, however, must be assessed on a site and activity specific basis before it can be included in the development landbase.

Different planning systems use different criteria to assess development suitability. The Ministry of Forests' forest development and timber supply planning procedures first identify the "forest landbase", or the amount of forested public land that is available for timber harvesting within timber supply areas (TSAs). A variety of biophysical and ecological criteria are then used to identify landbase "netdowns" such as non-forested, non-productive, non-merchantable, or environmentally sensitive sites. Sites with these characteristics are removed from the total forested landbase, and forest stands within the remaining "operable landbase" are then classed as good, medium, and poor growing sites depending on site characteristics. Information about the species, growth rate, and volume of trees on good, medium, and poor sites forms the basis for calculating an annual cut for the timber supply area. This annual allowable cut (AAC) forms the basis for operational planning throughout each TSA.

Silva's ecological sensitivity to disturbance rating system uses a broader range of ecological criteria to first identify and reserve areas that are unsuitable for industrial development within particular watersheds or landscapes. This approach focuses attention not on identifying the amount of forested land available for timber management, but instead on identifying areas and sites in each landscape or watershed that are too sensitive to support timber management and other extractive forest uses, or that need to be protected to maintain landscape functioning. These sites and areas are reserved from the development landbase. Silva's analysis system is more precautionary than the MoF's planning system, and consequently tends to identify a smaller portion of the landbase as being suitable for timber management and other aggressive development activity.

Various classes in the two systems such as the MoF's "environmentally sensitive" and Silva's complex terrain" often overlap; consequently, the sequence in which the classes are mapped affects the amount of land shown in each category. The mapping sequence used here was chosen to highlight the amount of landbase the MoF "nets down", and the additional landbase that is considered too sensitive for timber management and other intrusive development activities according to Silva's ecosystem-based criteria.

The classes have been mapped in the following sequence:

- **MoF Non-forested Areas**, which include water features, glaciers, rock outcrops, alpine tundra, wetlands, private property, and agricultural clearing.
- **MoF Netdowns**, which include:
  - **Non-productive, brush, and non-commercial –** areas which contain an ecologically stable community of herb and brush species, or non-commercial tree species. Such sites have little or no potential for conversion to commercial species.
  - **ESA 1 –** areas with significant non-timber values or fragile or unstable soils, or areas in which there are impediments to establishing a new tree crop. These sites typically contain steep slopes and unstable soils.
  - **Inoperable areas –** areas considered uneconomic to harvest due to poor accessibility, high elevation, low stand volume, and/or poor timber quality.
  - **Non-merchantable forest –** stands of non-merchantable deciduous species such as aspen and black cottonwood. These species are marginally merchantable, and are not generally included in estimates of commercial timber productivity.
  - **Low site index –** areas with low timber growing potential due to poorly-developed soils, cold climate, or poor site conditions.
- **SFF Ecologically Sensitive Netdowns**, which contain ecologically sensitive areas that have not been reserved from the operable landbase by the MoF. These areas include:
  - **Silva Riparian Zones –** a summary class which contains wetlands and riparian ecosystems (riparian zones and the riparian zones of influence) identified during the ecological sensitivity to disturbance classification.
  - **Silva ES –** a summary class which contains steep terrain, complex or broken terrain, and areas with shallow soils identified during the sensitivity classification.

The results of the "netdown" process are summarized in Figure 15 and Table 5 on the following page, and shown in Map 2. Approximately 52% of the Horsey Creek Landscape is not forested, and MoF landbase netdown criteria removes another 28% of the available forested land from the potential timber management landbase by netting out sites that contain private land, settlement clearing, and non-productive brush. The Silva ecological sensitivity to disturbance classification system reserves another 8.0% of the landbase. These additional reserves are areas that contain riparian ecosystems, slopes in excess of 60%, or which have ecologically sensitive characteristics such as thin soils or very wet moisture regime.

When all landbase netdowns are accounted for, just over 12% of the Horsey Creek Landscape is identified as potentially suited for timber management, road construction, and other intrusive development activities. Some parts of this remaining may also be removed from the development landbase to ensure adequate protection of old growth forests, rare plant communities, and landscape connectivity. This is discussed in the report section——Ecosystem-Based Analysis—that describes the proposed protected landscape network and planning for areas that lie within the potential timber management landbase.

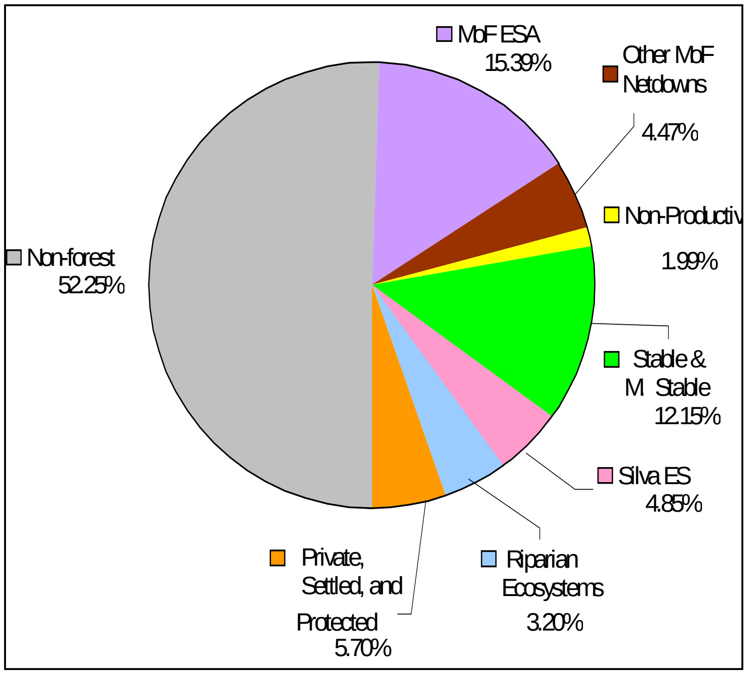


Figure 15. Summary of landbase netdowns

Description	Area (ha)	Percent of Total
Non Forest and Non Commercial Forest Cover		
Water	1,413.3	0.95%
Alpine	67,687.2	45.57%
Alpine Forest	4,158.3	2.80%
Settlement	4,358.6	2.93%
Subtotal	77,617.4	52.25%
Ministry of Forests Netdowns		
Non-Productive Brush	2,953.3	1.99%
Private Land or Protected Areas	8,468.8	5.70%
MoF ESA	22,855.7	15.39%
Inoperable Areas	688.9	0.46%
Non-Merchantable	3,479.5	2.34%
Low Site Index	1,264.7	0.85%
Inaccessible	1,211.2	0.82%
Subtotal	40,922.0	27.55%
Silva Netdowns		
Silva Riparian	4,753.8	3.20%
Ecologically Sensitive Terrain	7,208.1	4.85%
Subtotal	11,961.9	8.05%
Stable and Moderately Stable Terrain		
Stable Terrain	4,879.0	3.28%
Moderately Stable Terrain	13,168.0	8.86%
Total	148548.3	100.00%

Table 5. Summary of landbase unsuitable classification

Map 2 insert map of landbase unsuitable

HORSEY CREEK LANDSCAPE CONDITION

Landscape condition refers to how past and present natural events and human activities, or the combination of the two, have affected the composition, structure, and functioning of the Horsey Creek Landscape and the ecosystems that lie within that landscape. Assessing the ecological condition of the landscape is a critical component of ecosystem-based analysis and planning. This assessment forms the basis for determining which forest stands, wildlife habitats, and other ecosystem types need to be protected and maintained to prevent further ecological degradation. Knowledge of present ecological condition also provides guidance in planning management strategies and activities that will help to restore natural composition and structure in areas of the landscape that have been heavily impacted by previous human use and industrial development activities.

The history of human use of the Horsey Creek Landscape is one of traditional hunting and gathering activities, railway construction, mineral exploration and extraction, settlement and agricultural clearing, road construction, and industrial logging. Each of these activities affected the ecology of the Horsey Creek Landscape in various ways. Railroad construction, mineral exploration, and settlement affected ecosystems in the trench in the early part of the century. Industrial logging has had a serious impact on the condition and function of tributary watersheds in more recent decades.

Pre-Contact Landscape Use

The Lheidli T'enneh and Secwepemc peoples have used the ecosystems in the Horsey Creek Landscape extensively for centuries with little impact.[12] Their economies were based on craftsmanship and the efficient use of local wood, rock, and mineral materials to hunt and harvest a wide variety of animals and plants for domestic use and for trade. Local trees were cut or de-barked for shelter, cooking and hunting equipment, fish traps, canoes, and fire. A huge variety of plants and berries were harvested for food and medicine in different locations depending on seasonal availability. Deer, caribou, moose, mountain sheep, mountain goats, ducks, and geese were hunted for food, and fox, bear, wolf, cougar, beaver, ermine, martin, otter, and marmot were hunted or snared primarily for fur clothing and trade materials. Controlled ground-fires, used to enhance production of certain valuable plants, may have altered plant distribution, but otherwise Lheidli T'enneh and Secwepemc landscape use had little effect on local ecology.

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[12] See Wolf, A. 1996. *Shuswap History: A Century of Change.* Kamloops, BC: Secwepemc Cultural Education Society; and Furniss, E. 1993. *Changing Ways: Southern Carrier History, 1793-1940.* Quesnel, BC: Quesnel School District.

Historical Landscape Development

The arrival of industrial development and settlement activities beginning in the early 1900s, in contrast, had a profound impact on landscape pattern, forest composition, habitat availability, stream integrity, and wildlife abundance in the trench. The impacts were caused by a combination of land clearing for rail and road right-of-ways, agriculture, settlement, trapping and hunting, and by human-caused fires which spread across the floodplain and adjacent slopes (Figure 16).

Lower elevations in the trench historically contained a diverse multi-aged mosaic of forest stands containing old growth lodgepole pine and Douglas-fir on drier sites, and white spruce and subalpine fir on undisturbed moist sites. Western redcedar, black

Figure 16. Logging and land development in the Horsey Creek Landscape circa 1915. The forests around this pre-emptors cabin in Dunster have either been recently cleared, logged, or burned. Lower slopes in the background show areas burned by fires set by rail construction companies or by miners intent on exposing surficial geology. (Photo courtesy of the BC Provincial Archives)

cottonwood, and paper birch occurred on wet sites and areas next to streams and lakes. Clearing and fires eliminated these older forests, creating a patchwork legacy of linear roads, fields, and fragmented young successional forests on the floodplain, and a mosaic of young, even-aged stands containing aspen, Douglas-fir, lodgepole pine, and Engelmann spruce on adjacent slopes. Dense stands of aspen have regenerated to dominate sites where fires were most intense (Figure 17).

Figure 17. Aspen stands growing on disturbed sites. Fires from railway construction and land clearing in the early 1900s eliminated natural forest cover and consumed soil nutrients and seed legacies on slopes adjacent to the Fraser floodplain. Dense aspen stands tended to regenerate and dominate sites where fires were most intense.

The combined impact of this forest conversion and concentrated hunting on local wildlife was likely severe. Lowland and riparian forests and wetlands on the Fraser River floodplain historically provided important habitat for many old growth and riparian forest dependent species. Early development eliminated most of the contiguous mature, climax interior rainforest on the floodplain, leaving little habitat and few movement corridors for birds and animals which historically lived in, or traveled through, this broad, riparian ecosystem.

Early development also impacted stream ecology. Land clearing on terraces and floodplains near the Fraser River, particularly in riparian zones, likely enhanced peak flows and sediment inputs to tributary streams, leading to increased channel instability and deposition of fine sands and silts in lower reaches and side-channels close to the Fraser River. Straightening and containing stream channels to make way for roads and bridges and to increase the amount of arable land also likely reduced the amount of instream habitat available for resident stream invertebrates, trout, and salmon.[13]

[13] Stream channelization is still plainly evident at many locations. Holliday Creek and Nevin Creek for example, have been channelized and straightened above and/or below Highway 16.

Recent Industrial Development

Industrial development activities in recent decades have had an equally significant impact on landscape and site ecology within the watersheds tributary to the Fraser River, particularly the Small Creek, Kiwa Creek, and Horsey Creek drainages. Large scale natural disturbances such as stand-replacing fire are relatively infrequent in these watersheds, and the forest under natural conditions would typically be dominated by extensive areas of structurally complex mature Englemann spruce and subalpine fir forest surrounding smaller patches of younger even-aged successional lodgepole pine stands. Clearcut logging and fire escapes resulting from slashburning has altered the overall species composition and age-class distribution of the forests in these watersheds (Figure 18), eliminating many of the habitat structures important to local wildlife species.

Figure 18. Recent logging and escaped slash burns in the Kiwa Creek watershed have altered overall forest species composition and age class distribution within the watershed, and eliminated important stand level structures such as large old trees, snags, and fallen trees within clearcut areas. Many important landscape connections such as riparian ecosystems adjacent to small steams, wildlife movement corridors, and sensitive micro sites have also been eliminated or disturbed.

Riparian forests have also been eliminated along substantial lengths of stream channel in the Horsey Creek, Small Creek, and Kiwa Creek watersheds, likely resulting in increased peak flows, water temperatures, reduced instream nutrients,

Figure 19. Clearcut logging in the Horsey Creek headwaters has eliminated the riparian ecosystems adjacent to the river. These riparian forests play an important role in regulating streamflow and water temperature. Large trees and woody debris falling into the channel from riparian forests also provide important instream structures and nutrient inputs. Management planning should focus on restoring natural composition and structure to these riparian forests.

and loss of instream habitat (Figure 19). Road construction has also likely altered the course of ground and surface water flows, interrupted wildlife travel routes, and created unnaturally high levels of forest edge.

Realistic assessments of the impacts that this past logging has had, and that proposed development will have, on the forests of the Horsey Creek Landscape must include an evaluation of both the apparent and the actual impacts that those activities have had, or will have, on the condition of forest ecosystems and wildlife populations. **Apparent impacts** include the direct physical disturbances caused by road construction, land development, and logging, as well as the direct effects these landscape disturbances have on landscape function and diversity. The **actual impacts** of past and proposed development, however, include apparent impacts plus the additional physical, biological, and behavioral effects that extend beyond the physical boundary, or edge, of the disturbance. These **edge effects** negatively impact ecosystems, plant communities, and plant and animal populations adjacent to the physical disturbance.[14]

[14] For a more detailed discussion of apparent and actual impacts see Appendix V

The extent of the direct, apparent impacts of past logging that has occurred over the last forty years within the Horsey Creek Landscape, and the location of proposed logging cutblocks are shown in Map 3. The extent of edge effects are estimated in the mylar overlay. Most of the floodplain terraces surrounding the Fraser River were logged or burned between 1910 and 1950, but Silva was not able to describe the extent of this forest conversion because pre-1950 logging and land clearing information is not contained within MoF digital forest cover data. Figure 20 and Table 6 summarize the distribution of past and proposed logging that MoF forest cover data does describe. Slightly less than 5% of the total landbase has been logged in recent decades, and nearly 4% of the forested public lands have been logged. Approximately 21% or 1558 hectares of this logging has taken place on private land, 23% or 1646.3 hectares has occurred on ecologically sensitive terrain, and 55% or 3938.6 hectares has occurred on stable and moderately stable terrain. Licencees and the MoF propose to log another 135.3 hectares over the next few years.

These numbers may not seem like a large portion of the landscape, however, the logging that has occurred on public forested lands does represent approximately 21% of the landbase that Silva identifies is potentially available for timber management. In addition, all recent logging has involved clearcutting easily accessible mature stands on private land in the trench, or old growth stands in the Kiwa Creek, Horsey Creek, and Small Creek watersheds. Remaining forests on private lands in the trench are still in the process of recovering from fire and logging earlier in the century, and remaining stands in the tributary watersheds are less productive, ecologically sensitive, and more difficult to access.

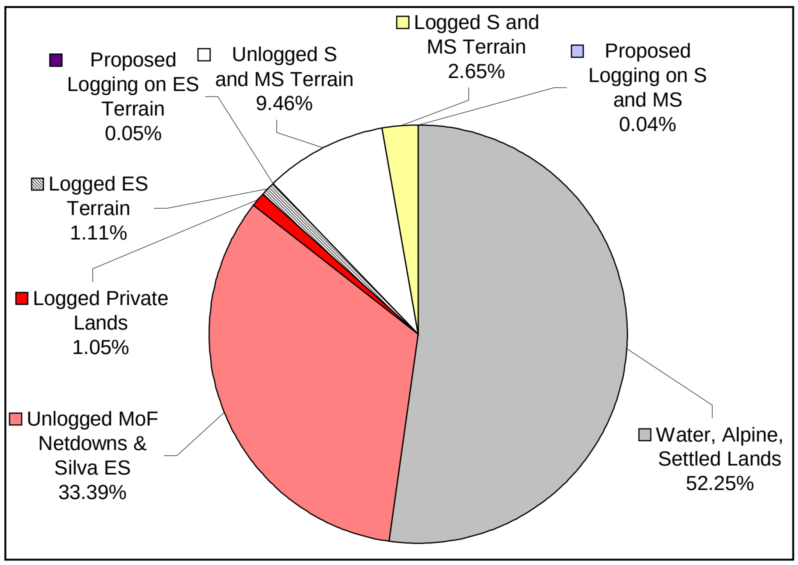

Figure 20. Summary of past and planned logging

Description	Area (ha)	Percent of Total
Water, Alpine, Alpine Forest, and Settled Lands	77,617.4	52.25%
Unlogged MoF Netdowns and Silva Ecologically Sensitive	49,601.1	33.39%
Logged Private Property	1,558.5	1.05%
Logged Ecologically Sensitive Terrain	1,646.3	1.11%
Proposed Logging on Sensitive Terrain	78.0	0.05%
Unlogged Stable and Moderately Stable Terrain	14,051.1	9.46%
Logged Stable & M. Stable Terrain	3,938.6	2.65%
Proposed Logging on S and MS Terrain	57.3	0.04%
Total	148,548.3	100.0%

Table 6. Summary of past and planned logging within the Horsey Creek Landscape

Map 3. Insert map of Past and Planned logging

Old Growth Forests

Ecological research over the last two decades has transformed our understanding of the role that old growth forest stands and large old trees play in overall landscape and ecosystem function. At the landscape level, patches of old growth provide critical habitat requirements for a variety of species. Large ungulates such as elk and deer, for example, depend on the protection and forage found in old forests during winter. Many plant, small amphibian, and invertebrate species also depend on the moist, moderated "interior" climate that is found only within old growth forests during dry summer months. Old growth forest in most landscapes contain a higher level of biodiversity than younger forests and provide habitat for many old growth dependent plant and animal species.

At the stand scale, the structural diversity—large diameter trees, snags, and fallen trees, and multi-layered canopies—common in many old growth patches supports processes which are not found in younger forests. Large live trees, for example, act as water pumps, bringing moisture from deep in the ground and making it available for nearby plants during dry periods. Large snags provide critical habitat for primary cavity-excavating birds such as woodpeckers, and for the variety of secondary cavity-dwelling birds that depend on the nesting sites created by woodpeckers. The large fallen trees characteristic of old growth stands also perform vital functions on land and in streams, providing water storage, habitat structure, and nutrients for a variety of aquatic invertebrates.

From a human perspective, old growth forests provide a variety of valuable benefits and services. The rich organic soil and root complexes that lie below old growth forests, for instance, act to filter and store subsurface groundwater, releasing regulated flows of high quality surface water downslope into nearby streams. The large trees growing above the ground also act as moisture traps and carbon stores, helping to regulate local, regional, and global climate regimes. Large old trees are also a unique source of tight-grained, high-quality wood.

The distribution of remaining old growth forests in the Horsey Creek Landscape was identified based on the stand age class, stand height, and dominant tree species combinations shown in Table 7. The first five classes are drawn from an old growth classification methodology developed by the MoF to prepare an old growth conservation strategy for the Robson Valley Forest District in

Dominant Tree Species	Stand Age Class	Stand Height Class
Douglas-fir	140 years plus	28.4 meters plus
Western Red Cedar	140 years plus	28.4 meters plus
Hemlock	140 years plus	19.4 meters plus
Engelmann Spruce	140 years plus	19.4 meters plus
Subalpine fir	140 years plus	19.4 meter plus
All Other Species	140 years plus	

Table 7. Age class and biogeoclimatic zone combinations used to identify old growth in the Horsey Creek Landscape

1992.[15] The sixth class—All Other Species—has been included in this analysis out of recognition that old growth characteristics are not just a function of stand height and species composition. Many higher elevation stands within the project area, for example, are not tall enough to fall within the MoF classification methodology. Nonetheless, these stands are considerably more than 140 years old, and contain many of the structures such as large fallen trees and snags that are characteristic of old growth forests in the area.

This classification should be viewed as a reasonably accurate "best estimate" that will need to be verified in the field. This is because MoF forest cover databases are designed as a regional timber management and timber inventory tool, not as landscape or ecological planning tool. This means that:

- it is difficult to identify smaller patches of old growth because MoF forest cover information is organized within relatively large spatial units called polygons, and the information in these polygons is uniform and does not capture local variation in tree age and stand composition
- the classification is based on only three attributes—dominant tree species, stand age, and stand height—and this may not be a reliable indicator of whether the forests within the polygon have developed old growth structural characteristics
- the classification may be inaccurate because the information within MoF forest cover data is developed using a variety of methods ranging from air photo interpretation to field sampling, and some of these data sources are inherently unreliable.

Silva's estimate of the distribution of remaining old growth forests is shown in Map 4, and summarized in Figure 21 and Table 8. Clearly, the majority of these forests lie in the tributary watersheds—a few isolated old growth patches do occupy the floodplains and terraces east of the Fraser River, but these are located mostly on private land. Conservation easements or land trusts should be considered as a means of protecting these remnant stands.

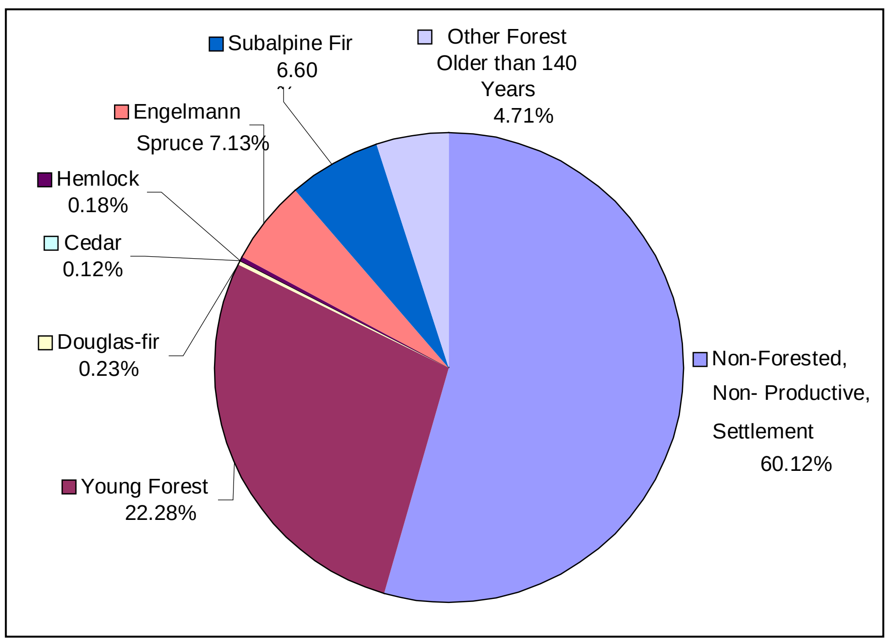

Figure 21. Summary of old growth distribution in the Horsey Creek Landscape

[15] Ministry of Forests. 1992. *Draft (Version III) An Old Growth Conservation Strategy for the Robson Valley Forest District.* McBride, BC: BC Ministry of Forests.

It is also clear that the majority of remaining old growth forests on public lands consist of stands dominated by Engelmann spruce and subalpine fir—Douglas-fir, western redcedar, and western hemlock old growth stands combined occupy less than 1% of the landscape. Old growth western redcedar, for example, occurs only in isolated stands adjacent to Swiftcurrent Creek and Nevin Creek, and on the lower slopes southwest of Shere. The extent of western hemlock old growth is equally limited, consisting mostly of a patch lying on the cool, east-facing lower slopes of the Trench southwest of Shere. Douglas-fir old growth is limited to a few small patches located on dry lower slopes in the trench on either side of Kiwa Creek. As the past and planned logging map shows, many of these remaining old growth stands have been selectively logged or high-graded during the 1950s and 1960s.

The most notable feature about the Horsey Creek Landscape, however, is the fact that nearly all old growth forest has been eliminated from the floodplains, terraces, and lower slopes on either side of the Fraser River, and from the most productive valley bottom sites in the Horsey, Small, and Kiwa Creek watersheds. Allowing the forests in the trench to recover old forest characteristics naturally, developing silvicultural plans that facilitate recovery of old forest characteristics where possible, and preparing land use plans that restore connectivity among remaining old forest stands should be a priority in the trench portion of the Horsey Creek landscape. Protecting and restoring forests on private lands can play an important role in this process. Developing and implementing long-term silvicultural plans that will allow forests in tributary watersheds to recover old forest characteristics is equally important.

Description		**Area (ha)**		**Percent of Total**
Non-Forested, Non-Productive, and New Forest				
Rivers, Lakes, Alpine, Alpine Forest, Settlement		89,314.0		60.12%
Young Forest		33,084.0		22.28%
Total Non Forest and Young Forest		122,398.0		82.40%
Old Growth Forests	**Stable Terrain**		**Sensitive Terrain**	
	Area (ha)	**Percent of Total**	**Area (ha)**	**Percent of Total**
Douglas-fir	172.6	0.12%	168.1	0.11%
Engelmann Spruce	2512.3	1.69%	6059.1	4.08%
Subalpine Fir	1363.8	0.92%	8434.7	5.68%
Hemlock	228.1	0.15%	41.5	0.03%
Cedar	148.5	0.10%	27.2	0.02%
Other Old Forest	687.0	0.46%%	6307.6	4.25%
Total	5,112.1	3.44%	21,038.2	14.16%

Table 8. Summary of old growth distribution in the Horsey Creek Landscape

Map 4. Insert map of Old growth forests in the Horsey Creek Landscape

Present Landscape Uses

Current human use in the Horsey Creek Landscape includes continued settlement and agriculture on private lands located on the Fraser River floodplain terraces, a small amount of logging in the Small and Horsey Creek watershed, grazing in the Kiwa, Small, and Horsey Creek watersheds, and backcountry recreational activities in portions of all tributary watersheds (see Map 5 on the following page).

Settlement in the trench remains sparse, but the amount of land cleared for development and agriculture has increased in recent years. Local residents and communities rely on surface wells and water drawn from numerous local streams for domestic and agricultural water supplies. These withdrawals for the most part are not sufficient to have a substantial effect on hydrology and stream function. Restoration of riparian forests and streamside vegetation that have been impacted by past development and recent clearing will help to protect water quality, stabilize stream banks, and regulate water flow. Forests regenerating on unused private lands are beginning to recover structural characteristics such as large mature trees, snags, and downed logs that provide habitat for old forest dependent species. Developing a land use plan that protects and develops connectivity between remaining old growth forests, recovering forests, and riparian forests located on private land would help to restore natural landscape conditions in the trench.

Grazing and recreational use of tributary watersheds is ongoing. Grazing leases are used in Kiwa, Small, and Horsey Creek watersheds; cattle generally forage on grasses growing in open stands directly beside access roads. Logging roads, de-activated logging roads, or maintained hiking trails provide four-wheel drive, recreational vehicle, and backcountry access to all tributary watersheds, which are used for hiking, backpacking, fishing, mountain biking, and back country skiing. A limited amount of clearcut and experimental selective logging is planned in the Horsey Creek headwaters and in the middle portion of Small Creek, but this will not likely have a significant impact on overall landscape function. Restoring forests that have been previously logged, establishing corridors that provide connectivity across the landscape and among remaining old forests, and developing forest use plans that protect and maintain opportunities for other forest uses such as recreation and non-timber forest products harvesting are the priorities in these tributary watersheds.

Map 5 Insert map of community uses

HORSEY CREEK LANDSCAPE ECOSYSTEM-BASED ANALYSIS

A precautionary, ecosystem-based approach to landscape and forest use seeks to identify where and when a variety of human activities can occur that do not have negative impacts similar to those caused in the past. The first step in this process assessed the ecological characteristics and sensitivities of the Horsey Creek Landscape. This involved combining background information, fieldwork, and GIS analysis to produce a description of landscape characteristics, and to prepare maps describing ecological sensitivity to disturbance and landbase netdowns. This analysis revealed a substantial portion of the Horsey Creek Landscape is sensitive to disturbance. Alpine tundra and alpine forests occur on nearly 47% of the landscape, and steep, complex terrain limits human use of another 22%. Lakes, rivers, streams, wetlands, and riparian ecosystem occupy another 7%, leaving only about 24% of the Horsey Creek Landscape potentially available for development.

The second step in this process assessed how previous development activities have impacted landscape condition. Review of historical development indicated early mineral exploration, railway and road construction, settlement, and logging had a profound impact on the ecological condition of the trench. Ecosystems on the floodplain and adjacent terraces and slopes are slowly recovering from forest clearing and fire disturbances that occurred in the early part of the century. Analyzing the extent of clearcut logging and road construction in more recent years indicates these activities have had an equal impact on the condition of ecosystems located in tributary watersheds. A considerable portion of the lower elevation riparian and old growth forests have been eliminated in the Kiwa, Small, and Horsey Creek headwaters, and roads have been built through some of the remaining productive forest land.

The third step in the ecosystem-based analysis process involves designing a protected landscape network that provides an ecological framework that protects and maintains ecological functioning in the Horsey Creek Landscape. The purpose of the protected landscape network is to maintain landscape connectivity, to provide pathways for wildlife movement and migration, to protect old growth patches, rare ecosystems, and important wildlife habitat, and to reestablish a natural distribution of forest age classes across the landscape.

Horsey Creek Landscape Protected Landscape Network

Undisturbed forest landscapes contain a spatially diverse and temporally variable mosaic of ecosystems and habitats. The spatial pattern of the ecosystems and habitats, and the changes that occur in that pattern over time, are the product of successional processes and natural disturbances interacting within the context of local climate and topography. These interactions result in naturally variable flows of water, energy, and nutrients, a diverse variety of ecosystems types and plant communities, and a wide range of habitats for birds, wildlife, fish, and other living organisms. Ecological diversity and natural variability are the basis of healthy landscapes.

Conventional timber management and other development activities typically impose disturbances and create landscape patterns that differ considerably from those that would occur naturally. Intensive timber management, for example, effects the functioning of forest ecosystems at landscape scales because it:

- changes the composition and age-class distribution of forest stands
- disrupts animal movement and plant dispersion pathways
- fragments important habitat and ecological patterns, and
- alters the pattern, timing, and intensity of water and stream flows.

Scientists now recognize the need to establish a protected network of ecosystems within natural and disturbed landscapes. The purpose of the network is to maintain and where necessary restore important landscape patterns and the processes that sustain the ecological functioning of the landscape. A protected landscape network accomplishes this goal by:

- protecting ecologically sensitive sites
- protecting important "biodiversity hotspots" such as wetlands, riparian ecosystems, and old forests
- protecting unique habitat types
- maintaining large, undisturbed patches of habitat for endangered wildlife
- recruiting old growth forests throughout the landscape, and
- providing pathways for animal movement and plant dispersion[16]

The protected landscape network maintains these components as a relatively permanent mosaic of ecological reserves. These reserves can only be used for non-extractive activities such hiking, and wildlife viewing, and for carefully planned "light impact" extractive activities such as botanical forest products harvesting where appropriate.

A protected landscape network is designed to be a permanent feature in terms of human time frames. The boundaries of the protected landscape network can be shifted to other locations over long time periods (250+ years), or it may be necessary to relocate boundaries after a shorter time if natural disturbance has affected ecosystems within a portion of the network. These boundary shifts should only occur, however, if the forest stands in the new location have developed structural attributes similar to the component that has been disturbed. Protected network

[16] For a more thorough discussion see Appendix V – Important Criteria and Parameters of Wildlife Movement Corridors

boundaries that encompass an old growth patch, for example, can be moved to a different location as long as the patch of forest within the new boundary has acquired the structure and composition characteristic of old growth forests in the area.

Protected network design is a combination of science and common sense. The selection and location of specific components of a protected landscape network are greatly influenced by local ecology, topography, and geography. All ecologically sensitive terrain and riparian ecosystems are by default part of the protected landscape network—they have sensitive biophysical or ecological characteristics that cannot be overcome. These ecosystems are off limits to all activities but those that have a very light impact.

The network of connecting corridors and small protected areas that are added to the sensitive areas are designed using air photo interpretation, GIS analysis, and knowledge of landscape ecology and habitat requirements. Corridors and small protected areas are not specifically designed to mimic large animal travel and migration routes. However, wherever possible they are designed to:

- avoid topographic features that are a barrier to wildlife movement
- protect known wildlife habitat
- protect rare and old growth forests
- recruit old growth forests in areas that have been extensively disturbed, and
- link undisturbed areas and reserves within the landscape.

Further study or local knowledge may indicate that some corridors and small protected areas should be shifted from their proposed location to take advantage of easier wildlife travel routes or to protect areas which have greater habitat value. This is not unexpected, and is part of the process of improving this initial analysis to meet final requirements for the community.

Horsey Creek Landscape Connecting Corridor and Protected Area Considerations

Identifying potential corridor and protected reserve locations in the Horsey Creek Landscape posed some unusual challenges. The vertical rock walls and complex terrain that surround most of the tributary watersheds, for example, effectively bar animal movement, leaving only a few small passes that provide viable pathways between adjacent drainages. The Fraser River—about 200 meters wide throughout most of the study area—also limits wildlife migration between east and west portions of the landscape. Steep, complex terrain also limits migration and dispersal between several of the tributary watersheds and nearby undisturbed areas in the surrounding region.

A second difficulty arises because there are currently no ecological reserves within the Horsey Creek Landscape. Mount Robson and Wells Gray provincial parks lie east and west of the Horsey Creek Landscape respectively, however, no reserves have been established within the landscape itself. Protecting ecosystem types and habitats large enough to support the plant communities and resident populations of wildlife that live within each landscape is a basic starting point for maintaining ecological function at larger scales. Lack of any smaller protected areas in the Horsey Creek Landscape highlights the need for an effective protected landscape network that achieves this goal.

Lack of comprehensive information about the location and distribution of rare ecosystem types and endangered wildlife habitats also limits effective protected landscape network design. Little is known, for example, about the specific location of rare plant communities and plants, or about the distribution and extent of habitat for rare or endangered wildlife. Silva identified a few rare forest stands during the analysis of old growth forests, but field inventories describing the location and distribution of rare plant communities, endangered plants, and the distribution of habitat and migration routes for endangered species are necessary to develop a landscape network that fully protects and maintains the full range of ecological functioning and forest resource values.

Horsey Creek Landscape Protected Landscape Network Overview

A proposed protected landscape network for the Horsey Creek Landscape is shown in the map on page 41, and the amount of area encompassed by different components of the network is summarized in Table 9 and Figure 22. Ecologically sensitive terrain occurs on approximately 25% of the landscape, and all forests within these areas—young, mature, old growth, and alpine—are reserved from timber management and other intrusive uses. Cold climate, steep complex terrain, and poorly-developed soils limit human use of these ecosystems.

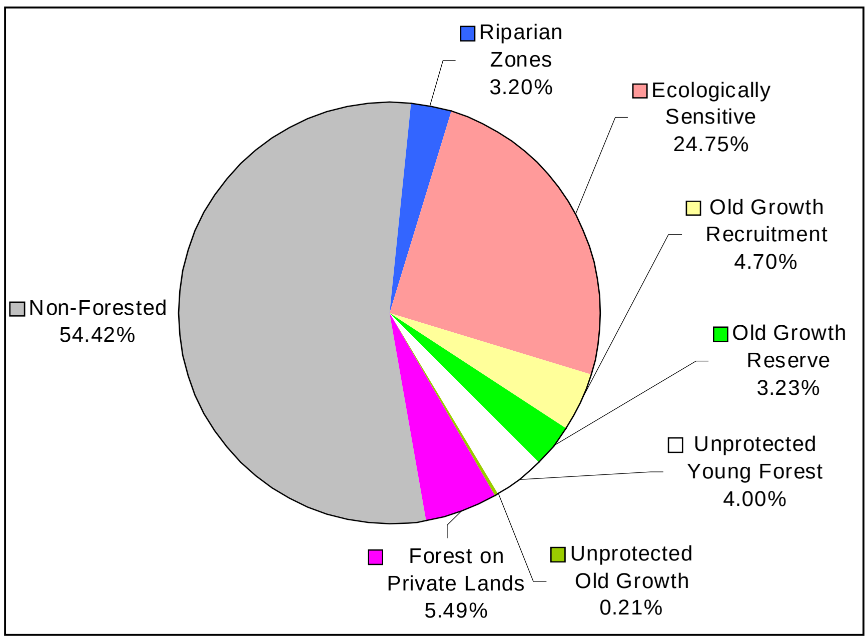

Figure 22. Summary of areas within landbase netdown and protected landscape network

Riparian ecosystems and wetlands occupy another 3.2% of the landscape. These ecosystems are also protected from development because they contain rich, diverse habitat, provide important migration corridors for wildlife, and play a critical role in regulating the timing and frequency of water flows into streams and wetlands.

Map 6. Proposed protected landscape network for the Horsey Creek Landscape

Another 11,700 hectares, or approximately 7.9% of the landscape is protected within a system of conservation corridors, old growth reserves, and old growth recruitment reserves. This system of reserves is designed to maintain landscape connectivity and to protect wildlife migration routes, wildlife habitat, and remaining old growth forests located on stable and moderately stable terrain. The old growth recruitment reserves are necessary to restore a relatively natural distribution of mature and old forest in areas that have been recently logged or extensively burned by fire.

Description	Area (ha)	Percent of Total
Non Forest and Non Commercial Forest Cover		
Rivers, Lakes, and Wetlands	1,413.4	0.95%
Alpine and Rock	67,687.2	45.57%
Alpine Forest	4,109.1	2.77%
Settlement Clearing	4677.6	3.15%
Non-productive Brush and Deciduous	2953.3	1.99%
Subtotal:	80,840.6	54.42%
Protected Landscape Network		
Riparian Ecosystems	4753.9	3.20%
Ecologically Sensitive	36761.0	24.75%
Old Growth Reserves	4797.9	3.23%
Old Growth Recruitment Area	6988.8	4.70%
Subtotal:	53,301.6	35.88%
Unprotected Forest Land		
Young Forest on Stable and M. Stable Terrain	5938.1	4.00%
Old Growth on Stable and M. Stable Terrain	318.2	0.21%
Forested Private Land	8149.8	5.49%%
Subtotal:	14,406.1	9.70%
Total:	148,556.3	100%

Table 9. Summary of areas within landbase netdown and the protected landscape network

Descriptions and rationales for each of the corridors, old growth reserves, old growth recruitment reserves, and rare ecosystems and wildlife habitats that form the final components of the protected landscape network are described below.

Corridor and Small Protected Area Descriptions

The Horsey Creek protected landscape network is designed to protect and maintain landscape function by including six key ecological components in the design process:

1. connections among the Horsey Creek and other existing and proposed parks and reserves in the surrounding region
2. ecological connections and wildlife movement corridors within the Horsey Creek landscape
3. remaining old growth forests that occur on stable and moderately stable terrain

4. areas of young forest that will be managed to restore old growth composition and structure
5. rare ecosystems and biodiversity hotspots, and
6. habitat for rare, endangered, and "at risk" species.

The following sections describe how each of the corridors and small protected areas within the proposed protected landscape network have been selected to achieve this design objective.

1. Regional Connectivity

The two major protected areas in the region encompassing the Horsey Creek Landscape are Robson Provincial Park to the east, and Wells Grey Provincial Park to the southwest. The proposed landscape network establishes connectivity between these existing protected areas and the Horsey Creek landscape in the following ways:

- *Raush River connecting corridors* link the Horsey Creek Protected Landscape Network to the Raush River watershed which lies next to Wells Grey Park. The northern corridor connects the lower portions of Holliday Creek and riparian forests of the Fraser River floodplain north of Dunster with the lower Raush River watershed. This corridor travels through alpine in a relatively low bench near the top of Collet Creek. The second corridor connects the west arm of Kiwa Creek with the main stem of the Raush River through a low pass above the Kiwa Creek headwaters. The proposed protected landscape network within the Raush River watershed provides connectivity to Wells Grey Provincial Park.

- *Swiftcurrent Creek reserve* includes the entire Swiftcurrent Creek watershed that lies west and south of Mount Robson Provincial Park. The purpose of the reserve is to provide an ecologically-based boundary to Robson Provincial Park—the current park boundary bisects Swiftcurrent Creek watershed in two places because it follows administrative jurisdictions rather than natural features. The proposed Swiftcurrent Creek reserve also provides connectivity with the Small Creek watershed through a small corridor that winds through a low elevation forested pass located above the Swiftcurrent Creek headwaters.

2. Landscape Corridors and Connections

Connectivity within the Horsey Creek landscape is provided by riparian and cross-valley corridors. There are relatively few options for cross-valley corridors within the Horsey Creek Landscape due to steep terrain, year-round ice and snow cover in the alpine, and the developed condition of the Fraser River terraces and floodplain. The following landscape connections are designed to take advantage of topography, land owership, and ecological features that do allow movement across the landscape.

- *Small Creek* riparian corridor provides connectivity between the Kiwa Creek, Small Creek, and Holmes River watersheds. The corridor connects to the Holmes River through two moderately sloped alpine passes that lie above the Small Creek headwaters. At lower elevations the corridor travels primarily through undisturbed riparian forests on either side of Small Creek to the confluence of Small Creek and the Fraser River. The corridor crosses a relatively narrow and shallow reach of the Fraser River to connect with riparian forests in the estuary of Kiwa Creek.

- *Horsey Creek* riparian and cross-valley corridor provides connectivity between the Kiwa Creek, Horsey Creek, Holmes River watersheds. The corridor connects ecosystems within the Horsey Creek watershed to the Holmes River watershed to the north through two relatively moderate alpine passes. Steep, complex alpine terrain prevents movement between the two watersheds elsewhere. The corridor also encompasses remaining riparian old growth adjacent to the Horsey Creek headwaters. Lower portions of the corridor travel through relatively moderate, forested benches located north of Horsey Creek. The corridor then winds down through riparian forests on the floodplain, crosses a relatively narrow reach of the Fraser, and connects to Kiwa Creek through a moderately sloped bench above Highland Creek.

- *Holliday Creek* riparian corridor provides connectivity between Holliday Creek and Horsey Creek watersheds through a narrow but moderately sloped alpine pass separating the headwaters. In upper portions of the watershed the corridor encompasses old growth sub-alpine fir forests on either side of headwater streams. The corridor winds down through younger riparian forests containing Douglas-fir, black cottonwood, and alder in the Holliday Creek estuary to a relatively narrow crossing of the Fraser River.

- *Kiwa Creek* riparian corridors encompass riparian ecosystems and forest stands adjacent to the east and west arms of Kiwa Creek. The corridor following east Kiwa Creek provides connectivity by protecting an important wildlife migration route between wildlife habitat in the trench and in the Kiwa Creek headwaters. The corridor following west Kiwa Creek protects remaining Englemann spruce and sub-alpine fir old growth stands, wildlife habitat, and wildlife migration routes on north facing slopes next to Kiwa Creek.

- *Horsey Creek to Small Creek* cross-valley corridor provides connectivity between Small Creek and Horsey Creek watersheds through two moderately sloped alpine passes. The glaciers and the steep and complex topography that separates these two watersheds limits cross-valley wildlife movement in other locations.

- *Kiwa Creek to Tete Creek* cross-valley corridor travels southeast from Kiwa Creek towards Tete Creek along stable terrain. The corridor encompasses a small patch of old growth forest and two small wetlands, and provides connectivity between Kiwa Creek and Tete Creek, and between the Horsey Creek Landscape and other portions of the trench southeast of the project area.

3. Old Growth Reserves

Past development and recent logging has eliminated most of the old growth forests on stable and moderately stable terrain in the Horsey Creek Landscape. Remaining old growth on stable and moderately stable terrain consists of relatively small patches that have become isolated by logging, settlement clearing, and human-caused fires. The following old growth reserves are included in the protected landscape network to maintain what is left of the natural distribution of stand age classes across the landscape:

- *Nevin Creek* – a small, remnant patch of old growth Englemann spruce located on stable terrain is protected the northwest side of Nevin Creek. A corridor winding through younger stands connects this old growth patch to riparian ecosystems on the Fraser River floodplain.

- *Horsey Creek and Small Creek* – several patches of old growth sub-alpine fir and Englemann spruce are protected on stable slopes in the middle portion of the Horsey Creek and Small Creek watersheds. Additional reserves protect several more patches of old growth Englemann spruce that are located on stable and moderately stable terrain surrounding the Horsey Creek and Small Creek headwater streams.

- *Kiwa Creek* – several patches of old growth sub-alpine fir and Englemann spruce on stable terrain are located on moderately stable terrain in the valley bottoms of the east and west arms of Kiwa Creek. These old growth stands provide connectivity between riparian forests surrounding Kiwa Creek and upland old growth forests located on steeper slopes and complex terrain.

- *Titan Creek* – a large reserve encompasses a patch of old growth Englemann spruce, western redcedar, western hemlock, and sub-alpine fir located on the south side of the Fraser River southwest of Shere. This is one of the few remaining stands of old growth western hemlock and western redcedar that occurs on stable terrain, and it provides important winter habitat for mule deer, moose, and blacktail deer.

- *Shere* — a small patch of old growth Douglas fir lies northwest of Shere on lower slopes of the trench. This small stand of old growth forest is partially included in the corridor that connects lower Kiwa Creek with the Horsey Creek corridor.

4. Old Growth Recruitment Areas

Restoring a natural distribution of stand age classes within the Horsey Creek Landscape will involve recruiting old growth compositional and structural characteristics within existing younger forest stands. Two general areas are proposed as old growth recruitment reserves in the protected landscape network:

- *Fraser River Trench* – the trench historically contained extensive areas of old growth Douglas-fir, subalpine fir, Engelmann spruce, western hemlock, and western redcedar surrounding patches of younger lodgepole pine and Douglas-fir. Old forests on stable and moderately stable terrain in the trench are now almost non-existent because of fires associated with railway construction, mineral exploration, and settlement in the early 1900s. Several areas of these young forests that occupy stable and moderately stable terrain adjacent to cross valley corridors and old growth reserves have been incorporated within the protected landscape network. These areas contain important grizzly bear, mountain goat, moose, elk, and deer habitat.

- *Headwater Forests* – the younger forests that now occupy extensive portions of Small Creek, Horsey Creek, and Kiwa Creek headwaters are the result of recent logging. Maintaining forests with mature and old growth characteristics in these headwater forests is essential for maintaining important wildlife habitat and naturally variable water flows and the ecology of aquatic habitats located downstream. Old growth recruitment reserves have been designated for these headwater forests to ensure that sufficient mature and old forests are developed.

5. Rare Ecosystems and Biodiversity Hotspots

In addition to the rare old growth forests on stable terrain discussed above, the rare ecosystems and biodiversity hotspots within the proposed protected landscape network include:

- *Riparian Zones* – riparian ecosystems in the Horsey Creek Landscape are located in valley bottom areas, near lakes, or in forested areas that contain wetlands. Due to the steep terrain over much of the landscape, movement corridors frequently follow proposed riparian ecosystem protection zones—for example, Holliday Creek, Horsey Creek, Small Creek, and both arms of Kiwa Creek. These corridors protect wildlife movement corridors, and also serve to protect the riparian zone and the riparian zones of influence adjacent to all streams within the landscape.

- *Wetlands* – the majority of the wetlands in the Horsey Creek Landscape occur within private land located on benches and floodplains next to the Fraser River. Wetlands contained within the proposed protected landscape network on Crown forested land include:

– *Tete Creek Corridor* – this corridor connects the Kiwa corridor to the west with Tete Creek to the east through a series of small wetlands located on lower slope of the Trench.

– *Shere Wetlands* – the small wetland southwest of Shere consists of a black spruce bog. This wetland is a rare and sensitive landscape feature, and provides a natural movement corridor to riparian ecosystems adjacent to the Fraser River.

6. Habitat for Rare and Endangered Species

The plant and animal species that are threatened or at risk and the rare plant communities that may occur within the Horsey Creek Landscape are described in the section on biodiversity. The field studies necessary to identify habitat for rare, threatened, or at risk species and plant communities were beyond the scope of this project. The proposed protected landscape network is designed with the intention of providing a general measure of protection for many of these species and communities by maintaining wildlife movement corridors, old growth forests, and rare ecosystems within the landscape. Further work is required to identify the specific locations and habitat requirements of rare, threatened and endangered species. As the location and distribution of rare plants and plant communities and wildlife habitats are identified, additional reserves can be included in the protected landscape network and species specific management objectives can be prepared.

Potential Timber Management

The final step in ecosystem-base landscape analysis involves identifying where and when a variety of ecologically responsible forest use activities can occur in areas that lie in between the components of the protected landscape network. Some non-intrusive human activities may also be appropriate in ecologically sensitive areas and other areas within the protected landscape network, but detailed site assessment must be carried out beforehand to ensure those activities will have little or no impact on site ecology. Hiking trails, for example, built and used to ecologically responsible standards for recreation and tourism, may be designated in various portions of the protected landscape network. Responsible harvesting of botanical forest products may also occur, as long as harvesting is carried out in ways that ensure the protection and maintenance of ecosystem functioning. More aggressive activities such as ecologically responsible timber management, however, should only be planned to occur in stable and moderately stable areas located in between the components of the protected landscape network.

Forest use activities, whether timber cutting, commercial tourism, watershed protection, or botanical forest products harvesting, must be carried out to high standards. This simply means that any activity within the Horsey Creek Landscape must ensure the protection and maintenance of fully functioning ecosystems. Human use areas identify the priority use and the conditions under which other uses may be carried out within a particular areas. A watershed protection area, for example, may also include ecologically responsible timber extraction as long as detailed site assessments and operational planning are conducted to ensure logging will not compromise watershed integrity and water quality, quantity, and timing of flows.

Human use areas commonly identified in an ecosystem-base analysis include:

1. ***First Nations Cultural Areas*** **–** these zones are identified and planned for in consultation with individual First Nations groups.

2. ***Ecotourism Areas*** **–** the priority use for these areas is ecologically responsible activities such as wildlife viewing, bird watching, backpacking, kayaking and canoeing, guide-outfitting, and so on. Any proposed timber management or similar intrusive activities must respect the needs of tourism operators and local residents.

3. ***Wildcrafting Areas*** **–** harvesting edible plants, mushrooms, medicinal herbs, and other non-timber forest products is the priority in these areas. Care must be taken to set sustainable limits and to define responsible harvesting practices for extraction of these botanical forest products. Ecosystem-based partial timber cutting may be compatible with botanical harvesting in many areas.

4. ***Watershed Protection Areas*** **–** even the most carefully planned timber cutting can potentially impact water quality and the quantity and timing of streamflow by altering snowmelt patterns, landslides, surface erosion of road surfaces, and concentration of drainage patterns by roads and trails. Watershed protection zones are often established in the headwaters of streams that are used as sources of domestic, community, or agricultural water.

5. ***Ecosystem-based Timber Areas*** **–** timber cutting can occur in areas of stable or moderately stable terrain. Within stable and moderately stable terrain, logging systems are designed to maintain or restore the ecological integrity of the forests.

Planning necessary to identify and designate areas within the Horsey Creek Landscape for a diver range of forest uses is best carried out among local residents through community meetings and local consultation. Conducting community meetings and extensive consultation was beyond the scope of this analysis. This section of the report focuses on identifying areas within the Horsey Creek Landscape that are suitable for timber management. The areas are termed “potential” because timber management may in fact not be the most desired forest use. Local residents may consider that managing for water quality, wildlife habitat protection, visual esthetics, biodiversity, and non-timber forest products is more important than timber production. If logging is the desired forest use for potential timber management zones, then silvicultural planning and operational activities must strive to protect and maintain important ecological composition and structures at the stand scale.

Map 7 on the next page shows the location of potential timber management areas within the Horsey Creek Landscape, and the amount of forest land in each of these zones is summarized in Figure 23 and Table 10 on the following page. The potential timber management areas fall within two categories:

- restoration areas on stable and moderately stable terrain, and
- potential timber management zones.

Another category—restoration areas on ES terrain—represents forests on ecologically sensitive terrain that have been recently logged. Restoration ES areas will become part of the protected landscape network when natural composition and structure is restored.

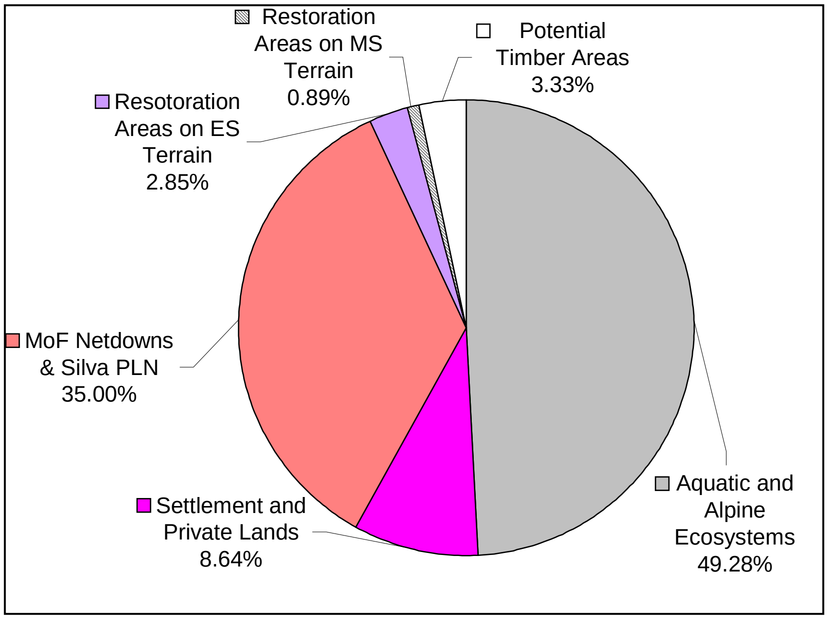

Figure 23. Summary of Potential Timber Zones

Description	Area (ha)	Percent of Total
Landbase Netdowns		
Water, Alpine, Alpine Forest	73,211.8	49.28%
Non-Productive	2,953.70	1.99%
Settlement and Private Lands	1,2840.5	8.64%
MoF Netdowns and Silva PLN	51,994.4	35.00%
Subtotal	138,046.6	92.93%
Forest Restoration Zones (ES)		
Restoration Areas on ES Terrain	4,236.9	2.85%
Potential Timber Management Zones		
Restoration Areas on S and MS Terrain	1,318.4	0.89%
Potential Timber Areas on S and MS Terrain	4,946.4	3.33%
Subtotal	6264.4	4.22%
Total	148548.29	100%

Table 10. Summary of Potential Timber Management Landbase

Map 7. Map of Potential Timber Management Areas

General management prescriptions for these three types of area are briefly described below.

1. ***Restoration Zones ES*** are ecologically sensitive areas that have been clearcut in the recent past. Management of these zones should focus on conducting site assessments to determine current stand conditions, and on developing long term restoration plans that seek to recruit natural composition and structure. In some cases this may involve simply leaving the stand alone. More aggressive strategies may be required in some sites to restore soil degradation and to facilitate the restoration of natural species composition and stand structure. These areas will become part of the protected landscape network as restoration proceeds.
2. ***Restoration Zones MS*** contain clearcuts or stands that have been high-graded on moderately stable and stable terrain. Existing clearcuts that occupy productive sites that can eventually be considered for partial cutting. Short and medium term planning should focus either on leaving these forests alone so they can recover natural characteristics, or on developing and implementing plans that will facilitate restoration of natural characteristics. The majority of "high-graded" stands were selection logged sometime during the period 1950 to 1960. The dominant, economically valuable trees were taken, and a substantial amount of natural forest composition and structure was removed. These zones are located on productive sites, and can be considered for partial cutting following site assessment and sufficient time to allow for restoration of natural composition and structure.
3. ***Potential Timber Management Zones*** are areas containing productive young, mature, and unprotected old growth forests located on stable and moderately stable slopes. Partial cutting can be carried out in these areas following the preparation of an ecologically responsible cutting rate for the Horsey Creek Landscape.

Protecting and Restoring Ecological Function in Timber Management Areas

Undisturbed forest, water, and stream ecosystems in the Horsey Creek Landscape, like the landscape they are in, have a diverse ecological composition and physical structure that reflect the interplay among successional and small-scale disturbance processes. The multi-layered canopies, large diameter stems, snags, large fallen trees, and small streams and wetlands that are found in mature and older natural forest stands, for example, support ecological functions not found in managed forests. Snags provide habitat for cavity nesting birds, bark crevice dwellers, and many other animal and invertebrate species that live in the Horsey Creek Landscape. The stable temperature and humidity and small hollows that occur in large fallen trees provide important habitat and refugia for many species of amphibians, invertebrates, fungi, and bacteria. Small ephemeral streams, ponds, and wetlands store, transport, and purify water, and the moist site conditions around these features provides habitat for plant and animal associations that are different from those elsewhere.

Ecologists have come to realize in the last two decades that maintaining natural composition and structural diversity in managed ecosystems is one of the foundations of ecologically responsible forest planning and management. Conventional timber

Figure 24. Differences between industrial logging and natural disturbance—clearcut logging eliminates many important ecological legacies such as large old trees, snags, fallen dead trees, and understory vegetation that remain on the site when small natural disturbances such as single tree death create canopy gaps. These structural legacies provide habitat and refugia for small birds, animals, invertebrates, fungi, and bacteria that contribute to overall forest function. The underside of large fallen trees, for example, provides habitat for mycorrhizal fungi which contribute to the productivity of regenerating forests by improving the nutrient uptake of young trees. A high percentage of these fungi disappear from the site when all trees are removed.

management and aggressive land development practices pay little attention to protecting and maintaining these stand-level attributes. Clearcut logging, for example, typically results in:

- loss of important structural legacies such as snags, large old trees, and fallen trees that contribute to overall landscape and ecosystem function
- altered hydrological function and streamflow regime by changing the timing and frequency of runoff, evapotranspiration, snow accumulation, and snow melt.
- reduced productivity because planting trees, rather than allowing for natural regeneration, may lead to reduced tree stability, vigor, and growth due to root deformities (Figure 25).[17]

[17] See Halter, M.R. and C.P. Chaway. 1993. *Growth and Root Morphology of Planted and Naturally-Regenerated Douglas fir and Lodgepole Pine.* Annals of Scientific Forestry 50: 71-77; Halter, M.R., C.P. Chanway, and G.J. Harper. 1993. *Growth Reduction and Root Deformation of Containerized Lodgepole Pine Saplings 11 Years After Planting.* Forest Ecology and Management 56: 131-146/

Road construction and rural land development practices often have a similar impact on local forests and streams because they can:

- eliminate connectivity among forest stands, disrupt important wildlife travel routes, and reduce the amount of habitat available for forest dependent species
- remove riparian trees and vegetation which act to regulate water flows into streams and to provide habitat for a variety of riparian forest dependent species at risk in the Robson Valley including fishers, American bitterns, yellow-bellied flycatchers
- channelize streams and alter streamflows to make way for bridges and right-of-ways, resulting in increased sedimentation, reduced channel stability, and loss of instream habitat.

Figure 25. Planted (left) versus natural (right) root systems in young seedlings. Recent research indicates that planted container stock suffer significantly reduced growth and increased root deformity 12 years or more after establishment.

Even seemingly necessary or benign activities such as forest fire suppression may have equally significant impacts because they can lead to:

- increased tree densities per hectare because understory trees and seedlings which would normally burn during low intensity ground-fires survive
- a shift in forest composition to shade-tolerant tree species
- increased tree mortality due to a higher incidence of pests, and
- slowed organic matter decomposition and nutrient cycling.

Ecologically responsible development seeks to avoid these negative impacts by protecting and restoring important ecosystem-level compositions and structures. Ecologically responsible timber management, for example, seeks to maintain or restore natural stand characteristics through the use of partial cutting methods. Those methods use a variety of logging prescriptions, setting designs, road layouts, and logging equipment to promote natural regeneration, to maintain forest tree cover, to protect important stand composition and structure, and to maintain natural tree densities in areas impacted by fire suppression activity (Figure 26). The overall goal is to design and implement forest management practices that provide a better balance between human use of the products and services that flow from forests, and the overriding need to protect and maintain the ecological compositions and structures that are the basis of those forests.

Figure 26. Selective skyline corridor logging in the Small Creek watershed. Efforts like these represent a significant step toward the use of logging practices that maintain important stand level forest composition and structures during harvesting. They also provide valuable experience with new logging equipment and silvicultural techniques, and present opportunities to monitor the ecological effects of innovative silvicultural systems

Ecologically responsible partial cutting differs from conventional selective logging silvicultural systems in three important respects:

1. **The stand-level prescription is designed within the context of a protected landscape network.**

   Conventional silvicultural prescription and logging setting design practices typically ignore landscape context. Timber cutting, as a result, often disrupts many important landscape connections and patterns, and creates unnaturally high levels of abrupt forest edge. Clearcut logging in the upper Kiwa, for example, has not protected wildlife travel routes, habitat patches, or stand composition within logged stands; nor do the block layouts and silvicultural prescriptions buffer the negative ecological effects caused by unnaturally abrupt forest boundaries. Those impacts include increased bird nest predation, altered wind vectors, and a reduced amount of interior forest in adjacent stands.

   A key goal of ecologically responsible timber management planning, in contrast, is to identify important connections and patterns that link logging cutblocks to the surrounding landscape, and to reserve those connections and patterns from cutting. Important connections include small streams, riparian ecosystems, and well-used wildlife trails that pass through logging block boundaries. Important patterns include small undisturbed patches of large old trees, patches of younger trees, and small swamps or fens that cross block boundaries.

2. **Full cycle trees are retained on the site in perpetuity.**

   Natural disturbances rarely eliminate all the trees and vegetation in a site. Fires, insects, and pathogens, for example, typically leave a legacy of small patches of large resistant trees, large standing single trees, and unharmed vegetation following disturbance. These undisturbed patches and trees provide habitat for wildlife and invertebrates, act as seed sources, and serve to protect soil communities from erosion while disturbed portions of the forest are recovering.

   Ecologically responsible silvicultural prescriptions seek to maintain a similar legacy of stand-level structure by reserving a percentage of the largest, healthiest trees currently on the site. These trees are the most valuable from an economic point of view, but they are also important ecologically. The exact number and distribution of full cycle stems reserved per hectare will vary with site characteristics and conditions, but typical prescriptions retain 20% of the co-dominant canopy as full-cycle trees. These trees are retained through the regeneration-growth-death-decay cycle to maintain large old trees, snags, and fallen trees on the site.

3. **Ecologically sensitive features identified within the stand during site assessment, timber cruising, and logging planning are reserved from logging and removed from the timber cutting landbase.**

   Industrial timber management practices typically treat logging cutblocks as uniform units. In the process they ignore many important small-scale ecological features including:

   - snags and fallen trees
   - small ecologically sensitive areas such as rock outcrops, ridges, depressions, ephemeral ponds, and ephemeral streams
   - rare or endangered plant associations, and
   - habitat structures for rare or endangered species.

   Conventional logging practices which ignore or eliminate these stand-level structures and features will negatively affect ecological functioning and site productivity over the short and long term.

   Ecologically responsible forestry, on the other hand seeks to protect, maintain, and where necessary restore these structures and features. Detailed site reconnaissance and mapping is used to identify the location and distribution of important structures and features that exist within previously undisturbed forest stands. Silvicultural prescriptions and setting designs are then developed to protect these features during timber harvesting and road layout. Appropriate silvicultural prescriptions and settings design are also used to restore natural structures and features within stands that have already been affected or degraded by previous logging activity.

IMPLEMENTATION

Implementation means putting ecosystem-based recommendations and plans into practice. This is typically much easier said than done when it comes to landscape, forest, and water planning and management. Powerful stakeholders and government ministries often have a vested interest in maintaining existing tenure arrangements, management practices, and financial opportunities. Lack of access to information and meaningful opportunities to participate in land use, operational forest management, and natural resource development planning add further difficulty for local communities and groups.

Fully implementing ecosystem-based landscape planning and ecologically responsible forest and water use in the Horsey Creek Landscape will require change in existing administrative arrangements, management practices, operational techniques, and economic strategies. Changes such as these take time, and are best achieved by focusing immediate efforts on short term plans and transition strategies that support a shift toward ecologically responsible landscape, forest, and water use. This means using available time and resources where they are most effective to protect, maintain, and where necessary restore the forest and water ecosystems in the Horsey Creek Landscape, and to develop a more balanced and equitable use of the benefits and services that flow from those ecosystems. Orienting these short term efforts around a few key objectives is central to achieving the longer term goal:

1. **Conduct presentations and hold community meetings to inform local residents and decision makers about ecosystem-based planning and the results of the Horsey Creek Landscape analysis.**

   Implementing ecosystem-based planning requires broad local support. A basic first step in implementing the results of this Horsey Creek Landscape analysis will simply involve "getting the word out" to local residents about ecosystem-based planning, and about the information and plans in this report. The principles and concepts underlying the Horsey Creek Landscape analysis are not new, but they are not yet incorporated in conventional resource management ideas and planning goals. Many local residents may be unfamiliar with ecosystem-based principles and practices, and so cannot evaluate the short, medium, and long term benefits that will result from implementing landscape and forest planning based on this approach. Organizing meetings with local community associations and groups and making presentations to a broader range of local residents is the best way to increase awareness of the analysis and the benefits that will flow from its implementation.

2. Using existing legal opportunities to promote ecologically-responsible, community-based, forest planning and management

Ecosystem-based landscape planning and forest use cannot ignore the jurisdictional lines and requirements set out in law. But pursuit of ecosystem-based landscape use by local groups and organizations can help to identify inadequacies in existing practices, regulations, and enforcement, can help to forestall ongoing irresponsible development, and can create opportunities for local groups and communities to participate in achieving ecologically responsible forest planning and balanced and sustainable use of the lands and waters near their homes.

Current planning laws and regulations do offer opportunities for local people and groups to advocate ecosystem-based planning and ecologically responsible development practices in the Horsey Creek Landscape. On public lands those opportunities include:

- seeking community forest agreement tenures to manage areas of the Horsey Creek Landscape as community forests
- applying for woodlot licences to manage forests adjacent to private lands in the Horsey Creek Landscape
- critically reviewing forest development plans being prepared by the MoF and timber licencees to ensure those plans are ecologically responsible
- contacting MoF and MoELP planning staff to provide local knowledge and critical input about non-timber resources, wildlife habitats, and rare plant species to interagency landscape unit planning teams, and
- working with local conservation groups such as the Fraser Headwaters Alliance to have areas with high ecological, social, or cultural values protected under the Heritage Conservation Act.

Current laws also provide a variety of opportunities for achieving ecosystem-based planning and development on private lands in the Horsey Creek Landscape. Those opportunities include:

- lobbying regional and municipal governments to pass zoning, subdivision, tree protection, and other environmental bylaws that promote ecologically responsible land development practices and use of private property

Ecosystem-based Planning and the Law

Major acts and regulations which apply to landscape planning and management include:

Federal

Fisheries Act
Migratory Birds Convention Act
Navigable Waters Act

Provincial

Forest Practices Code Act
Forest Land Reserve Act
Forest Act
Agricultural Land Reserve Act
Municipal Act
Growth Strategies Act
Land Titles Act
Health Act
Water Act
Soil Conservation Act
Wildlife Act
Fisheries Act
Highways Act
Heritage Conservation Act
Waste Management Act

Local Government

Official Community Plans
Development Permits
Subdivision bylaws
Tree Protection Bylaws
Environmental Bylaws

- encouraging local land owners to protect and restore old forest patches, wetlands, and riparian forests through land ownership alternatives such as stewardship agreements, conservation covenants, and easements.[18]

3. **Encouraging local foresters, loggers, land owners, and developers to adopt ecologically responsible forest management and land development practices.**

Resistance to ecologically responsible landscape planning, timber management, and land development is often due to the perception that such practices are more expensive than conventional practices, or due to the perception that economic opportunities are being lost because lower volumes of timber are being cut. The first view overlooks the fact that higher timber management costs are more often due to lack of knowledge, experience, and appropriate equipment than to real additional costs. The second view ignores the fact that economic opportunities are always changing. Higher timber management costs can be offset, new economic opportunities can be produced, and community well-being can be sustained by creating learning opportunities for workers, and by pursuing strategies that promote operational and market flexibility. These attributes can be developed in a variety of ways, including:

- <u>diversifying logging techniques</u>. Conventional forestry limits the knowledge and skills of local foresters, loggers, and silvicultural workers. Laying out block boundaries, filling out clearcut silvicultural prescriptions, logging all of the trees in a stand, and planting uniform rows of container-stock seedlings are not challenging tasks. Conventional forestry also limits licencees and logging contractors to a very simple product line of uniform sized conifer logs, delivered in large volumes when artificially regenerated, planted stands mature.

  Use of partial cutting methods and skyline, small skidder, and horse logging systems is not new to the Fraser Headwaters area, but the skills have been lost for the most part. So too have the knowledge and ability to selectively log forest stands to take advantage of market swings. In the past those skills were directed toward high-grading valuable timber. However, they can be re-oriented toward selection logging that improves overall stand quality and value, maintains critical stand composition and structure, and takes advantage of market swings and log niche markets. Intermediate silvicultural treatments such as commercial thinning and pre-poling coupled with long-term silvicultural planning, for example, can help to restore natural stand composition and structure to previously disturbed forests, and to improve wood quality and the overall value of the timber that remains after selection

[18] For further information on stewardship agreements, conservation covenants and easements see *Stewardship Options for Private Landowners in British Columbia* and *Community Greenways: Linking Communities to Country, and People to Nature*. Both are available from the Habitat Conservation Fund, Victoria, BC.

logging. Investment in these activities can also help to maintain a viable and knowledgeable forestry workforce through time.

- diversifying log sales and local manufacturing capacity. The most successful value-added operations are those that utilize wood that nobody else wants and that make products that are in high demand. This observation is particularly timely in light of the fact that managing second growth timber and manufacturing wood products from second growth forests is the future in BC. Small-scale logging, wood processing, kiln drying, value-added specialty construction, small-wood furniture making, and craft production technologies are well established and profitable in other areas of B.C., and in other jurisdictions outside of B.C. Coupling a more flexible and diversified local manufacturing capacity with long term silvicultural planning and intermediate timber cutting operations such as commercial thinning in the Horsey Creek Landscape can help to reduce current economic and workforce dependencies on large timber volumes.

- acquiring certification for logging, timber management, and manufacturing operations. Certified wood and wood products buyers are often reluctant to quote price premiums; however, demand for eco-certified products currently is high, and price premiums of 5% - 20% over conventional log and wood product markets can be realized by those who are able to enter the market early. This is where long term planning, ecologically-responsible silvicultural operations, and efforts to coordinate timber management operations with the needs of local specialty product manufacturers has great potential to help operators offset short-term higher costs.

  The time and costs of acquiring certification vary among applicants depending on such factors as the complexity of the operation, the number of other evaluations being performed, and the speed with which applicants fulfill their obligations. The procedures developed by the Silva Forest Foundation for certification are expected in most cases to require no less than 6 months but not more than 1 year to be completed. A summary overview of the Silva Forest Foundation's certification program is included in Appendix IV.

4. Promote, support, and invest in local botanical forest products businesses

The non-timber forest products industries are among the fastest growing sectors of the BC economy, and considerable attention is focusing on developing their associated production technologies and markets. Non-timber forest products include: wild food, nutraceuticals (health enhancing wild plants and plant by-products), and medicinal mushrooms and fungi; pharmaceuticals and nutraceuticals from plants, bark, lichens, insects, soil organisms, and wood waste; biocides (non-toxic insecticides) from the same sources; anti-phytovirals (medicines *for* plants); and floral greenery.

A recent report funded by Forest Renewal BC indicates that the non-timber forest product industries in BC:

- employed almost 32,000 people on a seasonal or full-time basis during l997
- produced direct corporate revenues of approximately $280m and provincial revenues in excess of $630m in 1997, and
- grew at a rate of l0%-12% for some of the wild food mushrooms industries, to in excess of 30% for nutraceutical products.[19]

The report also assessed the market value of one non-timber forest product—pine mushrooms—versus the market value of commercial timber in one area of BC, the Nahatlatch watershed, and found that over a 120 year cycle the value of the pine mushrooms alone was equal to about l7% of the market value of the timber. The report estimated that introducing agroforestry technologies used in Asia to enhance natural mushroom production would increase the value of the pine mushroom harvest to roughly twice that of timber cutting over the same period.

Promoting local and regional economic strategies that support the emergence and development of new businesses which rely on ingredients in (generally ignored) understory trees, herbs, and shrubs, lichens, insects, bark, soil organisms, fungi and other flora and fauna will focus attention on the impact that conventional timber management and land development practices have on other potentially significant economic opportunities. Assessing, developing, and taking advantage of those opportunities will serve to reduce workforce reliance and other economic pressures that motivate people to continue degrading remaining forests, provided non-timber forest products are extracted at ecologically sustainable levels, and in ecologically sustainable ways.

5. Promoting and developing local ecotourism ventures.

Ecotourism is the most rapidly growing component of BC's tourism industry. "Ecotourists" are interested in undisturbed nature, wildlife, traditional cultures, archaeology, and conservation. Approximately l3,000 people were directly employed in BC's ecotourism industry in l997 with estimated direct revenues of $l65m. When half of the revenues generated by provincial parks and amounts spent on outdoor accommodation are included, ecotourism is responsible for generating around $522m in annual provincial income in l997. Ecotourism, the least intrusive use of forested landscapes and river systems, has more potential than traditional resource-dependent development activities to bring significant revenues into shrinking local economies.

[19] Wills, R and R.G. Lipsey. 1998. *An Economic Strategy to Develop Non-Timber Forest Products and Services in British Columbia*. Forest Renewal BC Project No. A97538-ORE, draft working paper. Bowen Island, BC: Cognetics International Research Inc.

Promoting local strategies which support the emergence and development of non-extractive ecotourism businesses and low impact recreational activities such as guideoutfitting, wildlife viewing, backpacking, canoeing, kayaking, and camping is another way of reducing dependence on unsustainable forest uses. Assessing the economic value of these activities is also another way of focusing attention on the impact that conventional development practices have on other, more ecologically benign and sustainable economic activities.

6. Encourage local foresters, loggers, land owners, and other decision makers to adopt full cost assessment practices

Conventional economic analyses and impact assessments typically understate the costs associated with land, forest, and water development. Logging licencees, for example, are not required to consider the possible costs associated with damaged fisheries and wildlife habitat, impaired water quality, and lost tourism opportunities when they are preparing five-year forest development plans. The socioeconomic and multiple accounts analyses prepared by government agencies suffer from similar biases because they focus attention on the short term financial revenues and employment opportunities that will be negatively affected by proposed and actual land use changes, rather than on the long term cultural and ecological consequences of continuing to degrade landscape integrity.

Conventional analyses also often fail to adequately account for the benefits that flow from ecologically responsible development over the short, medium, and long term. Real benefits accrue almost immediately in forestry, for example, due to the reduced need for investment in planting, brushing, and spacing. Financial resources previously spent on those activities can be used to promote of more ecologically sustainable activities, and to develop improved silvicultural knowledge and operational skills among local forestry workers. Further benefits are realized over the medium term because ecologically responsible forestry practices eliminate, or at least greatly mitigate, the need for future expenditures on watershed, forest, stream, and wildlife or fish habitat restoration. Finally, long term benefits are realized by the protection and maintenance of the full range of products and services that flow from healthy landscapes and ecosystems, including high quality timber.

Economic analyses and planning assessments which ignore ecological and social costs and which do not fully appreciate short, medium and long term benefits of ecologically sustainable forest and water use, bias decision making in favor of conventional natural resource management and development practices. Local residents and community groups can help to promote a more balanced perspective by critically reviewing industry and government planning documents and reports to ensure that all possible damages and costs, and any benefits that will accrue as a result of proposed changes, are accounted for. Possible damages and costs include lost wildlife and fisheries habitat, reduced amount of non-timber forest product, backcountry recreation, and tourism opportunities, impaired water quality, and so on. Possible benefits include an improved local knowledge base, greater economic diversity and flexibility, opportunities to develop local botanical forest products and ecotourism industries, and reduced need to invest in forest regeneration and restoration of lands and waters damaged by inappropriate timber management.

7. Establish models of ecosystem-based forestry on private and Crown lands in the Horsey Creek Landscape

Achieving ecosystem-based forestry at the landscape scale may ultimately depend on the development and implementation of smaller scale models that demonstrate the benefits of ecologically responsible approaches at the stand level. Current tenure arrangements limit access to Crown land, but do not prevent local groups, communities, and operators from undertaking ecosystem-based forestry initiatives on local woodlots and on private lands. Such initiatives can help to develop and improve local planning, field inventory and analysis, and operational skills, and to produce more detailed knowledge regarding the costs and benefits of ecologically responsible forest use. This ecosystem-based landscape analysis provides the basis for identifying potential timber management areas in the Horsey Creek Landscape, and for identifying where additional field information is required before planning can proceed. Local residents should seek out and develop co-operative management arrangements with local First Nations, private landholders, and current woodlot owners to acquire necessary information, and to develop and implement small-scale examples of ecosystem-based planning and ecologically-responsible forestry on available lands.

MONITORING, EVALUATION, AND LEARNING

Monitoring means systematically collecting information about the changes that are occurring in landscapes and ecosystems over time as a result of natural processes or human activities. **Evaluation** means conducting practical, thorough analysis of that information to assess the causes of those changes and to determine how effective ecosystem-based plans are in protecting and maintaining landscape or ecosystem functioning and in sustaining the health of local households and communities. **Learning** means making the results of those analyses available to decision makers, resource users, and local communities and groups so that all stakeholders are able to participate in revising and improving future ecosystem-based plans.

Reliable data collection, rigorous analysis of monitoring data, and practical presentation and use of the resulting knowledge are the foundation of sustainable landscape, forest, and water use. Unfortunately these aspects of the planning and management process are typically ignored by conventional approaches to "natural resource" planning and management. Federal and provincial agencies charged with planning and managing natural resources do collect and analyze a variety of ecological, social, and economic information. However, that information is typically collected at a regional rather than landscape, watershed, or site scale; is rarely used to evaluate, learn from, and revise forest and water use planning; and is even less often organized and presented in ways that are practical and useful to local communities.

Ecosystem-based monitoring, on the other hand, strives to:

- determine whether progress is being made toward ecologically sustainable and economically balanced use of landscapes and ecosystems
- increase knowledge of ecological processes and the consequences of human activities at landscape, watershed, and site scales, and
- use knowledge gained from monitoring to improve the overall ecological sustainability of operational plans and activities.

A key component of ecosystem-based monitoring involves making sure that adequate information about the impact that current human uses are having on the landscape is collected and made available to local communities and groups. This kind of monitoring enables local groups and communities to participate effectively in ensuring that plans adequately protect and maintain the landscapes, forests, and waters near their homes, and that operational activities provide a balanced use of the benefits and services that flow from those landscapes, forests, and waters.

Monitoring Approaches, Purposes and Intensities

Monitoring can be understood in several ways. For example, monitoring can differ in its level of public involvement. Conventional or "professional" approaches focus on collecting and analyzing "hard" information such as log volume and grade, water flow and quality, salmon escapements, and other quantitative measurements. This approach to monitoring offers little opportunity for community participation, and is often costly because it assumes that technical expertise is required for the collection and analysis of monitoring data. Other "community-based" approaches rely on less technical but equally effective methods. These methods can range from systematic visual observation of changes in forest cover and streamside vegetation, to more detailed activities such as annual public bird and wildlife counts. In between these two extremes lie a range of methods that interested people and groups can use to systematically collect practical information about the lands and waters surrounding homes and communities.

Monitoring can also be understood in terms of its purpose. **Baseline monitoring** is used to assess the character and condition of a landscape, ecosystem, stream, or human community. Baseline conditions are those that exist before a planned forest or water use activity occurs. Comparing data from before and after an activity is one way of assessing its impact. Ongoing changes in landscapes and communities are assessed through **ambient monitoring**. Many ecological and social phenomena vary with the season, weather pattern, or economic trend. Distinguishing between natural variations and actual changes caused by human use requires measurement at consistent intervals over an appropriate period of time. Finally, **compliance monitoring** is used to assess whether legal standards or requirements are being met. Local groups can play an important role in compliance monitoring by bringing infractions to the notice of regulatory agencies such as the Forest Practices Board and the MoELP Wildlife Branch, and by ensuring legal requirements are met and penalties thoroughly applied.

Finally, monitoring methods can differ in intensity, where the level of intensity should vary according to the possible ecological risks associated with the activities being planned. Routine or **extensive** monitoring is carried out over large areas and long periods of time to determine general ecological and social trends. This type of monitoring lends itself well to more indirect or observational methods such as identifying the amount of land protected in reserves or photographing changes in vegetation. **Intensive** monitoring, on the other hand, is used when the risks associated with planned activities are high and knowledge about potential impacts is uncertain. In these circumstances, obtaining reliable information quickly about the effects of operational activities is necessary to quickly revise and improve plans and management strategies.

Ecosystem-Based Indicators of Sustainable Landscape, Forest, and Water Use

The purpose of ecosystem-based monitoring is to determine whether current landscape plans and ongoing timber management activities are achieving the twin goals of ecological responsibility and economically balanced landscape, forest, and water use. Effective ecosystem-based monitoring that will allow local groups and communities to determine if these goals are being achieved depends on a practical and reliable set of **indicators**. Indicators are direct measurements (*e.g.* log scales, wildlife population counts, number of jobs) or indirect observations and measurements (*e.g.* area of quality fish habitat, amount of land protected) that are systematically taken to assess changes that may be occurring in a landscape, ecosystem, or human community. Those changes may be due to natural trends or to human activity. Indirect indicators are often more effective because direct indicators can be very expensive and difficult to collect, particularly when the indicators being assessed are prone to large natural fluctuations.

Table 11 on the following page is intended to provide a starting point and an example of the type of indicators that can provide an effective basis for monitoring the landscape, ecosystems, and human communities within the Horsey Creek Landscape. The list identifies two types of monitoring data:

(1) information that is currently collected by different federal and provincial agencies but which is rarely organized at a landscape or local scale and presented to local communities, and

(2) community-based indicators that can be monitored by local conservation groups

The list identifies these types of data for two reasons. First, to focus attention on information government agencies do collect and should be making available to local communities. Second, to provide a guide to the type of monitoring that could be carried out by local groups interested in collecting reliable information about the condition of local forests and waters near their homes, and in monitoring the impact that current timber management activities are having on local forest and stream ecosystems.

The list can be changed or expanded as people gain familiarity with information sources and measurement and data collection techniques, and improved as monitoring data is evaluated for effectiveness and reliability. The Silva Forest Foundation is currently preparing a revised set of standards for assessing the ecological responsibility of forest planning and management as the basis for awarding eco-certification to logging, timber management, and value-added manufacturing operations. These standards will provide a comprehensive checklist for evaluating the sustainability of forest planning and timber management operations. People interested in exploring indicators and monitoring further may wish to contact Silva to obtain a copy of the certification standards. Appendix I also contains a list of monitoring-related references and publications.

Table 11. Monitoring Indicators for Ecosystem-Based Landscape Management

INDICATOR	DATA SOURCES	RATIONALE
Landscape or Watershed		
Percentage of Area Protected	MoELP Regional Planning Documents	Indicates how well planning is protecting the ecological functioning of the whole region
Ecological Representitiveness of Protected Areas	MoELP Regional Planning Documents	Indicates how well protected area and ecological reserve planning is protecting biodiversity and wildlife habitat at the regional and landscape scale
Percentage of Land Logged in Last Thirty Years	MoF Forest Cover Data and Maps	An indirect measure of landscape condition and watershed integrity
Percentage of Landscape Occupied by Old Growth	MoF Forest Cover Maps	An indirect measure of landscape condition and the availability of habitat for old growth dependent species
Amount of Mass Wasting on Logged and Natural Sites	MoF Forest Maps, Air Photos, Visual Observation	An indirect measure of the quality of road construction and logging practices and the impact development is having on hydrology and stream ecology
Percentage of Area Occupied by Roads	MoF Forest Cover Maps	An indirect measure of the amount of forest edge and potential impacts to hydrology and streamflow regime
Length of Riparian Streamside Forest Logged	MoF Forest Cover Maps, Visual Observation and Measurement	An indirect measure of watershed integrity and stream condition
Forest Stand		
Number of Large Trees Reserved per Hectare	Field Sampling, Visual Observation	Loss of large old trees indicates reduced structural diversity, impaired function, and loss of habitat for old growth and old tree dependent species
Number and Size of Snags per Hectare per Hectare	Field Sampling, Visual Observation	Loss of snags indicates reduced structural diversity, impaired function, and loss of habitat for old growth and old tree dependent species
Volume and Size of Large Fallen Trees	Field Sampling, Visual Observation	Abundance and distribution of large fallen trees provides an indication of how well forest practices are maintaining structural diversity
Number of Ecologically Sensitive Sites Protected	Field Sampling, Visual Observation	Indicates how well forest management practices are protecting stand level functioning and rare microhabitats
With of Riparian Zones	Field Sampling, Visual Observation	Indicates how well forest management practices are protecting and maintaining riparian habitat and function and stream integrity.
Water and Stream		
Water Quality	MoELP, Water Management Branch; Community Stream Monitoring	Changes in sediment load reflect the impact of upslope and upstream forest development practices. Short term increases in sediment load may be due to natural or human causes; long term increases usually reflect poor forest management practices
Stream Discharge	Water Survey of Canada, Community Monitoring	Changes in streamflow regime reflect climate trends, changes in watershed integrity, and the impacts of land use activity. Increased peak flow is an indication of excessive timber harvesting, road construction, and land clearing.

Streambed Stability	MoF stream channel assessments, Community Stream Monitoring	The stability of the pools, riffles, and the sands, gravels, and cobbles in the streambed provides an indication of overall watershed condition, quality of instream habitat, and changes in the intensity of peak and low flows
Channel Geometry	MoF stream channel assessments, Community Stream Monitoring	Channel width and depth is a function of streamflow regime; changes in streamflow regime and channel width and depth indicate increased channel instability likely cause by excessive logging, road construction, or land clearing.
Aquatic Macroinvertebrate diversity	Community Stream Monitoring	Changes in the composition, distribution, and abundance of stream insects indicate altered water quality, streamflow, and channel geometry
Community and Domestic Use Watersheds	MoELP Water Management Branch	Water licences indicate level of local water withdrawals and the impact withdrawals may be having on stream ecology and functioning.
Wildlife and Fish		
Number of Plant and Animal Species Listed as Endangered, Vulnerable, or at Risk	Conservation Data Centre; MoF and Licencee Forest Development Plans	Provides an indication of the impact that land and forest use activities are having on biodiversity. Forest Development Plans prepared by Licencees and the MoF should contain plans and strategies to protect habitat for red and blue listed species
Abundance and Distribution of Wild, Stocked, and CDC Listed Fish Species	Department of Fisheries and Oceans; MoELP; Conservation Data Centre	Indicates the condition of streams and the impact that land and forest use activities are having on stream functioning and instream habitat.
Cultural, Social, and Economic		
Number of Culturally Important Areas and Sites Protected	MoF, MoELP, Ministry of Small Business, Tourism and Culture	Provides an indication of the adequacy of management planning with regard to sustaining cultural heritage
Volume of Primary Forest Products Extracted	MoF	Tracking volume of timber and non-timber forest products is necessary to determine the sustainability of all harvesting operations and the contribution they make to local economies.
Direct and Indirect Local Employment	MoF, Stats BC, Local Business Directories	Amount and type of local employment generated by different forest use indicates the contribution that different forest use activities are making to local economies.
Number of Local Residents Involved in Planning and Management	MoF, Community Monitoring	Level of local involvement in landscape and forest use planning provides an indication of the adequacy of consultation and public involvement procedures
Type and Location of Recreational Use	MoF, MoELP	Intensity of forest use for wildlife view, backpacking, sport fishing, and guide-outfitting provide an indication of landscape quality the value of non-timber resources
Number of Locally Owned Value-Added Businesses	MoF, Local Business Directories	Indicates how well local forest resources are being allocated and used within local communities

CONCLUSIONS AND RECOMMENDATIONS

This report has described the results of an initial ecosystem-based analysis of the Horsey Creek Landscape. The purpose of this initial analysis was to:

- identify important landscape and ecosystem characteristics, assess ecological sensitivity, and determine where and how these factors limit human use of the Horsey Creek Landscape
- estimate how past and present development activity has affected the ecological condition of the landscape and ecosystems within the valley, and
- develop initial plans and related recommendations to guide the protection, maintenance, and sustainable use of the lands and waters in the Horsey Creek Landscape.

The overall purpose of the report is twofold. First, to provide the results of this initial analysis in a practical format to the Fraser Headwaters Alliance, the Dunster Community Association, and to other interested groups who are working to protect and maintain the forests and waters of the Horsey Creek Landscape. Second, to provide practical ideas and strategies to groups who are seeking to develop plans that promote balanced and healthy use of those forests and waters. Silva hopes these purposes and goals have been at least partially achieved.

Clearly the Horsey Creek Landscape is a diverse and sensitive landscape. Alpine tundra and steep, complex terrain occupy slightly more than 70% of the landscape. Very sensitive aquatic ecosystems, riparian ecosystems and transitional alpine forests occupy another 8%. Many rare and endangered plant communities, plants, and wildlife occur in other portions of the landscape, but the location and distribution of habitat for these communities and species remains poorly documented.

It is also clear that past development has had a profound impact on the lands and waters within the Horsey Creek Landscape. Settlement clearing, early industrial development, and fires eliminated nearly all of the natural forest cover and old growth forest stands from the Fraser River floodplain and adjacent terraces, and from lower and mid portions of the surrounding mountain slopes. Recent clearcut logging has fragmented a high percentage of the Engelmann spruce and subalpine fir old growth located on stable and moderately stable terrain in the Kiwa Creek, Horsey Creek, and Small Creek watersheds. Continued development clearing on private lands in the trench and a small amount of logging in tributary watersheds continues to impact landscape functioning by removing riparian forests and wildlife habitat and eliminating natural stand composition in remaining forests.

Based on the work conducted for this analysis, and on communication with the Fraser Headwaters Alliance, Silva makes the following suggestions for future plans, activities, and projects in the Horsey Creek Landscape:

1. Calculate ecologically-responsible, watershed-based annual timber cuts for areas and tributary watersheds within the Horsey Creek Landscape. Current logging plans are focusing on cutting remaining old growth located on moderately stable and stable terrain. Watershed-based cuts need to be prepared that fully account for the current condition of forests in the Horsey Creek Landscape, that acknowledge the need to protect ecologically sensitive sites and remaining old growth located on stable and moderately stable terrain, and that allow sufficient time for previously disturbed stands to recover natural structure and composition.
2. Establish a plan to restore natural forest composition and structure throughout the landscape. This restoration should focus on recruiting old growth characteristics in previously logged or burned upland forests, and on re-establishing natural structure in riparian forests in tributary watersheds and on lower benches and terraces in the trench. Valuable restoration could occur on private lands by increasing the number of large, old trees and the amount of old forest patches on the Fraser River floodplain, and by working with private landowners to establish conservation covenants that will protect mature forests and rare ecosystems located on private land.
3. Conduct field inventories to identify the distribution and abundance of threatened or endangered plants, rare plant communities, and botanical forest products. Many soils and site conditions within the Horsey Creek Landscape are rare in British Columbia. Inventories of rare and endangered plant communities, plants, and wildlife habitats are necessary to develop operational plans that will effectively protect and maintain these resources. Inventories of botanical forest products will provide baseline information to assess the economic potential of non-timber resources.
4. Develop and carry out examples of ecologically responsible timber cutting and compare the ecological and economic consequences of those activities with conventional timber management. Partial cutting involves leaving a complex array of tree sizes, ages, and species on the site. Knowledge of partial cutting yields, costs, and ecological consequences in interior rainbelt forests is small, and could be improved with practical models in the Horsey Creek Landscape.
5. Develop and implement an integrated watershed monitoring program for watersheds in the Horsey Creek Landscape. Field observations and baseline data collected during Silva's reconnaissance field trip indicate a monitoring program to assess ongoing changes in the forests and streams in the Horsey Creek Landscape would be feasible and relatively easy to implement. Partnerships should be formed between residents, MoF, DFO, and MoELP to design and implement community-based programs to monitor key indicators of landscape, forest, and stream condition.

6. Fully assess the costs and benefits of ecosystem-based plans and operations in the Horsey Creek Landscape. Current assessments reflect a biased view of the benefits realized by conventional timber management. Fair economic assessments should fully account for the direct costs associated with inventory, access planning, road construction, logging, hauling, and silviculture, and for the indirect costs associated with reduced landscape quality, lost non-timber economic opportunities, degraded wildlife habitat, and impaired forest ecosystem functioning.

7. Seek out, develop, and negotiate partnerships with local First Nations, logging contractors, and government agencies to implement ecosystem-based planning in the Horsey Creek Landscape and throughout the Fraser Headwaters. A key part of this process will involve developing appropriate, effective protocols for preparing forest plans and negotiating forest uses among First Nations, timber managers, and local residents of the Horsey Creek Landscape.

8. Improve and refine this ecosystem-based analysis. The results in this report are preliminary, and the mapping and assessment can be improved through further field inventory and data analysis. The Dunster Community Association and the Fraser Headwaters Alliance have worked hard to protect and maintain the forests and waters within the Horsey Creek Landscape. We encourage you to continue this effort, to keep on working to improve the reliability and accuracy of the maps prepared during this analysis, and to continue to improve the broader communities understanding of ecosystem-based planning and ecologically-responsible forest use.

APPENDIX I – Information Sources and References

Information Sources

Information collected and used in the Robson Valley ecosystem-based study includes:

- Dunster Community Association forestry caucus meeting results
- Informal interviews with Fraser Headwaters residents
- Forest and stream field data collected during a 10 day reconnaissance of the project area
- 1:250,000 and 1:50,000 NTDB topographic maps
- 1:70,000 black and white aerial photographs, dated June 1997
- BC Ministry of Forests forest cover maps
- BC Ministry of Forests digital forest cover data
- BC Ministry of Environment, Lands, and Parks terrain and resource information data
- BC Ministry of Environment, Lands, and Parks water license data
- Department of Fisheries and Oceans fisheries habitat and escapement data
- Water Survey of Canada streamflow summary data for the Upper Fraser River, Canoe River below Kimmel Creek, and Dore River near McBride
- Conservation Data Centre current lists of red and blue ranked vascular plants, vertebrates, and plant communities

Background Reference Material

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APPENDIX II – List of common and scientific names used in report

COMMON NAME	SCIENTIFIC NAME
Tree Species	
Lodgepole pine	*Pinus contorta*
Douglas-fir	*Pseudotsuga menziesii*
White spruce	*Picea glauca x engelmannii*
Subalpine fir	*Abies lasiocarpa*
Western redcedar	*Thuja plicata*
Western hemlock	*Tsuga heterophylla*
Trembling aspen	*Populus tremuloides*
Black cottonwood	*Populus balsamifera ssp. trichocarpa*
Common Plant Species	
Velvet-leaved blueberry	*Vaccinium myrtilloides*
Soopolallie	*Sheperdia canadensis*
Birch-leaved spirea	*Spiraea betulifolia*
Red-osier dogwood	*Cornus stoloifera*
Kinnikinnik	*Arctostaphylos uva-ursi*
Pinegrass	*Calamagrostis rubescens*
Twinflower	*Linnaea borealis*
Saskatoon	*Amelachier alnifolia*
Black huckleberry	*Vaccinium membranaceum*
White flowered rhododendron	*Rhododendron albiflorum*
False azalea	*Menziesia ferruginea*
Bunchberry	*Cornus canadensis*
Five-leaved bramble	*Rubus pedatus*
Oak fern	*Gymnocarpium dryopteris*
Red-stemmed feathermoss	*Pleurozium schrebi*
Rare and Endangered Plant Species	
Rusty cliff fern	*Woodsia ilvensis*
Canada anemone	*Anemone Canadensis*
Slender paintbrush	*Castilleja gracillima*
Gray-leaved draba	*Draba cinera*
Purple-leaved willowherb	*Epilobium ciliatum ssp watsonii*
Fornemanns willowherb	*Epilobium hornemannii ssp. behringianum*
Wooly daisy	*Erigeron lanatus*
Three-lobed daisy	*Erigeron lanatus*
Arctic eyebright	*Euphrasia arctica*
Rocky mountain sandwort	*Minuartia austromontana*
Meadow willow	*Salix petiolaris*
Plains butterweed	*Senecio plattensis*
Bald sedge	*Carex rugosperma var tonsa carex scoparia*
Pointed broom sedge	*Carex soparia*
Sheathed cotton-grass	*Eriphorum Vaginatum ssp. spissum*
Little fescue	*Festuca minutiflora*
Small deer-grass	*Trichophorum pumilum*

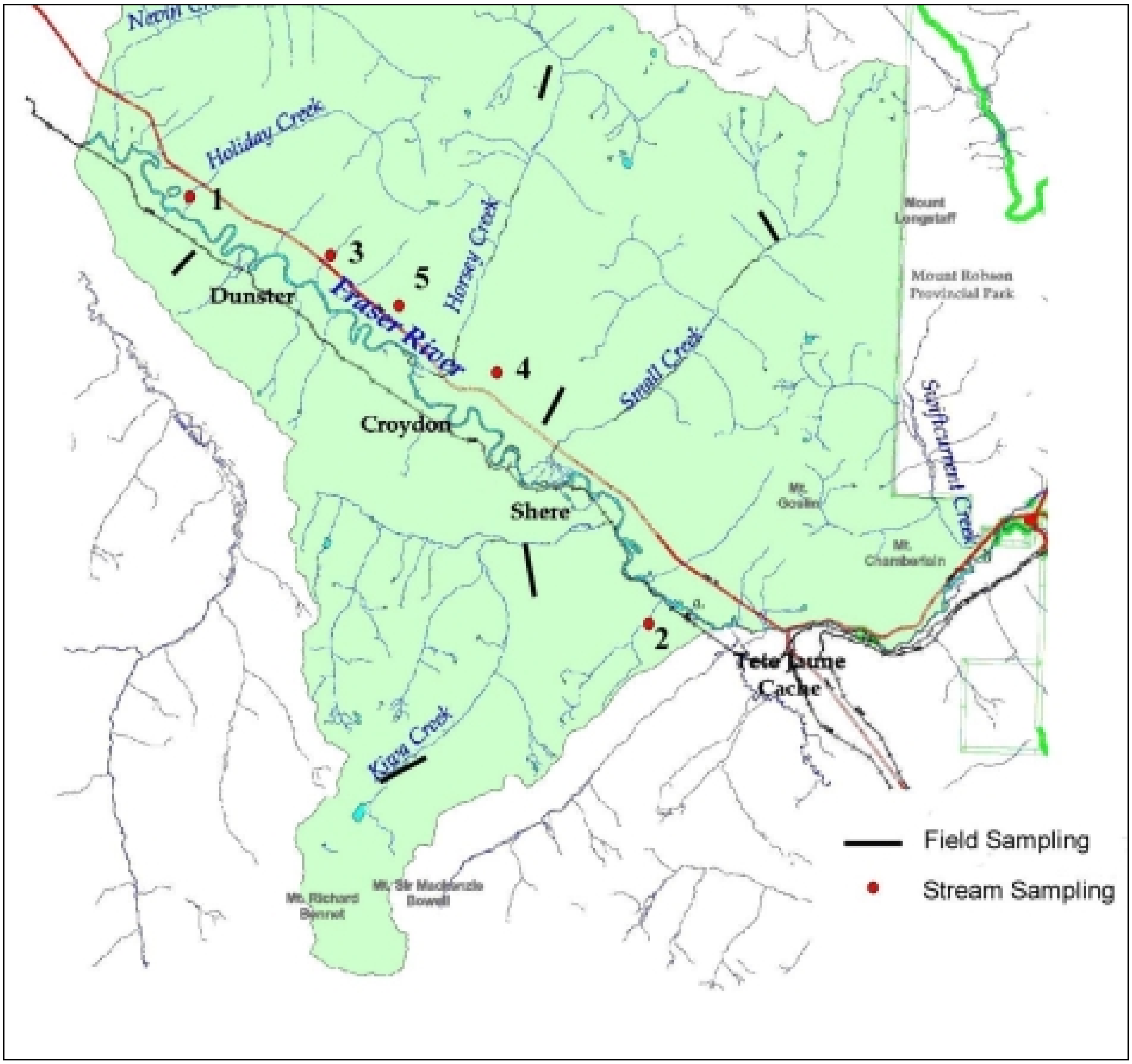
Mammals	
Grizzly bear	*Ursus arctos*
Wolverine	*Gulo gulo luscus*
Rocky mountain bighorn sheep	*Ovis canadensis canadensis*
Beaver	*Castor canadensis*
Fox	*Vulpes vulpes*
Coyote	*Canis latrans*
Weasel	*Mustela frenata*
Red squirrel	*Tamasciurus hudsonicus*
Northern long-eared myotis	*Myotis septentrionalis*
Fisher	*Martes pennanti*
Birds	
American bittern	*Botaurus lentiginosus*
Mallard	*Anas platyrhynchos*
White-crowned sparrow	*Zonotricha leucophrys*
Yellow-rumped warbler	*Dendroica petechia*
Black-capped chickadee	*Parus aticupillus*
Ruffed grouse	*Bonasa umbellus*
Bald eagle	*Haliaeetus leucocephalus*
Osprey	*Pandlon haliaetus*
Short-eared Owl	*Asio flammeus*
Fish Species	
Chinook salmon	*Oncorhynchus tshawytscha*
Sockeye salmon	*Oncorhynchus nerka*
Rainbow trout	*Oncorhynchus mykiss*
Cutthroat trout	*Oncorhynchus clarki clarki*
Mountain whitefish	*Prosopium williamson*
Bull trout	*Salvelinus confluentus*

APPENDIX III – Field observation routes and sampling locations

Silva staff conducted ten days of reconnaissance level fieldwork during July 7 - 17, 1998. The fieldwork involved visual observation and data collection. Specific goals for the field work included:

- visually ground-truthing preliminary air photo and map interpretations of ecosystem character, condition, and ecological sensitivity, and
- collecting reconnaissance-level baseline information on forest stand and stream channel characteristics and conditions.

The fieldwork strip mapping routes and field sample locations are shown below:



Field observation consisted of travelling by truck, quad, and on foot to view as much of the landscape as possible. All primary logging roads were driven. Upper portions or Kiwa Creek, Small Creek, and Horsey Creek were viewed by quad. Recent cutblocks, high-grade logging, and mature forests were viewed on foot in all major tributary watersheds. The purpose was to develop familiarity with important landscape characteristics and site conditions, and to verify air photo interpretations of ecological sensitivity.

Forest sampling involved gathering basic site characteristic and silvicultural data for representative forest types. Sampling consisted of strip mapping and fixed radius plots. Strip mapping involved simple survey traverses using a compass and chain. Notes of distance and direction traveled, slope, and the location of important physical features such as gullies, rock outcrops and small ponds and streams were noted. The location of forest stand structures such as snags, large trees, and small creeks were also noted.

Fixed radius plots were established within different forest types as strip mapping proceeded. The following information was recorded with each plot:

- dominant tree and shrub species
- tree diameter, height, and age
- landform and slope
- humus form, and soil rooting depth, texture, drainage, and profile.

Stream sampling focused on collecting data for a representative range of tributary watershed sizes. The purpose of the sampling was to develop baseline understanding of local stream channel characteristics and regional relationships between watershed size, streamflow, and stream channel geometry. This information is useful for estimating the width of riparian zones and the characteristics and conditions of instream habitat, and for designing stream and water quality monitoring programs. Sampling involved gathering basic streamflow and channel information including:

- Bankfull and present flow width and depth measured with an Esalon tape and metric rule. Channel width and depth were measured at 6 cross-sections along a representative stream reach equal in length to approximately 12 times stream channel width.
- Present discharge measured with a water velocity gauge at a uniform cross-section within the sample reach.
- Reach slope as determined by averaging the slope over two pool and riffle sequences.
- Streambed material distribution and size as defined by measuring the length, width, and height of 24 randomly selected pieces of gravel, cobble, or boulder bed material.

Stream sampling data is summarized below:

Stream Data Summary					
Stream Characteristic	**Stream**				
	(1) Holliday Creek	**(2) Tete Creek**	**(3) Bonney Creek**	**(4) Wardman Creek**	**(5) Un-named Creek**
Present Flow					
Average Depth:	0.38	0.30	0.25	0.13	0.16
Average Width:	8.86	6.48	1.29	2.55	2.17
Measured Slope (%):	1.79	5.77	0.52	4.14	3.92
Measured Discharge (m3/s):	0.96	0.85	0.89	0.06	0.07
Estimated Discharge (m3/s):	0.92	1.51	0.09	0.08	0.05
Bankfull Flow (estimated)					
Average Depth (m):	0.40	0.39	0.16	0.33	0.21
Average Width (m):	7.15	5.14	0.44	1.79	1.88
Estimated Discharge (m3/s):	3.59	4.23	0.03	1.48	0.53
Tractive Force:	7.21	22.28	0.83		8.42
Channel Characteristics					
Median Bed Material Size (cm):	10.17	11.67	9.00	14.00	6.42
Stream Channel Stability (%):	78	30	95	38	40
***Present Flow Channel Roughness:**	0.25	0.14	0.10	0.32	0.53
Bankfull Flow Channel Roughness:	0.06	0.06	0.06	0.06	0.05

* Channel roughness is calculated by estimating Manning's n at present and bankfull flow water depths. Manning's n is a measure of how rough a stream channel is in relation to the depth of the streamflow. A stream containing many large boulders, cobbles, and pieces of wood and a relatively shallow flow of water will have a higher Manning's n value than a stream with a gravel bed and deeper water flow.

APPENDIX IV – Summary of Silva Forest Foundation Standards for Ecologically Responsible Timber Management

July 1998

I. THE SILVA FOREST FOUNDATION AND ECOSYSTEM-BASED CERTIFICATION

The Silva Forest Foundation (SFF)'s involvement in forest certification began in 1992 when, in co-operation with the Ecoforestry Institute Society (Canada), we researched and wrote a report on the status of forest certification throughout the world. In October 1993 we were founding members of the Forest Stewardship Council (FSC) at its initial meeting in Toronto.

In 1994 we published our first set of standards for ecologically responsible forest use and timber management. These standards guided our first certification in late 1995 of a portion of the Ministry of Forests' Small Business Forest Enterprise Program in Vernon, British Columbia.

We have been working on standards writing in a variety of circumstances since 1993. In 1994 the Silva Forest Foundation became part of the Pacific Certification Council (PCC), a network of certifiers in northern California, Oregon, and British Columbia. On behalf of the PCC, we drafted a detailed set of standards to guide certifications throughout the region. These draft standards were sent out for extensive stakeholder review in both the United States and Canada. In 1997 the PCC was unable to obtain funding to continue its activities and a number of PCC network members from the United States joined the Smart Wood Network.

The Silva Forest Foundation has spent considerable time incorporating reviews of the PCC draft standards and revising those standards. The *SFF Standards for Ecologically Responsible Timber Management (SFF Standards)* document is the result of these efforts. We have now submitted that document to the Forest Stewardship Council as part of our application for FSC accreditation.

The *SFF Standards* represent a significant change from conventional timber management standards. Therefore, we are preparing a scientific rationale document that supports our standards. If you would like a copy of the rationale document, please let us know.

The Board of Directors of the Silva Forest Foundation wishes to express its sincere appreciation to fellow director Herb Hammond and to SFF's Certification Program Manager, Mark Kepkay, for the incredible amount of work that has gone into the current proof of the standards. Thank you also to the many people who provided thoughtful and critical feedback to previous versions of the standards.

SFF's certification standards will be a work in progress for the foreseeable future as we monitor certified forest operations over time and learn more. If you have suggestions for improvement to the standards, please let us hear from you.

Who Is The Silva Forest Foundation (SFF)?

The Silva Forest Foundation is a non-profit society actively involved in promoting and carrying out ecologically responsible forest use.

SFF includes among its directors, advisors, and associates people with extensive experience in ecology, biology, logging, forestry, and land use planning. These people have been pioneers in developing the philosophy and practice of ecosystem-based or ecologically responsible forest use. This diversity of complementary skills has enabled us to develop practical standards for forest use that can be expected to protect not only forest ecosystems but also the local human communities that are sustained by forests.

Members of SFF are committed to frequent evaluation of our activities and the activities that we certify to determine whether these activities comply with SFF Elements and Standards of ecologically responsible forest use and timber management summarised in this document.

SFF Values and Vision

High levels of social and economic health are maintained by protecting ecosystems and natural capital, which are the foundation for societies and economies. SFF believes that the primary concern of forest use must be the protection, maintenance, and, where necessary, restoration of fully functioning forests for the welfare of all beings and the whole forest. Ecosystem character (how a natural forest functions) and condition (how human use has impacted forest functioning) form the context within which social and economic criteria are designed and adjusted.

SFF does not value human life less than that of other species, but we do recognise that human social and economic welfare in forest ecosystems, like the welfare of all forest organisms, *depends* on the welfare of the forest ecosystem as a whole. Fully-functioning forests provide, for example, the clean water and air, building materials, food, clothing, and spiritual grounding that are essential to human physical and spiritual health. Other human or natural resources available on Earth cannot build systems that adequately replace these and other natural forest functions with human-designed production. The human animal, like other species, has adapted to the earth's design, and our survival depends on the continued integrity of that design.

Within the context of the protection, maintenance, and restoration of fully functioning forests, the unique issues of human communities and their economic activities must, of course, be addressed. Unstable communities produce human suffering and ecosystem degradation. Therefore, the *SFF Standards* include social and economic standards.

II. THE PURPOSE OF THIS SUMMARY DOCUMENT

This document is a summary of the *SFF Standards*, and provides an introduction to the general requirements for certification. A thorough presentation of *SFF Standards* is not provided in this summary.

The *SFF Standards* arise from a set of values that are fundamentally different from those that guide conventional timber management. The *SFF Standards* describe an ecosystem-based approach to timber management which is guided by the Elements Of Ecologically Responsible Forest Use:

Elements Of Ecologically Responsible Forest Use

1. Focus on what to leave, not on what to take.
2. Apply the precautionary principle to all plans and activities.
3. Protect the forest functioning by planning at all scales of time and space.
4. Respect the forest's ecological limits to human disturbance.
5. Ensure that all plans and activities protect, maintain, and, where necessary, restore natural biological diversity (i.e. genetic, species, and community diversity).
6. Protect, maintain, and, where necessary, restore natural composition, structures, and functioning at both the landscape and the stand levels.
7. Protect, maintain, and, where necessary, restore forest ecosystem connectivity at all scales of time and space during planning and implementation of forest activities.
8. Apply the concept of landscape to the forest organism or process under consideration.
9. Plan and carry out diverse activities to encourage ecological, social, and economic well-being.
10. Ensure that all forest use activities respect, protect, and provide for the independent maintenance and evolution of First Nation cultures, both traditional and current.
11. Evaluate the success of all forest use activities in meeting the requirements and goals of ecological responsibility.

The *SFF Standards* outline a vision, or a goal, for timber management activities. For initial certification, perfect compliance with *SFF Standards* is not required. However, certain entry-level minimum requirements must be met. As well, in order to maintain certification, once awarded, certified operations must demonstrate constant efforts to improve performance relative to the *SFF Standards*.

In reading through this Summary, keep in mind that the *SFF Standard* are applied in a flexible manner, in order to provide local, site-specific interpretations. Exceptions to particular standards may be permitted, if based on sound assessments of ecological, social, or economic impacts. This flexibility is provided by the Evaluation Scoring Checklist (Checklist), which is used by SFF to evaluate applicants for certification. In many cases, a low score on a particular point in the Checklist can be offset by a high score on another point. For a detailed understanding of how the scoring system works, see the SFF Evaluation Scoring Checklist.

While flexibility is important, to be certified ecoforesters must also err on the side of protecting, maintaining, and/or restoring ecosystem functioning at all scales through time.

Operations wishing to apply for certification fall into two categories:

1. *Whole-forest managers* – these are, generally, enterprises that have control over at least 1,000 hectares of forest.
2. *Small-holders* – enterprises that have control over less than 1,000 hectares of forest.

Whole-forest managers seeking certification are responsible for standards summarised in this document under the heading "Whole-Forest Applicants", as well as for those described under "All Applicants". Small-holders are only responsible for the standards described under "All Applicants". While the certification requirements for each category of operation are different, the end result of certification is the same: full SFF endorsement.

III. SUMMARY OF STANDARDS FOR ECOLOGICALLY RESPONSIBLE TIMBER MANAGEMENT

1. CHARACTER AND CONDITION OF LANDSCAPE AND STAND

All Applicants:

The first step in ecologically responsible timber management is taking a good look at the forest. Before developing a timber-management plan, applicants must complete an assessment of the forest. At the stand level, this assessment includes a description of stand "character" – how the natural forest would be expected to look over time. This description includes the variety of live and dead plants and animals ("forest composition"), the way these plants and animals are arranged ("forest structures"), and the roles played by various parts of the forest ("forest functioning"). Basically, the stand character description explains how the forest works in the absence of industrial activities.

Once completed, the description of stand character is used as a benchmark for describing current forest functioning. This assessment results in a description of stand "condition" – the cumulative impacts to natural forest composition, structures, and functioning from human exploitation or modification.

Based upon stand character and condition, the stand-level assessment also includes a description of rare, threatened and endangered genetic strains, species and/or ecosystems within the stand, and an assessment of the needs for restoration and protection of specific forest composition, structures, and functioning.

Whole-Forest Applicants:

Whole-forest applicants must also complete a landscape-level assessment, including an analysis of landscape character and condition; an assessment of ecological limits to human use in each ecosystem within the landscape; an assessment of whether old growth may be cut without significant ecological degradation; and identification of rare, threatened and endangered genetic strains, species and/or ecosystem types within the landscape.

2. THE STAND AND LANDSCAPE PLANS

All Applicants:

After the assessments of forest character and condition have been completed, applicants are in the position to produce a plan for ecologically responsible timber management activities. All applicants must produce a stand-level plan that describes and accounts for all the potential effects of timber management activities, over both the short and long term.

All plans must accommodate the aboriginal rights and title of First Nations.

In addition to documenting the information gathered during the assessment process, the stand-level plan also must include:

- evidence of legal rights and obligations
- a vision statement and list of related goals
- objectives related to natural disturbances (such as fire or wind); soil; hydrological functions (the movement of water); unique/sensitive ecosystems; healthy human communities; and the operation's economic viability
- maps and descriptions of all management activities and measures for protecting forest composition, structures and functioning
- estimates of ecologically sustainable levels of timber extraction
- planned annual rate and species for timber cutting
- maps, descriptions and reasons for extraction methods, silvicultural practices, felling guidelines, and deactivation procedures
- a summary of the social and economic needs of local communities
- training programs for staff
- a description of research plans
- provisions for plan review and revision
- identification of indicators (both "early-warning" and long-term) of success in meeting the plan's objectives

Whole-Forest Applicants:

Whole-forest applicants must, prior to creating their stand-level plan, prepare a landscape-level plan. When completed, this landscape-level plan forms the context for stand-level planning and activities. The landscape-level plan addresses many of the same issues as the stand-level plan, but does so from a landscape perspective. Usually a landscape plan encompasses the entire holding under consideration.

The landscape-level plan needs to include:

- maps and descriptions of:
    - ⇒ landscape character and condition
    - ⇒ ecological limits
    - ⇒ rare, threatened, or endangered genetic strains, species, or ecosystem types
    - ⇒ protected landscape networks (as described below) and other protective measures
    - ⇒ ecologically responsible forest use zones
    - ⇒ any large reserves
    - ⇒ proposed access roads and infrastructure
- a description of objectives related to the various ecosystem types found within the landscape; natural disturbances; soil; hydrological functions; unique/sensitive ecosystems; healthy human communities; and the operation's economic viability
- an estimate of ecologically sustainable levels of timber extraction

3. STAND-LEVEL STANDARDS

All Applicants:

Protected Stand Network

The protected stand network is a system of small reserve areas designed to protect and, where necessary, restore the full range of ecosystem composition, structure, and functioning found in natural, or unmodified, stands. With this in mind, the protected stand network includes:

- *riparian ecosystems (areas surrounding creeks, rivers, lakes and wetlands)*
- *ecologically sensitive areas (including places with steep or broken slopes, high elevation, very dry or wet conditions, shallow soils, or that are dominated by snow)*
- *old growth trees or patches of old growth*
- *uncommon wildlife habitat niches or small ecosystem types*
- *ecological resources needed by genetic strains or species that are rare, endangered or threatened at the local landscape or regional level*
- *small-scale connectivity that provides for the movement of native plants and animals at all life stages*

Stand Composition and Structures to be Permanently Reserved from Cutting

Applicants must permanently reserve at least 25 percent of the dominant trees from cutting (although an entry-level minimum of ten percent is acceptable). As well, three large snags, or standing dead trees, per hectare (with an entry-level minimum of one per hectare), and six large fallen trees per hectare (or the original count, whichever is lower) are also preserved.

Protection of Soil and Water
Applicants need to ensure that soil and water composition, structures and functioning are protected and maintained within their natural range of variability.

Pesticides, Fertilisers, and Other Chemicals
Pesticides, synthetic fertilisers, and other chemicals must not be used, except for ecologically justified restoration purposes.

Roads and Other Constructed Features
All constructed features must be located and built so as to minimise ecosystem degradation, and to maintain full forest functioning. In support of this general goal, design and construction needs to be carried out in a way that prevents or minimises soil compaction, soil erosion, soil displacement, water siltation and pollution, and the concentration of water. Specific requirements include:

- *mechanical disturbance of soil must be less than seven percent of the cutting area*
- *the right-of-way for roads must generally be less than 12 metres*
- *roads must be designed to maintain near-natural drainage patterns*
- *riparian ecosystem crossings must be designed to minimise impact*
- *roads must be designed as permanent fixtures*
- *road use must only occur when seasonal and weather conditions permit travel without ecological damage*
- *road maintenance must be ongoing*

Logging Systems
Applicants are permitted to use ground-based logging systems in areas where slopes do not exceed 30 percent. If the slope is between 30 and 45 percent, and well-spaced slope breaks exist, ground-based logging may still be appropriate. Otherwise, cable yarding and/or aerial yarding must be used. If the slope is between 45 and 60 percent, only cable yarding and/or aerial yarding is appropriate. If the slope exceeds 60 percent, logging generally must not occur. When ground-based systems are used, soil disturbance must be limited to seven percent of the cutting unit. With cable/aerial systems, only five percent disturbance is permitted.

Pollution and Waste Control
Applicants must maintain equipment and constructed features so that air, water and soil pollution is minimized. As well, any toxic or inorganic waste needs to be properly disposed of.

Ecologically Responsible Cutting Rates and Patterns
Ecologically responsible cutting rates and patterns are determined within the context of landscape character and condition, of maintaining permanent tree composition and structure, of protected stand networks, and of the natural disturbance and successional patterns (the natural process of change after trees die).

There are two general forms of ecologically responsible cutting patterns: Uniform Partial Cut, and Small Patch Cuts with Canopy Retention Areas. However, variations on these and other patterns may be acceptable, depending on the character and condition of the specific stand and landscape in question.

Regardless of cutting pattern employed:

- the frequency of entry must be lower where volume per cut is higher
- each cut must maintain, or if necessary, restore, the natural range of variability in tree species, tree size, tree age, and spatial distribution of trees
- the cutting rate over any ten year period must not exceed 75 percent of the total growth during that period
- whole tree logging (the removal of the entire tree, including branches and crown, from the forest) must not occur
- extraction methods must limit the damage to trees left standing

Generally, cutting must not remove more than 10-20 percent of the merchantable trees in any one entry.

Tree Age and Tree Selection
When choosing which trees to cut, emphasis must be placed more on successional patterns and forest history, than simply on tree age. The selection of trees to be cut needs to maintain or, where necessary, restore the natural range of variability in tree species, tree ages, and tree spatial distribution.

High-grading must not occur.

In stands where natural disturbance has been suppressed (such as fire suppression), the relatively young trees may be removed. As well, thinning and pruning may occur, either to develop sources of high-quality wood, or to restore natural composition, structure and functioning. In all cases, cutting in mature stands only occurs when such cutting will not degrade overall forest functioning, and when the trees have good economic value.

Tree Regeneration
Natural regeneration offers the most effective means of maintaining genetic and species diversity. The natural and successional processes needs to be respected and maintained during regeneration.

Tree planting generally may be used only in certain situations, for example where natural regeneration is ecologically inadequate. When planting does occur, stock must be suited to the site conditions. Site preparation (such as burning) needs to be justified from a site-specific, ecosystem-based perspective. In all cases, non-native (exotic) or genetically-engineered species must not be introduced or encouraged to spread.

Planning and Managing for Non-Timber Species and Natural Disturbances
Applicants must demonstrate a good understanding of the ecological functions and values of what are commonly called “pests” (e.g. diseases, insects, and mammals) and “non-commercial” tree species. Populations and influences of “pests” and “non-commercial species” must be maintained within ranges of natural variability for the ecosystem type. Expectation of human benefits from the forest needs to be consistent with “pest” activity, with “non-commercial species” needs, and with relatively predictable natural disturbances.

Salvage operations must protect and maintain natural ranges of variability in composition, structures, and functioning. Live trees need to be left standing during salvage operations. No more than 50 percent of the standing and fallen dead trees – well distributed spatially by size and by species – may be extracted after a large-scale disturbance.

4. LANDSCAPE-LEVEL STANDARDS

Whole-Forest Applicants:

In addition to the stand-level standards, whole-forest applicants must also meet the following landscape-level standards:

Protected Landscape Network
This is a system of reserves designed to protect the full range of ecosystem composition, structure, and functioning found in a landscape. The Protected Landscape Network is similar in parts and purpose to the Protected Stand Network (above), but at a larger scale.

Included in this protected network are:

- riparian ecosystems
- ecologically sensitive sites
- old growth nodes
- a representative range of all ecosystem types
- adequate additional reserves for the protection of rare, threatened, or endangered genetic strains, species, or ecosystem types
- cross-valley corridors or landscape linkages

In landscapes of 20,000 hectares or more, the Protected Landscape Network also includes whole protected watersheds.

Ecologically Responsible Forest Use Zones
Once the protected landscape network has been established, ecologically responsible forest use zones must be located – generally in areas between the parts of the protected network (like holes in Swiss cheese). Within these zones, a diversity of forest uses must be encouraged, without degrading forest functioning, in order to benefit as many interests as possible.

As well as timber management, ecologically responsible forest uses may include:

- cultural and spiritual uses
- watershed protection
- wildcrafting (harvesting non-timber forest products such as berries or herbs)
- tourism
- some conversion zones (areas converted to non-forest uses such as agriculture or settlement)

Access Systems
Applicants must plan the landscape's overall road and access system to minimise soil, water, and ecosystem degradation. Planning must prevent or avoid soil compaction, soil erosion, soil displacement, water siltation and pollution, and concentration of water.

Large Landscape Reserves
Timber management enterprises responsible for landscapes in excess of 100,000 hectares, must permanently protect large landscape reserves which represent at least 20 percent of the landscape. These reserves incorporate entire watersheds (preferably as unmodified as possible), and aim to represent the full range of ecosystem types found naturally in the greater landscape or region.

5. RESTORATION STANDARDS

All Applicants:

If assessment of the landscape and stand condition reveals that restoration is necessary, the focus should be on assisting, rather than fixing, natural forest processes. Within this context, restoration activities need to be carried out at all possible scales, and must strive to re-establish forest functioning by re-introducing natural composition and structure.

Restoration approximates both the spatial and time aspects of natural succession and disturbances. Restoration activities that alter natural forest composition or structures generally must not be carried out. Exotic species need to be avoided, unless these are the only means for moving the landscape and stand closer to a natural condition.

Previously clearcut young stands may be certified only if there is an active restoration program in place that complies with applicable SFF Restoration Standards.

6. SOCIAL STANDARDS

All Applicants:

All certified timber management activities must be socially, as well as ecologically, responsible. Socially responsible timber management provides for the balanced use of forests, and accommodates the diverse needs of humans and non-humans. The standards for social responsibility include the following:

Compliance with Laws and with *SFF Standards*
Applicants must comply with all applicable laws and regulations. As well, applicants must demonstrate a long-term commitment to following *SFF Standards* for Ecologically Responsible Timber Management.

First Nations
British Columbia and Canada have not negotiated treaties with most First Nations in British Columbia. Therefore, the province is largely unceded First Nations land. In other parts of Canada, treaties exist or are in various stages of negotiation. First Nations have special rights, and a special relationship with the forests and other ecosystems comprising the lands and waters of their territories. With this situation in mind, First Nations' aboriginal rights

and title, experience, knowledge, practices and insights must be fairly and fully considered and accommodated in the planning and practices of all applicants.

Local Communities
Local communities, including First Nations, must be given fair opportunity to participate in decision-making, and in the equitable distribution of timber and non-timber benefits. Communities with legal or customary tenure rights must maintain control over timber management activities, unless such control is delegated in a free and informed manner.

Applicants need to establish and maintain consultation with people affected by management activities. As well, recreational, educational, and subsistence uses of the forest must be allowed whenever possible; and timber management must be designed to provide long-term local employment and to promote long-term community stability.

Workers' Rights
All employees need to be provided with:

- fair compensation and benefit packages
- high standards for employee health and safety
- freedom from discriminatory employment practices
- freedom to organise
- opportunity to participate in, and give feedback on, management decisions and policies

7. ECONOMIC STANDARDS

All Applicants:

Applicants need to account for the full ecological, social, and financial costs and benefits of operations. Applicants must also secure enough human and financial resources to implement ecologically responsible landscape-level and stand-level plans. As well, all timber that is cut should be utilised as fully as possible. Local value-added production should be maximised; wastage must be kept to a minimum; and markets for under-utilised species should be actively pursued.

8. MONITORING STANDARDS

All Applicants:

All applicants must monitor and evaluate the ecological, social, and economic impacts of activities, at least once a year. Monitoring needs to include indicators such as:

- volumes of forest products
- tree growth rates
- changes in forest composition
- costs of timber management
- protection of reserved areas

The results of monitoring must then be incorporated into revisions to landscape and stand-level plans.

IV. HOW TO FIND OUT MORE

For more information about the SFF Certification Program, contact Mark Kepkay or Susan Hammond at:

P.O. Box 9
Slocan Park, British Columbia,
Canada V0G 2E0
Phone 250-226-7222; Fax 250-226-7446
E-mail mkepkay@netidea.com; silvafor@netidea.com

APPENDIX V – Assessing the Ecological Impacts of Timber Management: Apparent Impacts, Actual Impacts, and Precautionary Forest Development

INTRODUCTION

Broad public concern over the sustainability of forest practices in British Columbia (BC) during the early 1990s shifted attention from stand level to landscape scale ecological processes. The immediate result was that a bewildering mix of new jargon entered the forestry lexicon—fragmentation, connectivity, meta-populations, coarse and fine filters, conservation corridors, landscape mosaics, habitat patches, and so on. The next consequence was that an equally complicated and confusing array of policies, regulations, and guidelines was developed in the effort to translate new ideas into operational practices. Unfortunately, in all the confusion, little changed "on the ground." For the most part we still build roads through rich and productive valley bottom forests, and clearcut the biggest and most accessible stands of mature timber, further endangering the forest landscapes and biodiversity that all the research, policy-making, and planning efforts were supposed to protect.

Here we attempt to move things beyond the "all talk, policy making, and regulation but no action" phase by operationalizing the now well-known fact that forest management activities affect ecological processes and population dynamics well beyond the apparent physical boundaries of access roads and logging cutblocks. This zone of influence, or "edge effect", extends much farther into the surrounding landscape than is often realized. Efforts to understand and plan for the actual impact that past and proposed forest development activities have on landscapes, forest ecosystems, habitat quality, wildlife population dynamics, and hence biodiversity, must take edge effects into account. A basic first step is to assess the spatial extent of possible edge effects during forest development planning, and describe that extent on operational planning maps. Only then can decision makers, affected First Nations, and the public fully appreciate the implications of alternative forest management scenarios in terms of their impacts on landscape ecology and biodiversity.

We begin with a brief review of landscape ecology terms relevant to assessing the direct and indirect impacts of forest management activity. We draw on this review to develop a simple classification of impacts—apparent impact and actual impact—where apparent impact refers to the physical extent of road and logging disturbance, and actual impact refers to apparent impacts plus the additional ecosystems, habitats, and wildlife populations that are influenced by edge effects. We then explore the spatial extent of edge effects—physical, biological, and behavioral—through a "reconnaissance-level" review of relevant literature. In the final section we make recommendations for mapping apparent and actual impacts during forest development planning, and for developing precautionary timber management plans in light of this assessment.

FOREST LANDSCAPE ECOLOGY

Forest landscapes contain a spatially diverse and temporally variable mosaic of forest stands, ecosystems, and habitats. Understanding how a forest landscape functions and develops over time requires knowledge of the patterns created by different stands, ecosystems, and habitats within the mosaic, an understanding of the ecological and social processes that cause those patterns to occur and change, and an ability to interpret or predict the effect that those changes will have on ecological processes and the population dynamics of plants and animals at different scales. Forman (1995) offers a simple and practical classification system for describing the basic components of landscape mosaics (Figure 1):

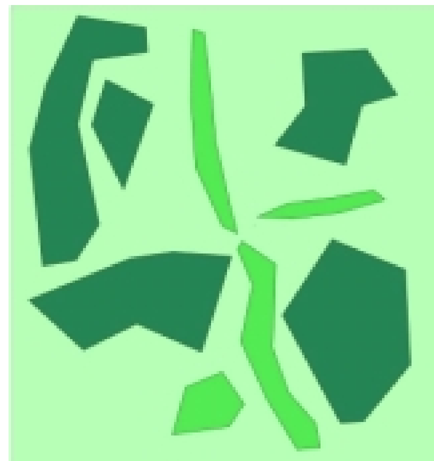


Figure 27. Matrix, patches, and corridors in a simplified forest landscape mosaic

- The term **matrix** refers to the most frequent and extensive feature in the landscape, usually a relatively uniform forest or vegetation community type. The composition and structure of the forest matrix in a particular landscape is a function of regional climate, geology, topography, and hydrology, all of which interact to facilitate the development of characteristic community assemblages (biogeoclimatic zones and subzones). Disturbances such as fire and logging may also play an important role in creating landscape matrices. The dry interior forests in south-central BC, for example, are maintained by frequent, small-scale ground fires that reduce vegetation and promote understory regeneration of Douglas-fir and ponderosa pine (Ministry of Forests 1996).
- A **patch** is a small area in the landscape that is ecologically different from the matrix in some important way. Patches in landscapes that contain a matrix of mature and old growth forest, for example, may consist of small irregular young stands or plant communities that have been created by natural disturbances such as windthrow or fire, , or by human disturbance such as clearcut logging. Patches in landscapes that are frequently disturbed by fire or logging activity, on the other hand, may consist of remnant mature and old growth forest stands. Patches can also be defined by their suitability as habitat for a given plant or animal species, and in this sense can be classed as optimal, moderate, marginal, or non-inhabitable depending on their structural attributes.
- **Corridors** are long, narrow ecosystems or habitat patches that differ from the surrounding matrix on both sides. Corridors often sustain important connections between other landscape features. Riparian forests next to streams, for example, provide suitable habitat and migration pathways for migratory wildlife such as moose, grizzly bear, and deer. The contribution that corridors make to wildlife migration, plant dispersion, and landscape function depends on the width of the corridor, the shape and linearity of the corridor, the ecological difference between

the corridor and surrounding matrix, the pattern of interconnections among patches and corridors, and the mobility of the organism (Rosenburg et al. 1997).

The boundaries that separate different patches and corridors from each other and from the surrounding matrix are referred to as **ecotones** or **edges** depending on the abruptness of the separation. When adjacent ecosystems or forest vegetation types grade slowly into one another—for example, where a wetland occurs between a lake and nearby forest—the resulting transition zone is referred to as an ecotone. Ecotones frequently contain high levels of biodiversity because they have the structural characteristics of both adjacent habitats as well as distinctive microhabitats found only in the ecotonal area (Risser 1995). Where the contrast between vegetation or forest types is abrupt and well-defined—for example, where a road right-of-way meets old growth forest—the boundary is described as an edge. The sharp changes in temperature, solar radiation, and vegetation associated with edges tend to act as barriers to animal movement. Amphibians, for example, are particularly sensitive to the abrupt transitions in microhabitat and microclimate that occur at clearcut – forest edges (Murcia 1995).

APPARENT IMPACTS

Past experience in BC and all over the world clearly indicates that forest development activities directly impact the pattern—in other words, the size, shape, and distribution of patches, corridors, edges, ecotones, and the matrix—of forest landscape mosaics in a predictable sequence. First access roads are built, then successive blocks of mature, commercially valuable forest are clearcut logged. Forman (1995) suggested the following terms to describe the basic steps:

- **Dissection** occurs when the landscape is "carved up" or divided by linear features, typically road networks, railways, and powerlines. Dissection has many negative impacts on landscape ecology including an increase in the number of landscape patches, a reduction in average patch size, reduced connectivity among patches and corridors, a substantial increase in edge length, and the introduction of chronic human disturbance. Road networks which are more evenly distributed across a landscape have a greater impact on landscape ecology than networks which are densely clustered (Tinker et al. 1998)

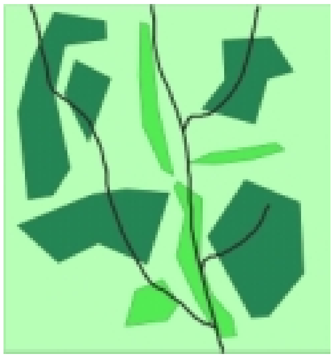


Figure 28 Dissection

- **Perforation**, or the process of "making holes" in the landscape, occurs when "first pass" timber management activities target particular forest stands, usually the most accessible, productive, and economically valuable forests located in valley bottoms. The perforation resulting from first pass dispersed clearcutting impacts landscape ecology by reducing patch size and increasing the amount of edge. The results are similar to those caused by roads—reduction in habitat patch quality and an increase in habitat isolation.

- **Fragmentation**, or the "breaking apart" of the landscape, occurs when second and third pass timber management activities have eliminated excessive amounts of one or more types of landscape patch or habitat. Fragmentation caused by the cumulative impact of second and third pass logging increases the number of isolated patches, reduces the size of those patches, and creates more edge, all of which lead to further reduction in habitat quality and an increase in habitat isolation.


Fig. 30 Fragmentation

Each step in the dissection–perforation–fragmentation process affects a range of landscape characteristics, including the size and shape of remaining landscape components, the amount of area covered by each patch or corridor type, the number and abundance of different patches and corridors, and the influence each component exerts on the landscape. Two of the most important impacts that these changes have on landscape ecology and biodiversity are habitat destruction due to a reduced total area of suitable habitat patch, and fragmentation resulting from reduced habitat patch size and increased habitat patch isolation. Both habitat destruction and habitat fragmentation result in loss of locally adapted plants and animals, reduced local plant and animal population sizes, and increased likelihood of extinction due to isolation from nearby populations. Developing management plans that maintain intact patches, natural corridors between habitat patches, and habit structure within the intervening matrix can help to mitigate the effects of fragmentation. They accomplish little, however, in reducing the overriding impact of habitat loss (Fahrig 1997)

ACTUAL IMPACTS

The spatial extent of habitat loss and fragmentation is rarely the same as the size of area directly affected. The actual impact of road construction and logging includes the apparent disturbance and the effects of the disturbance that extend beyond the edge. These **edge effects** can include changes in microclimate, vegetation community composition, habitat suitability, and wildlife population dynamics. How far edge effects extend into adjacent forests and habitats is influenced in particular situations by a variety of factors including:

- the character of the disturbance (e.g. fire, clearcutting, partial cut logging, road construction)
- the definition (i.e sharp or graded) and orientation (i.e azimuth, aspect, elevation) of the edge
- the shape, size, composition, and habitat suitability of the adjacent patches
- the life histories, population dynamics, and social structure of the organisms, and
- local topography and microclimate.

Variability among these factors means that edge effects will differ in width depending on site characteristics; however, it is possible to make some general predictions about the spatial extent of edge effects created by different types of disturbance. Roads, for example, have far greater impact on landscape condition and biodiversity than clearcuts of similar total size, because they dissect larger portions of the landscape, because they have abrupt edges, and because their edges persist longer than natural patch edges or those created by clearcuts (Reed et al. 1996; Tinker et al. 1998).

It is also possible to make general and rough predictions about the spatial extent of different types of edge effects. Forest development activities have physical, biological, and behavioral impacts on adjacent ecosystems, plant communities, and animal populations, and these different types of edge effect have a characteristic zone of influence in particular landscapes. The width of this influence will vary according to site characteristics; however, generalizations can be drawn because roads and logging cutblocks have similar disturbance characteristics in all landscapes (e.g. sharp edges, linear or rectangular shape, introduction of chronic human activity and noise), and because the ecological communities and the plant and animal populations within particular landscapes will have similar responses to those disturbances.

Physical Impacts

Roads and clearcuts influence the physical characteristics of adjacent forest ecosystems and wildlife habitat in many ways. The spatial extent of the influence varies among characteristics (Table 1). Recent research on the width of microclimatic gradients from logged stands into old growth Douglas-fir forests in northwestern Washington, for example, revealed that the edge effects of clearcut logging extended as far as 240 m into the adjacent old growth forest when the edge faced a southerly direction (Chen et al. 1995). Soil temperature stabilized after only 60 m, but higher

Variable	Effect Width	Reference
air temperature	up to 180 m	Chen et al. 1995; Brosofske et al. 1997; Young and Mitchell 1994; Matlack 1993
soil temperature	up to 60 m	Chen et al. 1995; Brosofske et al. 1997; Matlack 1993
humidity	up to 240 m	Chen et al. 1995; Brosofske et al. 1997; Matlack 1993
wind speed	up to 240 m	Chen et al. 1995; Brosofske et al. 1997; Matlack 1993
solar radiation	up to 60 m	Chen et al. 1995; Young and Mitchell 1994

water capture from fog	no specified distance	Dawson 1998
wildlife poaching/hunting	up to 2.5 km	Knick and Kasworm 1989; Horesji et al. 1998; Powell et al. 1996; Nagy 1989; Ballard et al. 1987; Wielgus and Bunnell 1994

Table 1. Physical impacts of edge effects

wind speeds extended up to 180 m past the clearcut boundary, and air temperature remained elevated for as much as 240 m. Similarly wide microclimatic gradients were found in riparian forests next to streams in northwestern Washington, with the result that a no-harvest buffer of up to 300 m was recommended in order to maintain natural microclimatic conditions in these riparian forests (Brosofske et al. 1997).

Roads and clearcuts also affect landscape function and biodiversity in adjacent forests because they act as physical barriers to movement, effectively dissecting habitat patches. Study of amphibian movements near road-forest edges in deciduous forests in Connecticut, for example, indicated that amphibian movement was reduced by more than 70% at the forest-road edge (Gibbs 1998). Salamanders in particular were sensitive to changes in solar radiation and temperature. The barrier effect produced by infrequently used, unpaved roads has also been convincingly demonstrated for small mammals (Barnett et al. 1978; Merriam et al. 1989) and invertebrates (Baur and Baur 1990). Study of small mammal migration across roads in Kansas, for instance, found that a backcountry road that was less than 3 m wide with vegetation growing on it and only 10 – 20 vehicles a day strongly inhibited the movements of prairie voles and cotton rats (Swihart and Slade 1984).

The most extensive physical impact resulting from the introduction of roads and logging is increased mortality due to legal and illegal hunting and road accidents. Studies in the Pacific Northwest, for example, found that 79% of gray wolf mortality (Ballard et al. 1987), 90% of black bear mortality (Powell et al. 1996), and 56% of grizzly bear mortality (Wielgus and Bunnell 1994) respectively were caused by people using backcountry roads for access. Researchers in BC attempted to assess grizzly bear activity near roads in the Selkirk Mountains, but 3 of 4 radio-collared male bears were shot illegally during the study (Knick and Kasworm 1989). The extent of these impacts can extend hundreds of meters into otherwise undisturbed forests. Research into legal and illegal bear hunting activity in Alberta, for example, revealed that substantially increased mortality of grizzly and black bears occurred as far away as 2 km from driveable roads (Nagy 1989).

Biological Impacts

Road construction and clearcut logging have a variety of less apparent impacts on the biology of local vegetation and wildlife. Again, the spatial extent of the impact varies according to the plant or animal of interest and edge orientation (Table 2).
Impacts

Variable	Effect Width	Reference
canopy cover	up to 60 m	Chen et al. 1992; Brosofske et al. 1997

stocking density	up to 120 m	Chen et al. 1992
tree mortality	up to 125 m	Chen et al. 1992
tree species composition	up to 140 m	Chen et al. 1992
lichen abundance and composition	up to 50 m	Essen and Renhorn 1998; Sillett 1995
understory vegetation abundance	up to 65 m	Jules 1998; Young and Mitchell 1994
vulnerability to pest infestation	no specified distance	Kouki et al. 1997
invertebrate abundance	no specified distance	Burke and Nol 1998
amphibian abundance	up to 100 m	de Maynadier and Hunter 1995, 1997; Gomez and Anthony 1996; Gibbs 1998
bird diversity and abundance	up t0 500 m	Kilgo et al. 1998; Kinley and Newhouse 1997
small mammal diversity and abundance	up to 50 m	Sekgororoane and Dilworth 1995; Stevens and Husband 1998

Table 2. Ecological impacts of edge effects.

on canopy vegetation range from 10 m to 150 m from the disturbance edge. Researchers studying changes in the abundance of epiphytic lichens growing in forest–cleacut edges in Sweden, for example, found that edge effects extend 25 m to 50 m into the forest at moderately exposed sites (Essen and Renhorn 1998). The major factor reducing lichen abundance was physical damage by wind. A similar study in the edge of a 700 year old Douglas-fir forest in Oregon indicated little change in overall lichen mass between the edge and interior; however significant differences in the composition of lichen communities extended well into the mature forest (Stillet 1995).

Edge effects also influence the composition and structure of understory vegetation and canopy trees in adjacent forests for considerable distances. Recent research on the distribution of *Trillium* next to clearcut edges, for instance, indicated there was no new recruitment of this otherwise common understory plant within 120 m of the edge (Jules 1998). Research on the silvicultural characteristics of mature and old growth Douglas-fir forests in northwestern Washington adjacent to clearcuts revealed that edge effects may extend up to 140 m depending the variable of interest (Chen et al. 1992). Basal area and regeneration patterns were negatively affected up to 120 m from the clearcut edge, and the forest canopy was affected up to 60 m from the edge due to blowdown and exposure.

Forest management activities also influence the distribution and abundance of animal populations near edges and in corridors. Studies of amphibian and reptile abundance in riparian forests next to streams, for instance, have indicated that riparian buffers of at least 75 m to 100 m are often necessary to maintain microclimate and vegetation conditions favorable to many species persistence (Gomez and Anthony 1995). Analysis of small mammal abundance and diversity near the edge of coastal coniferous forests in Brazil yielded similar results—both the number of species and individuals were reduced as far as 160 m from the forest edge (Stevens and Husband 1998). Research into the abundance of birds in lowland riparian forests in South Carolina indicated that a minimum riparian forest width of at least 500 m was necessary to support breeding populations of migratory songbirds (Kilgo *et al* 1998). Similar studies in montane spruce forests near streams in BC suggested that riparian reserves less than 70 m in width would result in lower densities and diversity of riparian-associated species (Kinley and Newhouse 1997).

Behavioral Impacts

The least apparent but typically most far-reaching impacts of forest development activities manifest themselves as changes in the individual and social behavior of migratory and resident amphibian, bird, and mammal populations (Table 3). The severity of behavioral change can vary from simple habitat loss because the animals avoids roads, clearcuts, and the activity that occurs in those areas, to serious population decline as a result of reduced food supply, poor juvenile survivorship, and

Variable	Effect Width	Reference
woodland caribou body mass	visual and aural range	Bradshaw et al. 1998
bald eagle nesting density and reproductive success	up to 300 m	Gende et al. 1998
spotted owl reproduction	up to 1.1 km	Thome et al. 1999
salamander migratory movements and survivorship	up to 150 m	Raymond and Hardy 1991
bobcat habitat use	up to 100 m	Lovallo and Anderson 1996
wolf habitat use	up to 2 km	Thurber et al. 1994
Roosevelt elk habitat use	up to 500 m	Witmer and deCalesta 1985
bear habitat use	up to 3 km	Mattson et al. 1987; Aune 1994; Kasworm and Manley 1990; Brody and Pelton 1989

Table 3. Behavioral impacts of edge effects

impaired reproductive success. Migratory species and populations that use extensive areas are more affected by behavioral responses to human disturbance than organisms that have comparatively localized life histories.

Amphibians provide an example of a species group with specialized and spatially limited habitat requirements whose behavior is affected by forest development activity. Research on the influence of edge effects on 14 amphibian species in Maine revealed that increased light penetration and temperature negatively affected the abundance and behavior of several species, particularly salamanders, as far as 35 m away from the edge of clearcuts that were 11 years old (DeMaynadier and Hunter 1998). Other research suggests the effects can be far more striking. One study of salamanders that rely on small ephemeral ponds in coniferous forests for breeding and found that timber harvesting as much as 150 m away affected the migratory patterns, survivorship, and abundance of resident populations (Raymond and Hardy 1991).

Roads, forest edges, and operational activities can affect the breeding and foraging behavior of birds for considerable distances. Study of the nesting densities and nesting success of bald eagles in sitka spruce and western hemlock forests in southern Alaska, for instance, revealed that both nesting density and nesting success increased in relation to distance from clearcut logged areas (Gende et al. 1998). The full extent of behavioral impacts were not identified, but a buffer zone of at least 300 m around eagle nests was recommended to maintain eagle reproductive success. Similar studies on the reproductive success of spotted owls in relation to the silvicultural characteristics of redwood and Douglas-fir forests in the northwest coast of California found that spotted owl nesting and breeding success was negatively associated with clearcuts (Thome 1999). The researchers hypothesized that reproductive success in mature and older forest stands was related to prey availability, and recommended establishing buffers of at least 1.1 km around nesting sites to maintain natural levels of prey abundance.

Large migratory mammals are the most adversely affected animal species. Roosevelt elk in the central coast range of Oregon, for example, were found to avoid using habitat within 125 m of forest roads, and 500 m of paved roads (Witmer and de Calesta 1985). Gray wolves in Alaska were found to avoid areas within 2 km of roads (Thurber et al. 1994). Other reactions are less apparent. Research on the effect that visual and noise disturbance associated with mineral exploration roads has on woodland caribou in northwestern Alberta, for example, revealed that 40 or more disturbances over a winter—an event that occurred in 4 of the 6 years of the study—could result in a loss of greater than 20% of body mass. This loss was considered sufficient to result in reduced calf survival due to increased predation and undernutrition (Bradshaw et al. 1998).

Bears are particularly susceptible to behavioral impacts. Research on landscape use by grizzly bears in Yellowstone National Park, for instance, indicated that resident bears avoided habitat located within 3 km of backcountry roads (Mattson et al. 1987). Similar research in the Rocky Mountains of BC revealed that grizzly bears avoided habitat located within 500 m of roads, and that black bears habitat use was significantly reduced with 100 m of the same roads (Aune 1994). Similar “zones of influence” were found in western Montana where grizzly and black bears avoided habitat within 900 m of roads (Kasworm and Manley 1990).

SUMMARY AND DISCUSSION

Realistic assessments of the impacts that forest development activity has on forested landscapes in BC must include an evaluation of both the apparent and the actual impacts that those activities have on the condition of forest ecosystems, plant communities, habitat suitability, and wildlife populations. Apparent impacts include the physical disturbances caused by road construction, logging, and silvicultural practices, as well as the direct effects these disturbances have on landscape function and biodiversity, particularly those associated with landscape dissection, perforation, and fragmentation. These changes in the composition and structure of the landscape impact biodiversity in two important ways—through patch or habitat destruction, and patch or habitat fragmentation and isolation.

The actual impacts of forest management activities reflect apparent impacts plus the additional influence that edge effects have on the ecosystems, plant communities, and plant and animal populations adjacent to the physical disturbance. Road and clearcut edges have physical, biological, and behavioral effects that extend beyond the boundary of physical disturbance. The spatial extent of these effects is influenced in particular situations by local site characteristics and ecological processes; however broad ecological similarities within landscapes and among different forest management activities allow general estimates to be made. Brief review of current literature suggests that physical impacts extend up to 180 m, that these physical changes affect the biology of plants and animals as far away as 300 m from the edge, and that hunting disturbance and behavioral impacts can affect wildlife population dynamics at distances of 1 or more kilometers.

Kareiva and Wennergen (1995), Fahrig (1997), and Woodroffe and Ginsberg (1998) provide useful summaries about the actual impacts that habitat destruction and landscape fragmentation have on ecosystem processes, plant and animal population dynamics, and biodiversity. They suggested that ecological research on these topics had some practical implications that apply to forest landscape planning and management, including the knowledge that:

- Plant and animal populations live with a threshold requirement for habitat, below which they face inevitable extinction. Extinction will occur long before all of the habitat has been removed because suitable habitat consists of more than just physical structure—it also has biological and behavioral attributes.
- The arrangement of habitat across the landscape and the ability of plants and animals to disperse or move among habitat patches and across the matrix influences to some extent whether populations remain stable, fluctuate, or go extinct. Landscape plans that maintain natural habitat patterns and enhance the habitat value of the intervening matrix will help to offset the effects of landscape fragmentation, but will not mitigate the overall impact of habitat destruction.
- Destruction of habitat inevitably causes a dramatic loss in biodiversity, but that loss does not appear until after significant habitat been degraded or destroyed. Monitoring programs—particularly those having low statistical power (Anderson 1998)—can offer a false sense of security that hides the risk of sudden population decline or extinction as a result of continued habitat loss.

Kareiva and Wennergen (1995) also suggested that:

> "*maps of fragmentation and habitat structure alone do not lend much insight without hard data on how species disperse and interact with other species. Current biodiversity mapping projects that use geographic information systems will be most useful when they are used to look at dynamics, as opposed to static snapshots, and are connected to theories that predict population dynamics as a function of landscape attributes*" (1995: 302).

We agree, but argue that research and management efforts directed toward protecting landscape functioning and biodiversity in BC have a long way to go before we have a basic idea of the diversity and abundance of plants and animals that occupy a given landscape, let alone knowledge of their migration and dispersal patterns or the dynamics of their interacting populations. In the face of this high level of uncertainty, it makes far more sense to focus on what we do know—the effects of fragmentation can be mitigated to some extent by developing landscape plans that maintaining natural landscape patterns, connectivity, and the habitat suitability of the matrix; however, habitat loss has a far greater impact on biodiversity than fragmentation (Fahrig 1997). The most rationale first step we can take toward developing forestry practices that sustain biodiversity in BC is to protect and maintain the natural habitats and landscape components that still remain. The necessary second step will involve restoring natural forest landscape patterns and habitat structures in areas that have been impacted by past development activity

Both of these goals can be made much simpler by adopting a precautionary approach in forest development planning. Implementing such an approach will involve embracing the now obvious assumption that forest development activities have both apparent and edge effect impacts, and that the actual impacts as a result extend well beyond the physical boundaries of road building and logging disturbance. Making this knowledge explicit will involve mapping the full spatial extent of the actual impacts of past road construction and logging activities, and assessing the effect this has on the size and distribution of the remaining operational landbase. Implementing the element of caution involves adjusting timber supply estimates and forest development plans accordingly, and maintaining these adjusted values until research indicates that increasing annual cutting rates and the amount of forest land logged in each landscape or watershed poses little or no ecological risk.

The first of these tasks can be achieved by clearly describing the actual impacts of past road construction and logging activity on forest development planning maps. These impacts include the physical extent of road right-of-ways and logging blocks, and the additional physical, biological, and behavioral effects that extend beyond the disturbance edge. The spatial extent of edge effects will vary among sites and variables of interest; however, review of current literature indicates that physical and biological impacts range from 0 m to about 250 m, and that behavioral impacts range from 0 m to 2 km depending on the animal or wildlife population. Adding 100 m to road and cutblock boundaries to account for physical and biological impacts, and 500 m to account for behavioral impacts, provides a reasonable average estimate of the spatial extent of actual disturbance.

The second of these tasks can be achieved by analyzing the impact these estimates have on the availability of commercially viable timber stands and suitable wildlife habitat. A study undertaken in Wyoming revealed that when edge effects were taken into account, roads and clearcuts affected 2.5 – 3.5 times the area occupied by these disturbances (Reed et al. 1996). Conducting this of type analysis during forest development planning in BC will facilitate realistic assessments of the amount of undisturbed forest that is currently available for timber management activity, and of the impact that proposed operational activity may have on landscape integrity and biodiversity. Acting on this knowledge will involve adjusting timber supply estimates to reflect the reduced available operational landbase. This reduced level of cut should be maintained until field research indicates that an increase in the area of forest land harvested each year poses little or no risk to local, regional, or provincial biodiversity.

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APPENDIX VI – Important Criteria and Parameters of Wildlife Movement Corridors—A Partial Literature Review

by Evan McKenzie R.P.Bio
(for the Southern Columbia Mountains Environmental Sector of the West Kootenay CORE Table)

INTRODUCTION

Some of the most recent literature on wildlife movement corridors was reviewed and summarized to provide a better understanding of important evaluation criteria and design parameters for corridors. The summary includes a section on "Criteria for Evaluating and Designing Corridors" and a list of important parameters that can be used by environmentalists and land use planners to design, map, and monitor inter-refuge wildlife corridors on the landscape. Also included in the summary are sections on arguments for and against corridors, important questions to ask when designing corridors, and priorities for future corridor research.

CURRENT WILDLIFE MOVEMENT CORRIDOR DEFINITIONS

Current definitions emphasize that a wildlife corridor is a linear landscape element which serves as a linkage between historically connected habitat/natural areas, and is meant to facilitate movement between these natural areas (McEuen, 1993).

ARGUMENTS FOR CORRIDORS

McEuen (1993) provides a review of both the history of and current wildlife corridor theory that includes a number of arguments for and against wildlife corridors. The possible conservation benefits of linking reserves with corridors listed in her review are as follows:

1. *Enhanced immigration*, which would enhance gene flow, increase genetic diversity, allow recolonization of extinct patches, and enhance overall metapopulation survival in connected patches.
   - This is related to the "rescue effect" concept in which immigration decreases the extinction risk of an isolated population by boosting local numbers and increasing genetic diversity which leads to increased fitness and survival.
   - Beier (1993) observed through modeling that the presence of a corridor allowing even low levels of immigration improved the probability of survival of a cougar population in Southern California.
2. The opportunity for some species to avoid predation.
3. Accommodation of range shifts due to climate change.

4. Provision of a fire escape function.
5. Maintenance of ecological process connectivity.

The fact that the natural landscape had been connected in the past may be the best argument for corridors (Noss 1987 as cited in McEuen. 1993).

ARGUMENTS AGAINST CORRIDORS

Critics of corridors feel that the corridor concept has been prematurely accepted despite the absence of data on corridor use, insufficient and/or inconclusive corridor research, and the failure to consider possible negative impacts of corridors. McEuen (1993), in her review of wildlife corridor theory, lists a number of arguments by several authors against wildlife corridors. Simberloff et a1(1992) question the rationales for movement corridors and suggest that evidence for corridor use is ambiguous or lacking. The authors also discuss the potential biological disadvantages of corridors which are included in the following list of arguments against corridors:

1. Paucity of data on corridor use and a lack of sufficient controls in corridor field studies
2. Paucity of data on significance of loss of genetic variation due to inbreeding and in small populations
3. The establishment of smaller reserves as a result of corridors
   - There is the possibility of a loss of genetic variation due to genetic drift in an ensemble of smaller refuges that would be greater than the gain in genetic diversity due to immigration and gene flow through corridors.

   NOTE: Genetic drift is the change in genetic composition of populations that result from random effects (random combinations of parent genes in the next generation)
4. Habitat unsuitability of corridors (i.e. riparian corridors will not serve as a conduit for non-riparian species)
5. High rates of poaching or trapping in corridors
6. Increased exposure to domestic animals harboring disease
7. Avenues for the spread of catastrophes (predators, fire, disease) may be provided through corridors
   - corridors have a high fraction of edge habitat and may attract edge-inhabiting predators
   - the negation of the quarantine effect of isolation would allow disease to spread between populations
8. Entry routes, avenues, and reservoirs for weedy or exotic species may potentially be provided by corridors
   - some corridors may favor movement by introduced species

9. Corridors may function as genetic traps or sinks
    - low quality (habitat) corridors could act as genetic sinks due to increased mortality. resulting in local extinctions and a decrease in the size of a metapopulation
10. Economic factors, including higher management costs due to high edge-inferior ratio and the cost of building bridges over corridors
    - preserving corridors may not be the most cost-effective way to facilitate survival of all conservation-priority target species
    - relocation of animals might be as effective as corridors and less costly
11. Conflict with other conservation acquisitions
    - Is preserving corridors sufficient to maintain species viability where wildlife refuges are insufficient ?
    - Is a corridor the only or even the best way to provide whatever movement is necessary between populations?
    - Does preserving corridors foster the belief that one has done enough and need not preserve larger tracts of valuable habitat?
12. The theory of central place foraging predicts that species with colonial social structure and that consume widely dispersed food may be disadvantaged in narrow, linear-shaped habitats (Lindenmayer and Nix, 1992). The authors observed that arboreal marsupials in Southeastern Australia with this type of social structure and foraging pattern were rarely encountered in corridors. This study indicates that some species may be poorly conserved by a network of reserves and wildlife corridors, hence wildlife corridors alone may be insufficient as a strategy for nature conservation.

Critics of the corridor concept also pose the following philosophical questions:

- Although the concept of corridors is easily understood, is it good conservation biology to sell legislators and the public on the easiest program for them to understand, in the absence of evidence that it is the most effective one?
- Is it beneficial for people to feel they are doing something important for conservation by preserving corridors in the absence of evidence that they really are doing something?

CONSERVATION-STRATEGY ALTERNATIVES TO CORRIDORS

General alternative strategies to wildlife corridors have been proposed to facilitate population survival where refuges alone are insufficient. Several of these strategies suggested by Simberloff et al (1992)consist of:

- providing a network of unconnected patches of forest or "stepping stone" remnants to facilitate the persistence of populations

  - ⇒ "stepping stone" patches on their own, or in conjunction with corridors, could be part of an entire landscape managed for both extraction and conservation

- managing the entire landscape as a matrix that supports the entire biotic community
  - ⇒ Thomas et al (1990), as cited in Simberloff et al (1992), suggest managing the entire matrix surrounding Northern Sported Owl habitat conservation areas to make it suitable for owl dispersal in random directions
  - ⇒ it is important to determine the life-histories and habitats of target species before attempting this type of conservation strategy

DESPITE CRITICISMS OF THE CORRIDOR CONCEPT AND ARGUMENTS AGAINST CORRIDORS, MOST RECENT THEORISTS HAVE SIDED IN FAVOR OF CORRIDORS AND FEEL THAT, ALTHOUGH BY NO MEANS PERFECT, THEY ARE THE BEST SOLUTION TO A COMPLEX PROBLEM (McEuen. 1993).

IMPORTANT QUESTIONS TO ASK WHEN DESIGNING CORRIDORS

Which types of species (species groups) utilize corridors?

How does residency within corridors and movement rates through corridors differ among species groups?

How does utilization by species groups change with changing corridor conditions (shape, width, length, location, and vegetation composition)?

How do habitat requirements and a species' perception of the environment affect the utility of corridors, for example, does a particular target species have the ability to distinguish and utilize a corridor?

Will corridors provide avenues of movement for exotic species and disease as well as for native target species?

What types of wildlife movement and habitat do you want to conserve within corridors, i.e. what are the conservation goals for a particular corridor?

CRITERIA FOR EVALUATING AND DESIGNING CORRIDORS

Species Groups and Target Species

When evaluating a corridor, it is important to determine which species the corridor will serve. Corridor use can be evaluated with respect to both broad species groups or specific target species.

McEuen (1993) groups potential corridor users into six species categories that might be important to corridor theory and research. The categories include:

- edge vs. interior species
- exotic vs. native species
- regionally abundant vs. regionally rare species
- generalists vs. specialists
- coarse-grain vs. fine-grain species
- naturally fragmented vs. naturally continuous habitat species

Beier and Loe (1992) group corridor users into two general types: <u>passage species</u> and <u>corridor dwellers</u>. Passage species include large herbivores and medium to large carnivores that need corridors to allow individuals to pass directly between two areas in discrete events of brief duration. For these species. corridors facilitate juvenile dispersal. seasonal migration and home range connectivity. Corridor dwellers include species with limited dispersal ability that take several days to several generations to pass through a corridor. These species must be able to live in the corridor for extended periods. Therefore, the corridor must provide most or all of the species' life-history requirements. Corridor dwellers include most plants, reptiles, amphibians, insects, small mammals, and birds with limited dispersal ability.
A <u>target species</u> may be any species that has the greatest need for a corridor to survive, or an “umbrella species" whose protection will likely provide benefits to the greatest number of other species. Current wildlife corridor theorists place an increased emphasis on the need to design corridors specifically for native, conservation-priority target species. Beier and Loe (1992) reinforce the importance of the target species by stating that the species of interest is the most important factor of a number of parameters used to determine corridor width.

<u>Movement and Habitat Types</u>

Stenseth and Lidicker (1992), as cited in McEuen (1993), refer to three types of movement in corridors and three types of habitat. The three types of movement include:

- *dispersal* . . . one way movement away from a home site
- *migration* . . . round trip movements
- *home range* movements

The three habitat types include:

- *transitional habitat* . . . suitable only for movement of a disperser
- *marginal habitat* . . . allows survival and sometimes reproduction
- *survival habitat* . . . “good habitat" in which both survival and reproduction can occur

The two types of corridor users described by Beier and Loe (1992) in the above section are compatible with these movement and habitat types. Passage species demonstrate dispersal and migration movements and may utilize all three habitat types. Corridor dwellers have home range movements and would use the survival, and to a lesser extent, the marginal habitat types.

Models for Corridor Movement

Based on the different types of movement and habitat, McEuen (1993) proposes two models for corridor movement. Model A illustrates that a corridor consisting of transitional habitat facilitates only dispersal and migration movements of passage species. Model B shows that a corridor containing survival habitat throughout facilitates residency of corridor dwellers throughout the corridor, with home range movements occurring entirely within the corridor.
In Model A, length and optimal width of a corridor are critical issues, since dispersers must reach the other patch to reproduce. Increased length and width (beyond optimum) would reduce chances of dispersers reaching a connected parch.
In Model B, length and optimal width of a corridor are no longer issues because there is no need for an individual to reach the other patch. Minimum width, based on edge-effects, may still be a critical parameter in this model.

Important Criteria For Evaluating The Suitability Of Corridors

Beier and Loe (1992) suggest five functional criteria that can be used to evaluate corridor suitability. Corridors are considered suitable for wildlife movements if they provide avenues along which:

1. wide-ranging animals can travel, migrate and meet mates
2. plants can propagate
3. generic interchange can occur
4. populations can move in response to environmental changes and natural disasters
5. individuals can recolonize habitats from which populations have been locally extirpated

These five functions should be used to evaluate the suitability of land as a wildlife corridor. A corridor is suitable when it meets the five functions for each target species.

Beier and Loe (1992) also provide a checklist for evaluating and designing corridors. The checklist can be used as a means to improve the treatment of wildlife corridors in environmental impact analyses of development activities such as roads, power and gas pipeline corridors, logging, mining, recreation facilities, urbanization, clearing for agriculture, etc. Observations made by other researchers are included in the checklist to embellish upon certain points.

A Checklist for Evaluating and Designing Corridors

1. **Identify the habitat areas (specific target areas) the corridor is designed to connect.** Determine if the areas will remain suitable habitat in the future.
2. **Select several species of interest (target species) from the species present in these areas.** Focus on "umbrella species" whose protection is expected to provide benefits to the greatest number of species, and on species that have the greatest need for a corridor for survival.
3. **Evaluate the relevant needs of each selected species.** For passage species, identify movement and dispersal patterns. including seasonal migrations, of local animals. For corridor dwellers, identify habitat needs including special needs such as nesting, rearing, or germination sites, as well as dispersal or migratory patterns of the animals.
   - Examination of movement pattern during natal dispersal can provide insights into the requirements of corridors (Harrison 1992).
   - The level of predation risk strongly affects dispersal patterns and must be considered in corridor design (Harrison 1992).
   - Lindenmayer and Nix (1992) state that the effectiveness of wildlife corridors may be improved by considering the social structure, diet, and foraging patterns of target species
4. **For each potential corridor. evaluate how the area will accommodate movement by each species of interest (i.e. evaluate availability of suitable habitat).** Important questions to consider for both passage species and corridor dwellers are as follows:
   - Given the animals' movement patterns, are the topography, vegetation and location of the corridor such that individuals will encounter, enter and follow or live in the corridor?
   - Is there sufficient shelter, cover, food, and water for passage species animals to reach the other end?
   - Does the habitat meet the life-history needs of corridor dwellers?
   - What are the current and future impediments to use of the corridor (i.e. gaps, domestic animals, and human activities)?
   - The effectiveness of wildlife corridors may be improved by considering the landscape context of a corridor (Lindenmayer and Nix. 1992). Successional changes affecting suitability of habitat in areas adjacent to a corridor may influence the use of the retained area by wildlife. Such changes highlight the potential influence of the status of a surrounding area on the biota within a corridor, and thus the landscape context of a wildlife corridor. The landscape context criteria may also indicate the need for buffer zones around wildlife corridors.

- For wildlife corridors to alleviate the effects of global warming, regional corridors may need to preserve entire communities and serve as habitat that permits survival and breeding for passage species as well as corridor dwellers, not just linkages for movement (Simberloff et al, 1992).

5. **Draw the corridor(s) on a map.** Effective protection of wildlife corridors requires putting them on a map. This step includes connecting larger habitat areas, stating the corridor widths, describing the vegetation and topography, and explaining how each corridor meets the needs of target species. It is also important to specific management guidelines for each corridor.

   - Important management guideline questions to consider during this step include:

     ⇒ Are there any prohibitions on land uses within the corridor that will impede functioning as a corridor (i.e. approved logging plans for the next 1-2 years)?

     ⇒ What land uses may be permitted adjacent to the corridor?

     ⇒ How should domestic animals and human activities be controlled in and adjacent to corridors?

     ⇒ How should future road crossings be designed (i.e. minimize crossings and include underpasses and animal guide fences)?

     ⇒ What recommended changes can be made to enhance the utility of the corridor (i.e. restoration)?

   - Use a geographic information system (GIS) that covers a regional landscape for putting wildlife corridors and other critical habitat on planners' maps. GIS provides the only efficient means of addressing cumulative impacts and an accessible forum on which developers, conservationists, and other citizens can express their vision of the regional landscape.

6. **Design a monitoring program.** This step includes monitoring animal use of each project-impacted corridor to determine the failure or success of various designs. Monitoring will yield the data needed to preserve or create functional corridors in the future. Monitoring programs can include track monitoring, photography, radiotelemetry, and measures of gene flow.

   - Monitoring for corridor use should occur:

     ⇒ before and after a development project

     ⇒ on the adjacent matrix outside the corridor before and after development

     ⇒ to determine preproject use of any forfeited corridor that will be destroyed by a project

     ⇒ on at least one undisturbed corridor, before and after development, to provide a control for effects that might affect animal movement

NO WILDLIFE CORRIDOR DESIGN SHOULD BE APPROVED WITHOUT MANDATING THAT THE PROJECT PROPONENT FUND MONITORING PROGRAMS TO DETERMINE USE OF THE PROPOSED CORRIDOR

Site-specific data (utilization of corridor) in conjunction with model conclusions is sufficient documentation to protect a corridor. In a study to determine minimum habitat areas and habitat corridors for cougars in Southern California, Beier (1993) collected site-specific data using radio telemetry to confirm use of corridors by cougars in the Santa Ana Mountain Range. The field study showed that telemetered cougars could quickly identify movement corridors.

Important Corridor Design Parameters

A number of parameters have been observed to be important in affecting wildlife movements in recent wildlife corridor research studies. Some of the most important parameters are listed below.

Habitat:

Habitat has been observed to be a critical design parameter of corridors. The extent to which a corridor will be used by dispersers depends upon the habitat within the landscape linkage.

It is important to have patches connected by "high-quality" habitat that provides for both species survival and reproduction. Henein and Merriam (1990) observed that for two isolated parches, increasing the number of high quality corridors increased metapopulation size, while adding low-quality habitat corridors actually decreased metapopulation size. They also observed that the addition to a metapopulation of a patch connected by a low-quality corridor had a negative effect on the metapopulation size, indicating increased mortality during movement.
Dispersal patterns for some prey and associated predator species indicate that effective corridors must contain enough "suitable habitat" for the target species to reside permanently within the corridor and to permit normal dispersal (Harrison 1992).

NOTE: "suitable habitat" Is synonymous with "high-quality" habitat and "good habitat".

Continuous "suitable habitat" corridors are preferable to facilitate wildlife movements as corridor function is thought to be hindered by the presence of gaps. Data from Lovejoy et al (1986), as cited in McEuen (1993), supports this theory. Harrison (1992) also states that gaps between suitable habitat should be small relative to dispersal distances. A CORRIDOR IS ONLY AS STRONG AS ITS WEAKEST LINK (Beier, 1993).

- A strong tendency to remain within suitable habitat while dispersing has been observed in studies of several species of rodents (Harrison, 1992).

Several wildlife species indicated a preference for wider and more complex vegetation corridors, as shown in recent studies that observed the combined effects of width and vegetation composition on corridor use (McEuen 1993).

Corridor Shape:

Linear corridor shape was found to be superior to all other shapes modeled in the first theoretical model on corridor capability developed by Soule and Gilpin (1991) as cited in McEuen (1993).

Corridor Width:

Corridors may have an optimum width determined by edge effect and the tendency of dispersing animals to wander (Soule and Gilpin, 1991, as cited in McEuen, 1993). Minimum widths of corridors may be estimated from data on target species home range sizes and shapes as well as considering widths necessary to maintain desired habitat against penetration of other vegetation types from edges (Harrison, 1992). Harrison also suggests that if a corridor is to contain enough suitable habitat for a given species to permanently occupy the corridor, then the corridor must be at least as wide as the width of one home range and contain home ranges that are designed to be rectangular and twice as long as wide.

Corridor Length:

Effective corridors may be narrower than minimum width based on home range size if they are less than the length of one average home range, so that dispersers may pass through without foraging (Harrison, 1992).

Corridor Location:

The location of a corridor may be affected by the relationship between seasonal movement patterns and the specific purpose of the corridor (Harrison, 1992). For example, it is important to locate corridors for migrating or wide-ranging species using seasonal ranges based on the time of migration or dispersal. Corridor location may be different for the different sexes of the same target species. It is also important to align corridors with other habitats that are suitable to the target species (Beier and Loe, 1992).

Landscape Context:

The "context" of the wildlife corridors in the landscape may be important for corridor use. In a study on arboreal marsupials in southeastern Australia, Lindenmayer and

Nix (1992) observed that wildlife corridors that contained a variety of topographic positions (i.e. gullies to ridges) supported more species and a greater abundance of animals than sites confined to a single topographic position, such as a midslope. This study indicates that landscape connectors with a variety of sites due topography have higher habitat, and hence, species, diversity.

Human Activities:

The effectiveness of corridors will be affected by the type and extent of human activities and land use practices both within and adjacent to the corridor (Harrison, 1992).
Important considerations include:

- the impact of hunting and trapping (both legal and illegal), intrusion of domestic dogs, livestock grazing, and disturbance due simply to human presence
- the greatest human impact will occur near towns and along roads and edges where access to the corridor is easily available
- the type of human development, such as agrarian or industrial, in the vicinity of corridors will affect the extent of harmful and illegal activities

CORRIDOR DESIGN MAY HAVE TO INCLUDE BUFFER ZONES TO REDUCE UNDESIRABLE HUMAN ACTIVITIES

PRIORITIES FOR FUTURE CORRIDOR RESEARCH

Harrison (1992) states that our knowledge of the basic principles determining the effectiveness of corridors is extremely limited and we need much more data on dispersal patterns and the use of natural corridors. He suggests the following list of critical research needs:

- monitor movements of dispersing wildlife continually in relation to habitat type, topographic features, and territories of conspecifics
- investigate cues used to determine dispersal direction
- investigate mortality and movement patterns in unsuitable habitat to determine the effect of gaps between refuges
- identify and monitor potential natural corridors such as riparian zones for dispersal movements
- determine the minimum width of effective corridors, possibly by measuring the minimum width of home ranges
- quantify the impact of human activities on wildlife populations as a function of activity and distance from roads and other developed sites

Bier and Loe (1992) suggest that future research should investigate:

- home range sizes, movement, dispersal, and habitat use patterns of target species
- minimum widths for corridors for target species based on corridor length, topography, and vegetation, and corridor location

Simberloff et al (1992) state that the value of corridors for maintaining biological diversity depends on the relative costs and benefits of a proposed corridor and alternate uses of the funds, such as purchasing wildlife habitat refuges. To date, no thorough cost-benefit analysis on the importance of movement through corridors has ever been done. Limited resources will almost certainly limit conservation strategy options. Consequently, one must be willing to set priorities, and these should be based on relative costs and benefits. Cost-benefit analyses on wildlife corridors and alternative strategies that can facilitate the setting of conservation priorities is another critical research need for the future.

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APPENDIX VII – Ecological Sensitivity to Disturbance Ratings