WORKING PLAN

Northern Wetbelt Silvicultural Systems Project :

A Study of Alternative Silvicultural Systems in Northern Wetbelt ICH and ESSF Forests

University of Northern British Columbia
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1. INTRODUCTION

Interior wet-belt Cedar-Hemlock (ICH) and Engelmann Spruce-Subalpine Fir (ESSF) forests in the northern interior of British Columbia possess a number of ecological attributes and management concerns that are unique relative to other BC Interior forest ecosystems. Interior wet-belt ESSF and ICH subzones are typified by geographic locations and forest types with most or all of the following characteristics (adapted from Jull, 1998):

1. Located on continental Interior mountain ranges of British Columbia generally windward to Pacific air masses with high winter and summer precipitation;
2. In Wet and Very Wet ICH or ESSF biogeoclimatic subzones;
3. high precipitation and snowpack, the latter particularly at higher elevations;
4. forest types naturally predominated by mature and climax forests older than 200 years of age;
5. NDT1 or NDT2 natural disturbance regime classification (BC Ministry of Forests and Ministry of Environment) with apparently low frequency and extent of natural fire relative to other continental BC ecosystems;
6. mixed species composition, multi-layered stand structure, and high levels of snags and coarse woody debris; and the
7. ecological importance of canopy processes, bryophytes and arboreal lichens due to cool, humid climates.

In British Columbia, wet-belt ESSF and ICH forests are extensive, as well as economically and ecologically important forest types. In the wet-belt ICH, coniferous forest tree species include western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), hybrid white spruce (*Picea glauca X engelmannii*), subalpine fir (*Abies lasiocarpa*), and Douglas-fir (*Pseudotsuga menziesii*). In the wet-belt ESSF, subalpine fir and Engelmann spruce (*P. engelmannii*) occur together in most natural stands. In Interior wet-belt ICH and ESSF, precipitation is high, climates cool, and the frequency and extent of stand-destroying fires low. The landscape tends to be naturally dominated by mature and old forests. Over time, forest gap creation through the death of individual trees or groups, with subsequent regeneration, has often resulted in old, complex, relatively uneven-aged stands. The regional biota includes species such as mountain caribou that are dependent on the structural attributes of these old and complex stands.

In BC, ESSF forests cover 12.94 million hectares, of which 49.4% or 6.39 million hectares are wet or very wet biogeoclimatic subzones. The less extensive but proportionately more productive ICH forests cover 5.19 million hectares, of which 27.7% or 1.44 million hectares are wet or very wet ICH subzones. In total, wet and very wet ESSF and ICH subzones cover 7.83 million hectares of forest land in British Columbia. (Marvin Eng, BCMoF Research Branch, unpublished data, 1997).

In recent decades, timber harvesting activities have been increasingly prevalent in wet-belt ICH and ESSF forests, with clearcut silvicultural systems by far the most common method. Increasingly, timber production objectives need to be balanced with non-timber resource objectives. These include old-growth and biodiversity objectives, high scenic values, mountain recreation, and mountain caribou habitat.

Traditionally, the predominantly mixed-species old stands of wet-belt ESSF and ICH forests are regarded by many silviculturists and forest resource managers as “decadent” or senescent forest types from a timber production perspective. In this context, forest managers have often argued for the complete and rapid harvest and replacement of such stands through clearcut logging. Leaving these stands unharvested, it has been argued, leaves the stands to be lost to decay processes with a presumed eventual collapse of timber and habitat values. Though widespread, these assumptions have gone relatively untested.

In recent years, there has been a widespread reappraisal of forest practices and key assumptions. Forest managers today must consider a range of resource objectives in their plans and practices. Traditional silvicultural goals of enhancing regeneration and timber growth are being increasingly complemented in prescriptions by objectives for maintenance of ecosystem processes and structural diversity, habitat elements for many plants and animals, aesthetic values, and visual quality concerns (Kohm and Franklin, 1997). Partial-cut silvicultural systems may provide forest managers with some tools for addressing multiple resource management objectives.

In northern wet-belt forests, ecosystem management concepts for maintaining the ecological processes and biodiversity of natural stands increasingly include the recommendation of silvicultural systems in which structural elements of the original stand, including living trees, standing dead trees, and fallen trees are carried forward into the post-harvest stand. Stands resulting from treatments based on these concepts would develop and maintain complex stand structures with diverse horizontal and vertical structure and species compositions. Silvicultural approaches for complex stands have been variously termed partial-cut silvicultural systems (BC Ministry of Forests et *al*., 1995b), variable retention systems (e.g. - Franklin *et al*., 1997), partial retention logging, patch retention, new forestry, and new perspectives forestry. Regardless of terminology, the common element of all these approaches is the prescribed post-harvest retention of living and or dead trees and related stand structural elements (e.g. residual live trees, coarse woody debris) within a harvested area.

This study addresses the need for enhanced testing and improved knowledge of alternative silvicultural systems in the wet-belt ICH and ESSF subzones of the Northern Rockies and northern Cariboo Mountains in the Prince George Forest Region. Improved knowledge of silvicultural system options and outcomes will help forest managers meet resource and ecosystem management goals. While the ICH and ESSF subzones of the northern wet-belt broadly resemble similar ecosystems elsewhere in British Columbia, the northern wet-belt also has distinctive characteristics which set it apart from other ICH and ESSF subzones in BC.

Provincially, the ICH zone occurs at low to middle elevations of the interior wet-belt from the United States border in the south to the MacGregor River drainage in the north (Ketcheson et al., 1991) As well, there is a discontinuous area of ICH in the Nass Basin and adjacent mountains of northwestern British Columbia, which is floristically and climatically intermediate between coastal and Interior conditions. Southern subzones of the ICH are warmer and usually drier than those in the northern Cariboo and Rocky Mountains, and support a different assemblage of tree species. The extensive area of cedar-dominated old-growth stands in this northern region distinguishes the northern ICH wet-belt from other ICH subzones further south or west. The combination of humidity and continentality may be unique in the world (Goward, 1995). The distinctive climate and species composition of the ICH subzones in the northern wet-belt further justifies and reinforces the need for regionally-based silvicultural systems testing and research.

Likewise, as reviewed and summarized extensively by Farnden (1994), the ecological conditions, climate, and processes characteristic of northern Interior ESSF subzones in this region appear to differ substantially from more southerly ESSF subzones. A replicated series of ESSF silvicultural systems trials is therefore justified in the Prince George Forest Region to ensure that results of comparative trials of different silvicultural systems reflect the ecological response of northen ESSF ecosystems.

The study described in this working plan builds conceptually on earlier (and continuing) local "first-generation" research trials at Fleet Creek in the ICHwk3 subzone (Stevenson et al, 1994; Jull et al, 1999), and at Lucille Mountain in the ESSFmm subzone near McBride BC (DeLong et al, 1991; Jull et al, 1996). This study also complements other regional silvicultural systems research trials in throughout British Columbia. These include ESSF trials at Sicamous Creek in the Kamloops Region (Hollstedt and Vyse, 1997) and in the Quesnel Highlands in the Cariboo Region (Sutherland et al, 1991; Newsome et al, 2000). As well, there are similar ICH trials at Date Creek in the Prince Rupert Region (Coates et al, 1997) and Keystone Creek and other trials in the Revelstoke District (Waters et al, 1997).

This study is an experimental test and comparison of alternative silvicultural systems in wet-belt ICH and ESSF forests. The study will consist of a replicated series of clearcut, partial-cut, and uncut control treatments in the northern wet-belt subzones. These "second-generation" replicated trials will test early findings of other local trials at a large spatial scale, broad geographic scale, and across a broad range of treatments. Pre-harvest baseline conditions will be documented. Post-harvest treatment response variables, including changes in stand structural attributes, coarse woody debris, conifer regeneration performance, understory vegetation response, and windthrow will be examined. Study areas will provide useful demonstration sites for foresters, decision-makers, and the public, and will provide other research opportunities in the future.

2. IDENTIFIED RESEARCH NEEDS

Forest managers today are faced with the challenge of trying to design and implement timber harvest and silvicultural system prescriptions that address multiple ecological, social, and economic objectives. These often call for the development and maintenance of complex stand structures with diverse horizontal and vertical structure and species compositions (Franklin *et al.*, 1997). While such prescriptions are gradually becoming more commonplace in British Columbia and western North America, our understanding of the short-term and longer-term outcomes of creating such complex stand structures is rudimentary at best. There are few well-documented long-term examples or empirical data to rely on for guidance. The old age, diversity and variability of many forest types in wet mountainous areas of British Columbia and western North America greatly compounds these knowledge gaps and resultant management uncertainty.

Weetman (1996) summarized a wide range of information on European and North American approaches to silvicultural systems and their potential application in British Columbia. Notably, Weetman observed that:
"Public demands for partial-cutting silvicultural systems in very old forests (in BC) call for a type of 'geriatric' silviculture that has never been practised before, not even in Europe. …These demands for cut modification in 150- to 500-year-old western mountain ecosystems focus close attention on stand structure and stand development. In particular, there is a demand for stand management objectives such as maintenance of old-growth structure, biological diversity, and vertical stand structure on cutover conditions. The feasibility of such objectives for many forest types and sites is questionable…"

Among other recommendations, Weetman recommended that research strategies to meet the new demands for silvicultural systems in the western Canadian mountains require the following:
- an analysis of stand structure and stand development in old-growth and second-growth forests;
- a program of adaptive management, i.e. - a system of good feedback from operational successes and failures on each major site type and forest site combination, no matter which system is used;
- a co-operative program between industry and government to develop and test a range of feasible silviculture prescriptions that are carefully documented and measured.

Franklin et al (1997), also promoted formal research on retention harvest approaches, noting that "particularly critical are experiments designed to provide quantitative information about the types and levels of structures and spatial patterns of retention to achieve various objectives." They stated that " the relative merits of dispersed and aggregated retention currently rank as one of the most important silvicultural research questions associated with retention harvest approaches. This is because of the important economic and operational trade-offs between the two approaches as well as issues of ecological effectiveness. Currently there are no empirical data comparing the two approaches."

Recently, forest researchers and operational practitioners from around British Columbia identified key research directions and information needs in Interior wet-belt ESSF and ICH forests at the University of Northern British Columbia in June, 1997 (compiled by Jull et al, 1998, pp. 61-66). These included the need for a greater number of practical operational demonstration sites of different harvest methods and silvicultural systems, for multiple public audiences (professional, technical, and public). Specific research needs identified included:

- Greater understanding of 'natural' stand dynamics and responses of ecosystem processes to harvest methods,
- Strategies to ensure silvicultural systems are more ecologically sound both in function and appearance, and to identify the critical ecological processes and attributes that need to be maintained in the stand, and;
- Research on the effects of different harvesting systems on regeneration and leave trees (natural and artificial, advance regeneration, ingress of natural regeneration, performance of residual leave trees, and mortality and damage to leave trees).

3. LITERATURE REVIEW: Influence of Silvicultural Systems on Structural Biodiversity

In the northern wet-belt ESSF and ICH occurring in the Northern Rocky Mountains, large, catastrophic, stand-initiating fires appear to be very rare. In these forests, classified as Natural Disturbance Type 1 and 2 (NDT1 and NDT2) in the Biodiversity Guidebook (B.C. Ministry of Forests and Ministry of Environment 1995), small disturbances in which one or a few trees are killed seem to be the most important agents of natural forest regeneration. The canopy gaps, standing dead trees, vegetation mosaics, and coarse woody debris that result from small-scale mortality events may have a pervasive influence on the ecology of these forests, including tree recruitment, understory vegetation dynamics, wildlife habitat, stream structure and dynamics, biomass dynamics, and carbon budgets (Lertzman *et al.,* 1996).

Increased scientific understanding of the ecology of natural disturbances has led to a paradigm shift in forest management, described by Rogers (1996). In the past, managers have viewed disturbances negatively, and have often tried to suppress them. Many of these attempts, such as fire suppression and insecticide application, have been found to have unanticipated negative consequences of their own. The disturbances themselves have been shown to have a key role in maintaining the ecosystem processes essential to forest productivity and biodiversity. Increasingly, managers view disturbances as natural processes that must be maintained if we wish to maintain ecological integrity.

Furthermore, natural disturbance regimes are seen today not only as natural processes of value, but as models for management regimes. Thus, the Biodiversity Guidebook states as its first principle, “The more that managed forests resemble the forests that were established from natural disturbances, the greater the probability that all native species and ecological processes will be maintained.” (B.C. Ministry of Forests and Ministry of Environment, 1995). This assumption, while widely held, has been little tested in a scientific context.

The landscape pattern that results from logging may be conceptualized as a secondary mosaic of disturbance overlaying nature’s disturbance regimes (Ripple *et al.* 1991). Regardless of whether or not the human-caused disturbance pattern resembles the natural disturbance pattern, the natural agents of disturbance continue to operate. However, the frequency, severity, and nature of these natural disturbances may be affected by forest harvesting. In some areas foresters expect that windthrow will occur routinely along the downwind edges of cutblocks. They also know that windthrown timber can increase the probability of spruce beetle *(Dendroctonus rufipennis)* epidemics or of fire (Stathers *et al.* 1994). Forest harvesting can upset the equilibrium between the root disease *Armillaria ostoyae* and its host, so that within three years the stumps become a source of inoculum, spreading the disease to advanced regeneration, mature trees along the edges of openings, and seedlings (Morrison and Mallett 1996).

Although disturbance ecology is currently an active area of research, we are aware of little work on the effects of silvicultural systems on the disturbance regimes and development of structural attributes in the residual stands. Some specific relationships have been examined. For example, silvicultural systems that result in multi-storied stands are thought to be more susceptible to spruce budworm than silvicultural systems that produce even-aged stands (Carlson and Schmidt

1989, Wulf and Cates 1984). Windthrow in circular retention patches of Norway spruce *(Picea abies)* in a clearcut in Sweden ranged from 30% of the stems in a 1-ha patch to 98% of the stems in a 1/16-ha patch (Esseen 1994). In contrast, 6.5% and 7.2% of the trees $\geq$ 7.5 cm dbh blew down in wildlife tree patches in two study areas in the Prince Rupert Forest Region (D. Steventon, unpublished data). Nevill and Whitehead (1996) examined the occurrence of decay organisms and insects in windthrown trees in partially cut stands in the coastal western hemlock zone. However, there seems to be little information on the relationships between silvicultural systems and the overall assemblage of disturbance agents in the post-harvest stand.

Disturbance events which remove, damage, or kill single trees or small groups of trees may affect biodiversity in a variety of ways. Gaps in the canopy alter the light and precipitation regime at the forest floor, resulting in a different assemblage of understory species from that occurring under the closed canopy (Anderson *et al.* 1969, Stewart 1988). They provide habitat for wildlife that prefer openings for one or more of their life requisites, such as foraging. The pits and mounds that result from uprooted trees create a variety of soil microsites, contributing to the fine-grained heterogeneity of the forest floor (Beatty and Stone 1986). The damaged trees themselves, whether standing or fallen, provide a rich variety of habitats for the 58 vertebrate species that are obligate or frequent users of wildlife trees, and the 49 vertebrate species that are obligate or frequent users of coarse woody debris in the interior of British Columbia (Keisker, in press).

The way in which a tree is damaged or killed may also affect its value as wildlife habitat. Trees that have been attacked by insects provide foraging habitat for bark-foraging woodpeckers, nuthatches, and creepers and foliage-gleaning chickadees; these birds also play a significant role in maintaining pests at endemic levels (Machmer and Steeger 1995). Recently burned trees attract a variety of insectivorous birds, especially Black-backed Woodpeckers (Hutto 1995). In a wide variety of forest types, heartwood decay is characteristic of trees selected for nest sites by primary cavity excavating birds (Harestad and Keisker 1989, Mannon *et al.* 1980, Winternitz and Cahn *1983).* Some trees that are infected by heartwood fungi, especially Indian paint fungus *(Echinodontium tinctorium)* develop large cavities that provide habitat for a variety of wildlife, including den sites for black bears (Akenson and Henjum 1994), night roosts for Pileated Woodpeckers (Bull *et al.* 1992), and nesting and roosting sites for Vaux's Swift (Summers and Gebauer 1995). Broken tops resulting from wind damage not only provide an entrance point for heartwood fungi, they may also form nest sites for a variety of large birds, including Osprey, Red-tailed Hawk, Northern Goshawk, Great Horned Owl, and Barred Owl (Campbell *et al.* 1990). Witches' brooms resulting from rusts (*Chrysomyxa* spp.) or dwarf mistletoe (*Arceuthobium* spp.) are used as den sites by flying squirrels (Mowrey and Zasada 1984), resting sites by fishers (Weir 1995), and nest sites by Great Gray Owl and Great Horned Owl (Campbell *et al.* 1990).

Mode of death seems to have less influence on the habitat value of fallen trees than of standing trees. Some relationships have been identified. Hollow logs, created either by heartwood fungi when the tree was standing or by subsequent decay processes, are important as cover or denning sites for a variety of large mammals, including snowshoe hares, bushy-tailed woodrats, weasels, skunks, and black bears (Akenson and Henjum 1994, Maser *et al.* 1979). Some animals, such as red squirrels, cache winter food supplies in hollow logs (Maser *et al.* 1979). The root wad of uprooted trees is an important habitat feature that is used by flycatchers for perching, by grouse for dusting, by juncos for nesting, and by winter wrens for both foraging and nesting (Campbell *et al.* 1997). However, other factors, such as the size, decay stage, orientation, and quantity of coarse woody debris have a greater influence than mode of death on how the fallen trees are used by wildlife (Caza 1993).

Recent studies of natural disturbance regimes in Interior wet-belt ESSF and ICH and similar forests (Jull and Farnden *in prep.*, Lertzman 1992, Lindgren and Lewis, 1999, Parish 1997) suggest that these forests tend to be subject to frequent small-scale disturbances, but may also have a form of dynamic stability over time. Limited experience elsewhere in western North America suggests that the key to understanding stand-level responses of old-growth stands to partial-cut stand entries is knowing both the short-and long-term trends in mortality and abiotic damage to the residual stand, as well as the growth functions of individual trees. In the past, many short-term and retrospective studies have been unable to reliably assess these processes due to the limitations of methods employed.

4. STUDY OBJECTIVES

This study is a long-term experimental test and comparison of alternative silvicultural systems in wet-belt ICH and ESSF forests. The primary goal of this study is to provide short- and long-term scientific testing and comparison of alternative systems in an replicated series of controlled, operational-scale research trials in ICHwk3, ICHvk2, ESSFwk2, and ESSFwc3 subzones. Study areas will also serve as demonstration sites, and will provide related future research opportunities.

The study addresses the need for improved knowledge and comparisons of the outcomes of different silvicultural systems in northern wet-belt ICH and ESSF forests, to meet alternative resource management goals. Specifically, the study examines the stand-level and smaller-scale effects of different silvicultural systems on interior wet-belt ICH and ESSF sites, on:

- short-term and long-term stand and structural development (including live, standing dead, and downed trees), stand productivity, regeneration processes, understory vegetation development, and potential damaging agents. And;
- short-term and long-term processes of loss and creation of structural biodiversity attributes, specifically wildlife trees and coarse woody debris.

<u>Key Questions</u>

We expect that the focus of key questions being asked of the trial may evolve over time, as forest management objectives evolve. The following is not an exhaustive list, even at present.
Key management questions for wet-belt ICH and ESSF silvicultural systems considered in the design of this study are:

1. What are the effects of different silvicultural systems and harvest patterns (including no harvest) on present and future late-seral (or "old-growth") forest and habitat attributes? Can these attributes be maintained in managed or unmanaged stands?
2. What is the effect of different silvicultural systems on conifer regeneration, including species composition, vigour, growth and development, and stocking?
3. Do different silvicultural systems mitigate or exacerbate the incidence of current or future biotic or abiotic damage to forests?
4. How do different silvicultural systems (or lack of harvesting) influence the types of range of wildlife habitat features found in the resulting forest?
5. To what extent do biotic and abiotic damage agents contribute to specific habitat features?

<u>Focus</u>

As will be discussed in following sections, the study will consist of a replicated series of trials in the northern wet-belt subzones. Pre-harvest baseline site and stand conditions will be documented. Post-harvest stand-level treatment response variables to be examined include changes in the abundance, composition, and/or distribution of stand structural attributes, tree and plant species, coarse woody debris, conifer regeneration performance, understory vegetation response, and windthrow.

The study will also examine processes contributing to experimental treatment outcomes at finer spatial scales below the stand level (such as individual tree responses). The importance of individual biotic and abiotic processes on the cumulative effect of a treatment on stand-level response variables will be examined and quantified. Contributing processes will be assessed by measures of:

a) Damage or mortality due to logging activities;
b) Rate of standing mortality;
c) Wind damage and windthrow of residual growing stock (treefalls) ;
d) Rates and types of resulting habitat features due to wind, pathogen, and logging damage;
e) Composition and dynamics of advance regeneration and pole layers;
f) Regeneration dynamics and growth of natural and planted trees, and;
g) Variation in all of the above relative to distance from edges of harvested areas.

5. SITE SELECTION

Study sites are selected according to the following criteria:

1. Sites are ecologically representative of similar widespread areas in the surrounding ICH and ESSF subzones;
2. Candidate sites have sufficient area of relatively homogeneous mature forest and ecological site units for layout of a full set of treatment replicates (including uncut control areas);
3. A suitable number of candidate sites in both ICH and ESSF subzones provide replicated sets of target treatments;
4. All weather summer road access is available close to the study sites to allow efficient access for research and extension activities;
5. Prescribed experimental treatments are large enough to be operationally feasible for economic harvest on the sites;
6. Area forest licensees are involved in layout, operational planning, and partial-cut harvesting of the study sites;

Site selection in the wet-belt ESSF was constrained to mountain caribou habitat in "Medium" rated zones where partial-cut selection harvesting is permitted, but clearcut harvesting is not currently permitted.

Site selection, design, and layout follows the following process and timeline:

1. Consultation with project partners, other area licensees, public interest groups, and the research community (1995-97).
2. Identification of preliminary candidate areas based on helicopter and ground reconnaissance, and areas of interest based on Land and Resource Management Plan (LRMP) and Resource Management Plan (RMZ) objectives emphasizing partial-cutting silvicultural systems and related objectives (1997-98);
3. field assessment of each preliminary candidate area identified (1998) to determine:
   - operational viability and economic feasibility of harvest treatments;
   - suitability and homogeneity of area for experimental purposes, and;
   - detailed refinement of treatment units prior to submission of working plan;
4. detailed ground reconnaissance and tentative identification of boundaries of candidate areas with project team members and partners (licensees and districts; 1998);
5. preliminary treatment unit allocation (1998/99);
6. detailed evaluation of preliminary treatment unit plans with forest licensee involved (1998/99), and;
7. Detailed treatment unit and silvicultural prescription development, to research standards (1999).

6. STUDY AREA DESCRIPTIONS

Northern wet-belt ICH and ESSF subzones are located in the northern Cariboo and Rocky Mountains east of the central Interior Plateau, between the communities of Prince George and McBride BC. This general area is located between the latitude of 53 and 54^{O} 30' North, and longitude of 120 and 122^{O} West. This area includes the Rocky Mountain Trench and adjacent areas of the McGregor Mountains to the north, the Rocky Mountains to the north-east, and the northern Cariboo/Columbia Mountains to the south. This mountainous region is bisected by the upper Fraser River, and Highway 16 East, which follow the northern Rocky Mountain Trench.

The ICH biogeoclimatic subzones within the study area include the Goat River Wet Cool ICHwk3 and Very Wet Cool ICHvk2 between about 800 and 1200 metres in the Rocky Mountain trench and adjacent side valleys. The ESSF subzones in this area include the Cariboo Wet Cool ESSFwk1, Wet Cool ESSFwk3, and Wet Cold ESSFwc3 subzones at higher elevations above 1200 metre a.s.l. (BC Ministry of Forests, 1996a; 1996b).

Within this broader area of interest, 5 study areas were selected. These included three ICH study areas, and two ESSF study areas. Figure 1 shows the location of the study areas. A summary of study area information and descriptions of treatment units within each study area are provided in Sections 6.1 and 6.2, and Tables 2 and 3.

6.1 Interior Cedar Hemlock (ICH) Study Areas

The three ICH study areas include two in the ICHwk3 subzone west of McBride BC (East Twin, Minnow), and one in the ICHvk2 subzone east of Prince George, BC (Lunate Creek).

The East Twin Creek study area (53^{O} 30' N, 120^{O} 20' W) is located in the Rocky Mountains approximately 35 km north-west of McBride BC on the north-eastern side of the Fraser River. The East Twin drainage is a relatively narrow, generally steep-sided valley running perpendicular to the Rocky Mountain Trench. The East Twin study are is located between 1.0 and 3.5 km on the East Twin Forest Service Road, branching from 7.5 km of the Mountainview Forest Service Road.

The Minnow Creek ICH study area (53^{O} 28' N, 120^{O} 18' W) is located in the Rocky Mountain Trench south of the East Twin drainage. The Minnow Creek study area is located approximately 32 km north-west of McBride, BC. It is accessed at 4 km on the Minnow Creek road branching from 5.5 km of the Mountainview Forest Service Road.

Though both the Minnow and East Twin sites are in the ICHwk3 subzone, the Minnow Creek study area is distinct from the East Twin study area due to differences in elevational range, terrain and slope, aspect, and soil type. The East Twin area is representative of ICH stands in cooler, narrow steep-sided valleys, while Minnow Creek is typical of late seral ICHwk3 sites in the main Rocky Mountain Trench. Due to its location, the Minnow Creek study area has moderate visual sensitivity to harvesting, while the East Twin area does not.

The Lunate Creek ICH study area (53^{O} 50' N, 121^{O} 28' W) is located approximately 100 km east of Prince George and 110 km west of McBride BC on the southern flank of the Rocky Mountain Trench just east of the Hungary Creek drainage. The study area is accessed 6 km from Highway 16 East, on the Hungary Creek Forest Road. The Lunate Creek study area also has moderate visual sensitivity to harvesting.

6.2 Engelmann Spruce-subalpine fir (ESSF) Study Areas

The two ESSF study sites include the Pinkerton Mountain site in the ESSFwc3 subzone in the Cariboo Mountains south of the Rocky Mountain Trench, and the Bearpaw Ridge site in the ESSFwk2 subzone in the McGregor Mountains northeast of the Rocky Mountain Trench and Fraser River.

The Pinkerton Mountain ESSF silvicultural systems study area (53^{O} 37' N, 121^{O} 30' W) is located in the Cariboo Mountains 130 road kilometres southeast of Prince George, BC. The site is located at 3 km on the CP377 Road branching at 13 km on the Pinkerton Forest Service Road. The Forest Licensee A18165 is Canadian Forest Products Ltd. (formerly Northwood Inc.), of Prince George. The Pinkerton ESSF study area was harvested as part of this study, in March and April 1998. The approximately 130 hectare site is approximately 90 km ESE of Prince George, on a southwest-facing aspect at an elevation of 1350-1470 m.

The Bearpaw Ridge ESSF silvicultural systems study site (54^{O} 03' N, 121^{O} 34') is located on Canadian Forest Products Tree Farm License (TFL) 30 in the McGregor Mountains east of Prince George, BC. The site is 20 km east of McGregor, BC, and approximately 110 km east of Prince George BC. The site is adjacent to, and accessible from several recent and proposed cutblocks located between 3 and 5 km on the Crotch Creek Road, branching from 20 km on the Pass Lake Road on Tree Farm License 30. The Bearpaw site is located in the ESSFwk2 subzone (DeLong *et al.,* 1994), between the elevations of 1200 metres and 1425 metres on a northerly aspect. The Bearpaw Ridge site will be harvested by hand-felling and helicopter yarding.

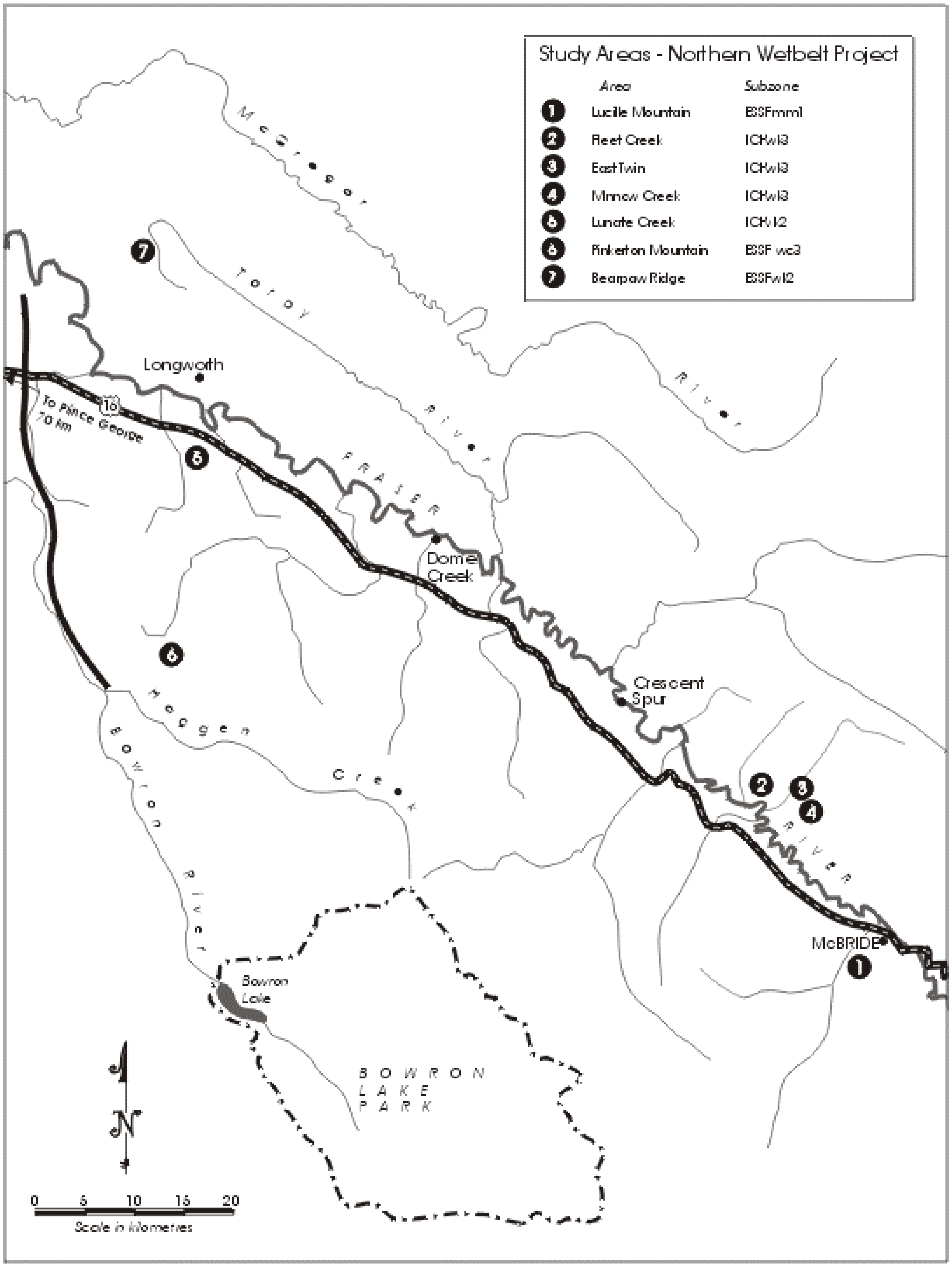

FIGURE 1: Geographic Location of EP 1119.03 ICH and ESSF Study Areas, and pre-existing Lucille Mountain (EP 1119.01) and Fleet Creek (EP 1119.02) silvicultural systems trials.

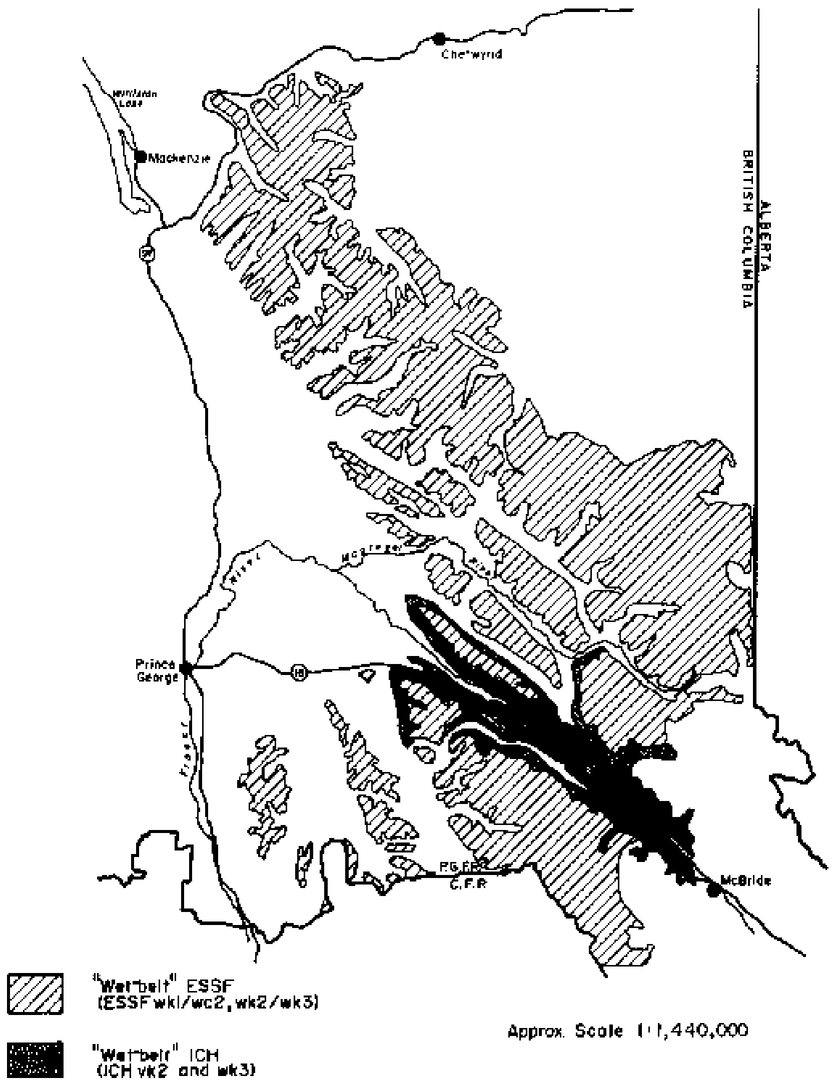

Figure 2: Distribution of Wet and Very Wet biogeoclimatic subzones of the ICH and ESSF zones in the Northern Rockies-Cariboo Mountain, east-central British Columbia.

TABLE 1: Descriptive Summary of Northern Wetbelt ICH and ESSF Silvicultural Systems Study Areas

Study Area Name	**BEC Subzone**	**Elevation range**	**Aspect**	**Slope, range**	**Forest Cover**	**Area (ha)**	**Timber Sale / Cutting Permit**
East Twin Creek	ICHwk3	900-1050 (975 m)	NW	20-65% (40%)	Cw(SxHw) 94G5	26.0	TSL A61743
Minnow Creek	ICHwk3	1050-1200 (1100 m)	SW	15-45% (30%)	Cw(SxHwBl) 94G5	39.2	TSL A61746
Lunate Creek	ICHvk2	950-1200 (1000 m)	N	25-45% (35%)	Cw(SxHwBl) 94G5	72.4	TSL A57901
Pinkerton Mountain	ESSFwc3	1300-1500 (1400 m)	SW	10-40% (25%)	SB 93M	130.0	CP 377 FL 18163
Bearpaw Ridge	ESSFwk2	1200-1450 (1375 m)	NE	20-60% (40%)	SB 93M	140.1	CP 17E TFL 30

Table 2 : Summary of ICH Treatment Areas (hectares) by Study Location

Study Location	TREATMENTS				Total Area all Treatments by Area (All Units)
	100% Retention (Uncut Control)	30% Retention (Group Retention)	70% Retention (Group Selection)	0% Retention (Clearcut)	
East Twin	9.9	-----	8.7	7.8	26.4
Minnow	9.9	10.7	11.2	7.4	39.2
Lunate	20.3	16.7	20.8	14.6	72.4
Total Area by Treatment Type	40.1	27.4	40.7	29.8	138.0

Table 3 : Summary of ESSF Treatment Areas (hectares) by Study Location

Study Location	TREATMENTS				Total All TU's by Study Area (All Units)
	Uncut Control (100% Retention)	Single-Tree Selection (70% Retention)	Group Selection (70% Retention)	Patch Cut (70% Retention)	
Pinkerton	30.0	48.0	59.0	----	137.0
Bearpaw	28.4	25.5	27.0	59.2	140.1
Total Area by Treatment Type	58.4	73.5	86.0	59.2	277.1

7. TREATMENT AND EXPERIMENTAL DESIGNS

Basic Design Principles

The range of experimental treatments selected in this study are designed to create a wide range and extremes of stand disturbance that will provide long-term scientific insights into ecosystem and stand response. This range of treatments may also represent the range of present and future operational objectives and extremes of treatment likely to be used in ICH and ESSF forest types to meet present and future resource objectives.

The size of experimental treatment units was influenced both by experimental objectives and operational harvest logistics. To assess stand-level treatment response variables with minimal edge effect, a minimum treatment-unit area of 7.5 hectares or more was set, with a desired range of 7.5 to 20 hectares. Size of ecologically homogeneous candidate study areas were 25 to 80 hectares in the ICH, and 100 to 150 in the ESSF. Due to spatial and logistical limitations on the number and range of treatment combinations that could be implemented at each study site, the number of treatments at each study area was limited to four. Treatments were replicated in different study areas (between blocks), but not replicated within study areas (within-block).

In the experimental design, the ICH and ESSF studies must each be considered as separate experiments due to:

1. differences in specific objectives of the two studies;
2. differences in the range and types of treatments applied; and
3. current forest management priorities which influence and limit the candidate sites available.

The ICH and ESSF study components differ mainly in the range and type of harvest treatments being tested. The ESSF study sites selected are constrained by established land use objectives for maintenance of mountain caribou habitat (which constrain percent volume removal per stand entry to 30%). Within this objective, a broad range of opening sizes from single-tree removals to 1.0 hectare openings are being tested. The ICH sites selected are not constrained by such land use objectives or limitations. While key questions for the ICH portion of the overall study will be addressed by manipulating and measuring treatment response to different post-harvest levels of stand retention, the ESSF portion of the study focuses on stand-level response to different opening sizes.

7.1 Interior Cedar-Hemlock Treatment and Experimental Design

7.11 ICH Treatments

The four experimental treatments designed for the three ICH study areas are as follows:

TABLE 4 : Summary of Interior Cedar-Hemlock (ICH) Treatments

Treatment Name	Removal (% basal area)	Retention (% basal area)	Size range of harvest openings or retention patches	Treatment Code
Uncut control	0 %	100 %	No harvest	*ICH-UN*
Group selection	30 %	70 %	0.1 - 0.3 ha. harvest openings (1 to 2 tree heights width)	*ICH-GS*
Group Retention	70 %	30%	0.1 - 0.3 ha. retention patches (1 to 2 tree heights width)	*ICH-GR*
0 % retention Clearcut	100 %	0%	8 to 15 ha.	*ICH-CC*

On harvested areas within each treatment unit, harvested openings generally will be planted to a 50-50 mix of western redcedar and hybrid white spruce, with minor amounts of planted Douglas-fir and subalpine fir may be included. Species composition of planted stock will be augmented by advance regeneration and natural regeneration of western redcedar, western hemlock, subalpine fir, and spruce.

7.12 ICH Experimental Design

The experimental design for the ICH study component is a randomized complete block design with three blocks (study areas). Within each block, the four treatments are replicated once and randomly allocated to treatment units.

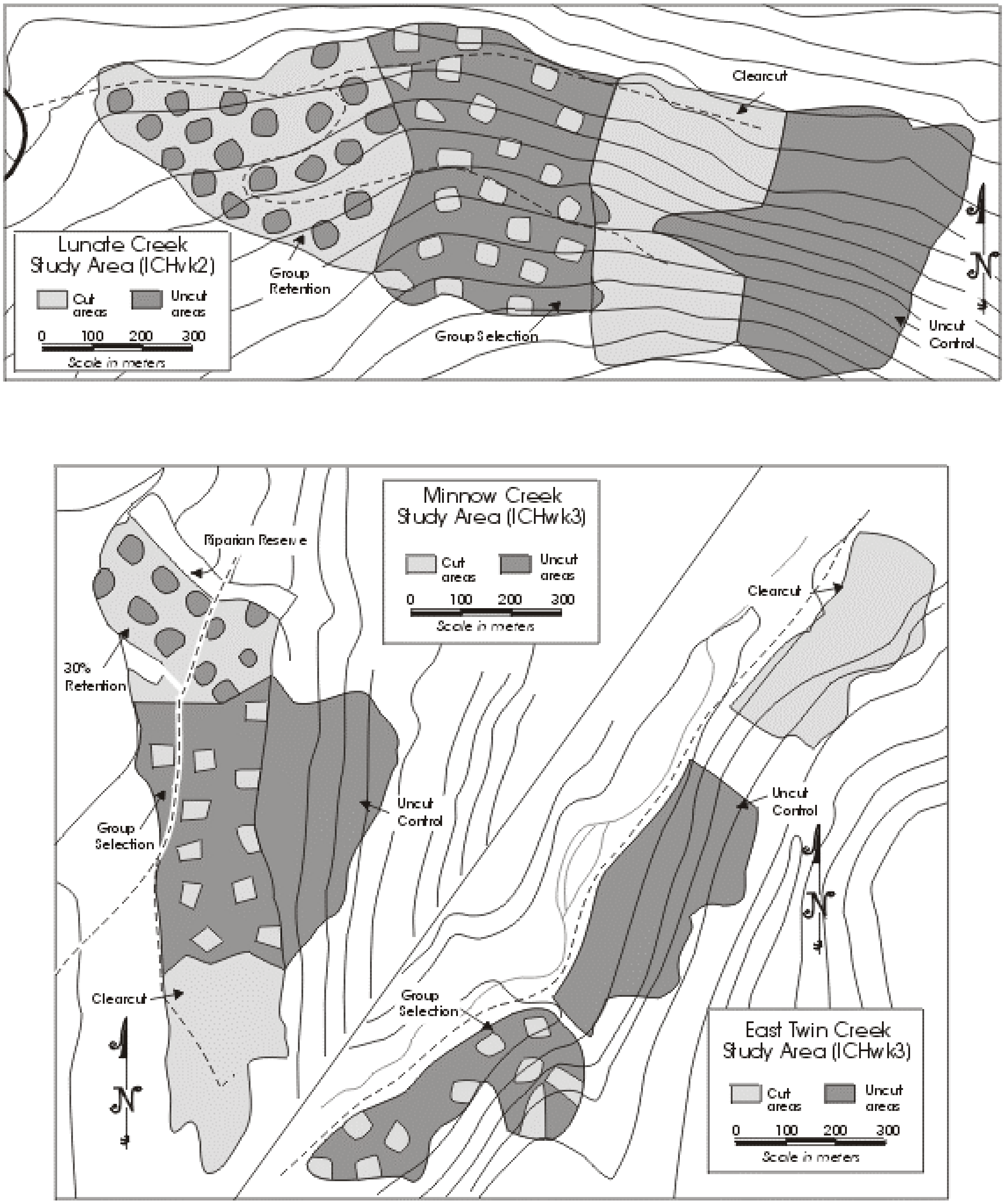

Figure 2 : Layout of Northern Wetbelt ICH Silvicultural Systems Study Areas (Lunate Creek, Minnow Creek, and East Twin Study Areas, 1:10,000 scale). Established 2000-2001.

7.2 ESSF Treatment and Experimental Design

7.21 ESSF Treatments

The four experimental treatments selected for the two ESSF study areas are as follows (Patch cut at Bearpaw only):

TABLE 5 : Summary of Engelmann Spruce-subalpine fir (ESSF) Treatments

Description	Harvest Opening Size Range	Removal (% of total area)	Treatment Code
Uncut control	n/a	0 %	*ESSF-UN*
Single-tree / clump selection	Harvest opening size range from single-tree or few trees	30 %	*ESSF-STS*
Medium group selection	0.1 - 0.3 ha (avg 0.25 ha)	30%	*ESSF-GS*
Patch Cut / Clearcut	± 1.0 ha	30%	*ESSF-PC*

On all harvested areas within each treatment unit, harvested openings will be planted with Engelmann spruce and some subalpine fir. Species composition of planted stock will be augmented by advance regeneration and natural regeneration of subalpine fir and spruce.

7.42 ESSF Experimental Design

The experimental design for the ESSF study component is a randomized incomplete block design with two replicated blocks (study area). In the two experimental blocks (Bearpaw and Pinkerton), three treatments are replicated twice and randomly allocated to treatment units within each block. The 1-hectare patch cut /clearcut treatment at Bearpaw Ridge is unreplicated within the experimental design; 20 individual 1-hectare openings are pseudo-replicated within the treatment unit at this site. The patch cut will be analysed as an unreplicated case study. One-hectare patch cut treatments were not possible at Pinkerton Mountain due to operational and logistical constraints.

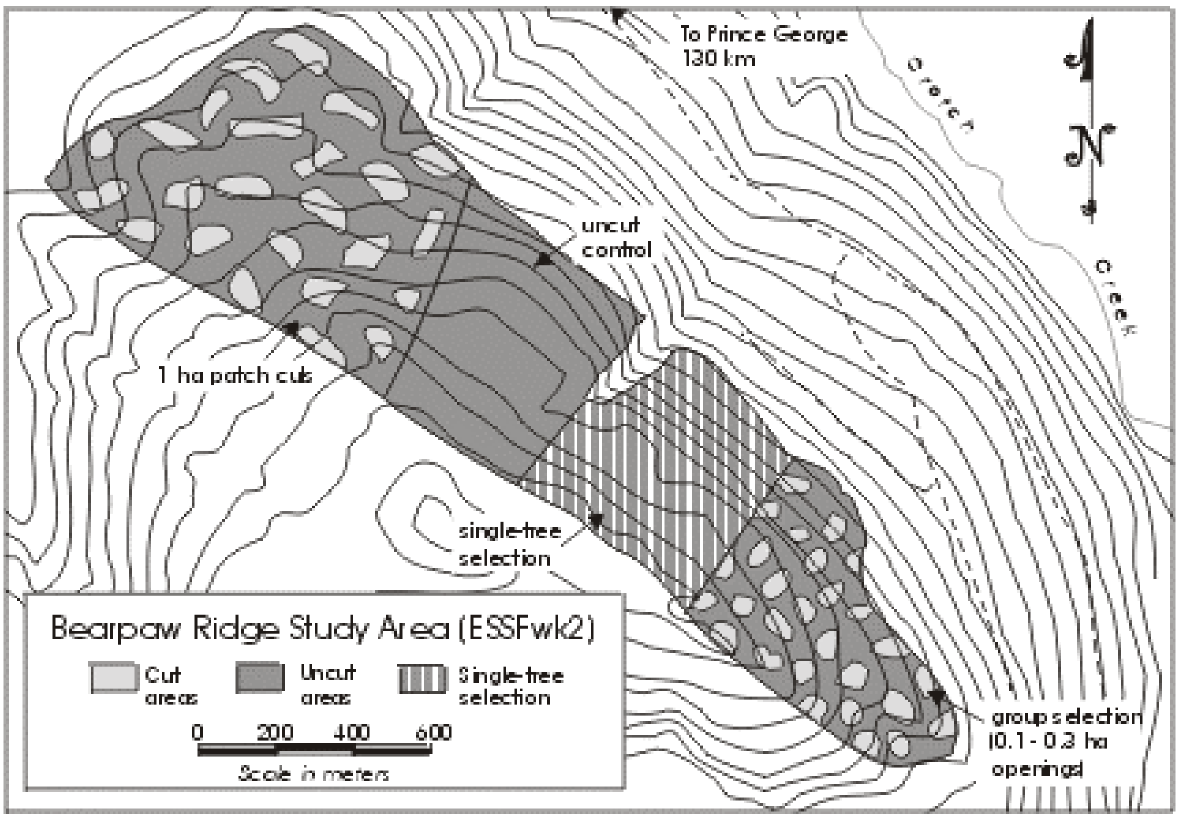

Figure 4: Experimental Design and Layout of the Bearpaw Ridge ESSF Study Area

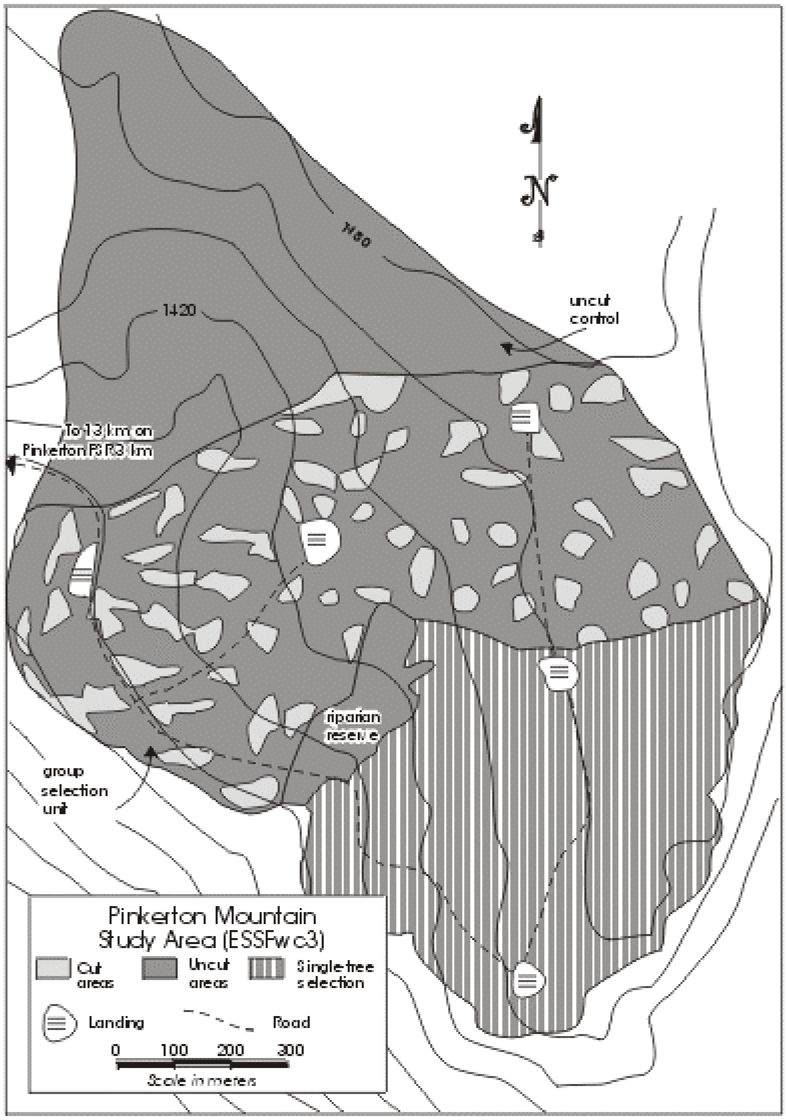

Figure 4: Experimental Design and Layout of the Pinkerton Mountain ESSF Study Area

8. DATA COLLECTION METHODS

8.1 Methods for Baseline Site Descriptions of Study Areas

8.1.1 Ecological Stratification and Description of Site Series

Prior to harvest, 1:10,000 or 20,000-scale air photo coverage is obtained and preliminary site series boundaries delineated for each study area. The study area is field sampled in the middle of the growing season when the vegetation is leafed out and fully developed (July 15th to August 15th). Transects are run 75 or 100m apart throughout the site, depending on the area of the site and the level of detail of ecological stratification necessary. Changes in site series and any map or photo ties are noted in strip field notes along the transects. Initial site series maps are developed in the field, and the site series described at a sampling intensity of one full site description with soil pit for every 2 hectares.

Site descriptions are recorded on B.C. Ministry of Environment, Lands, and Parks (MoELP) Ground Inspection Forms or FS882's. For ecosystems with more than 10% of the total area, 4 to 5 FS882's are completed to describe mineral soil to the subgroup level and detailed humus descriptions. On site series with less than 10% of the total, only 1 or 2 FS882's are completed. This site description information is then compiled to provide a field description of the site series and to identify potential soil pedon reference sites. The data is entered into Venus 4.0 (VENUS., 1999). Venus reports are used to create more complete site series descriptions for each of the study areas.

The transects and field mapping information are used to create the ecosystem map. Ecosystem maps are drafted at a scale of 1:5000, and legends developed for the maps.

For each of the study areas the following is described:

- biogeoclimatic zone, subzone and variant, and rationale for the decision if in question;
- elevation of site;
- complete site series description including vegetation by layers and soils and environment;
- where required, a description of the site phases is described and mapped; and a comparison made of the study area and site series to the other study areas in the same biogeoclimatic zone.

8.1.2 Soil Pedon Descriptions

Following the site series mapping prior to harvest, reference pedon sites (for soil pits) are selected for all site series occupying more than 10% of each study area. The number of sites chosen range between 4 and 6 per study area. For each site series stratum in each study area, reference pedon sites are selected in locations reflecting representative soil, topographical, and vegetation conditions for that stratum. At each reference site, pedons are described, classified, and sampled to a depth of 1 m or the bedrock contact, whichever is shallower. Standard soil horizon and humus form descriptions are prepared for each pedon, using criteria defined by Green et al. (1993), Soil Classification Working Group (1998), and Ministry of Forests (1998).

Samples of all described organic and mineral horizons are submitted for standard physical and chemical analyses at the Ministry of Forests analytical laboratory (Glyn Road).

In the field, locations of soil pits are clearly marked in four directions by 50 cm X 50 cm diamonds of reflective orange thick plastic sheeting, which are stapled to large trees adjacent to the soil pits, at heights of approximately 2 metres.

8.2 Sampling and Monitoring of Forest Stand Attributes

8.2.1 Overview

Sampling of stand structure and attributes is designed to collect pre- and post-harvest data on the following features:

- Live trees equal or greater than 4.0 cm dbh or dead trees greater than 17.5 cm dbh;
- Regeneration less than 4.0 dbh.
- Coarse woody debris (CWD; large dead downed tree stems) greater or equal to 7.5 cm in diameter. And;
- Understory vegetation (lichens, bryophytes, mosses, herbs, and woody shrubs).

In this study, sampling methods for all these features must be flexibly designed and adaptable enough to meet sampling objectives under a diverse range of ecological and pre- and post-treatment conditions. These conditions include:

1. Operational variability in the exact final (post-harvest) locations of minor access roads and landings, group selection openings, and group retention patches;
2. Pronounced pre-harvest differences in the spatial structure and stand density of ICH vs. ESSF stands: the pre-harvest ICH stands are relatively denser and more uniform than the open, relatively clumpy pre-harvest ESSF stands.
3. Very diverse range of post harvest stand conditions and treatment effects in different experimental units following harvesting, including:
   a) relatively uniform treatment effects in uncut controls and clearcut units (ICH and ESSF) and single-tree selection treatments (ESSF);
   b) creation of heterogeneous patchwork of harvested and uncut trees in group selection (ICH and ESSF), group retention (ICH), and patch cut (ESSF) treatments;

An overview of the sampling methods selected for collection of large-tree, regeneration, CWD, is provided in Table 6.

In general, temporary sampling methods used for characterization of forest attributes within each treatment unit prior to harvest will be replaced by permanent monitoring plots or transects in different, statistically-independent locations following harvest. In uniform treatments (UN, CC, and STS), all post-harvest sampling methods will be similar to pre-harvest methods, except that new, statistically-independent sampling locations will be established for post-harvest permanent plots. In patchy heterogeneous treatments (GS, GR), sampling methods and layout will differ from pre-harvest approaches as summarized in the previous table and following section.

The exception to the above rule is for sampling of coarse woody debris (CWD), where permanent transects will be used for both pre- and post-harvest sampling. This exception is based on the experience of Coates et al (1997), who used independent temporary pre- and post-harvest transects for sampling CWD at Date Creek. These investigators found large differences in pre and post-treatment sample means due to high population variability that was at least partially unrelated to treatment effects. For example, Coates *et al* found that, even in the uncut control units at this trial, sequential CWD surveys indicated widely divergent sample means due to high sample variance. The use of permanent CWD transects in the present trial is felt to be a more effective method for capturing a truer measure of treatment-induced changes in CWD frequency and loading in both control and treated units over time.

8.2.2 Stand Development Monitoring (Large Trees $\geq$ 4.0 cm dbh)

Based on preliminary sampling, a minimum sampling intensity of 5% by area was selected for ICH study areas, and 2.5% for the larger ESSF areas. For pre-harvest temporary plots, a plot size of 1250 m^2 or 0.125 hectare was designed to capture minimum of 60 live trees > 4.0 cm dbh per plot. Based on these criteria, and sampling cost considerations, a minimum sample size of 8 stand development plots per treatment unit was determined. At the Bearpaw study area, a greater sample size was established. Plots were systematically established in each treatment unit, usually in a grid pattern along strip lines at pre-set distances.

For pre-harvest temporary plots are circular temporary fixed-radius plots are established systematically, usually at locations along strip lines through out the treatment. Where locations of planned and existing landings and bladed roads are known, plot locations were adjusted so that plot boundaries are $\geq$ 30 m away from the plot centre. The circular plots are established as per the general plot layout methods described by the Forest Productivity Council (BC Ministry of Forests, 1998).

Based on higher-than-needed numbers of stems per plot in pre-harvest sampling, post-harvest permanent sample plot sizes were reduced to 1000 m^2 or 0.1 hectare. Layout of post-harvest permanent stand development plots (PSDP's) as follows. The 9 plot and sector corners in the standardized 20mX50m rectangular plots are marked with large 1.5" wide 1 metre high angle-iron posts painted with red rust- inhibiting enamel Tremclad™ paint. Within each transect identified for sampling, all large trees > 4.0 cm dbh meeting the above criteria will be identified, tagged, location within the transect recorded (distance along centre-line), and all applicable data recorded as per above standards.

For treatment units with a relatively uniform distribution of residual stems (i.e. - uncut control units, clearcut units, ESSF single-tree selection treatments), plots will be laid out on a systematic grid pattern.

In treatment units where the treatment produces a patchy, heterogeneous spatial distribution of residual stems (group selection, group retention), plot location and layout will be modified. For patchy heterogenous treatments, the sampling method must to adequately sample and describe the continuous gradient of edge and interior stand conditions created by these treatments. To achieve this objective, fixed-area sample transects are laid out following harvesting, commencing from the centre of a randomly-selected group selection opening (or group retention patch), and ending in the centre of a second randomly-selected adjacent harvest opening or retention patch. The transects will have a standard fixed width of 20 metres (2X10m on either side of transect centre line) in order to generate per-hectare statistics. The transects to be sampled will be selected based on systematic random sampling, from the total population of possible transects within the treatment unit. Within each transect identified for sampling, all large trees > 4.0 cm dbh meeting the above criteria will be identified, tagged, location within the transect recorded (distance along centre-line), and all applicable data recorded as per above standards.

The process for physical layout of the strip-transect plots is as follows. Relevant information for location and re-location of plots will be recorded on a plot establishment form developed for this project.

1. In the field season following completion of harvesting, the centre of each selected group selection opening or group retention patch will be determined by locating the intersection of the long axis and short axis of these units. At this centre point, a metal angle-iron station marker will be installed and labelled, with identifying aluminum tagged with applicable information denoting patch or group number and location information.
2. The bearing for the straight-line transect joining the centres of the two adjacent patches and forming the centre-line, will be determined and verified in the field to ensure accuracy. The point of commencement of the transect line will be designated as zero metres on the transect. Once the transect is laid out and flagged in the field, metal posts with affixed information will also be installed at the two stand edges (internal harvest boundaries) encountered along the transect, and distance recorded. At the point of intersection of a harvest boundary nd the centreline, corner posts for the PSDP will be installed 10 metres in 2 directions perpendicular from the centre-line.

3. All live trees > 4.0 cm dbh and dead standing trees > 17.5 cm dbh with point of germination within the transect will be fixed at breast height (1.3 metres) with a red plastic numbered tree tag nailed to the tree with an aluminum nail. Harvested cut stumps > 17.5 cm at stump height will be described by tree species, diameter at the top of the stump, and height from the point of germination to the top of the stump. The tag shall face directly towards the transect centre-line. Each tagged live and dead tree and stump in the plot will be stem-mapped relative to the point of commencement of the plot centre-line at the first harvest edge.

In heterogenous stand types including group selection and group retention treatments, post-harvest permanent regeneration and vegetation plots (described in the following sub-sections) are nested within both uncut portions and harvested portions of these units.

Data collected in Stand Development Plots

For each plot, the following information will be collected before the harvest for each tree ≥ 17.5 cm within the stand development plots:

a) *Basic mensurational data* (B.C. Ministry of Forests, 1998).
Species, dbh, height, percent live crown, and pathological indicators will be recorded.

b) *Wildlife tree attributes* (Resource Inventory Committee 1998).
These include Visual Appearance, Crown Condition, Bark Retention, Wood Condition, Lichen Loading, Wildlife Use, and User Species. Lichen Loading will be recorded only at Bearpaw Ridge and Pinkerton Mountain, where it is relevant to caribou habitat value.

c) *Wildlife tree type* (Keisker, in press)
The Wildlife Tree Types that pertain to each tree will be recorded. A Type is a configuration of habitat features required by one or more wildlife species for specific functions. For example, Type 1 trees, those with hard outer wood surrounding decay-softened inner wood, are needed by strong primary cavity excavators as substrates for excavation of nest-holes. The Types are described in Appendix 2.

d) *Damage agents* (Resource Inventory Committee 1998)
Damage agents will be recorded, using Allen *et al.* (1996) as a field reference.

8.2.3 Regeneration

Four 0.005-ha nested sub-plots (radius = 3.99 m) are established within each large-tree plot to measure the abundance and vigour of regeneration (trees < 4 cm dbh). In the pre-harvest temporary plots, regeneration plot centers are located at a distance of half the large-tree plot radius from the large plot center, in each of the four cardinal directions. In permanent post-harvest plots, regeneration subplots are located at the centre of each of the 4 sectors of the large-tree stand development plots, and the regeneration plot centre marked with a white painted angle-iron marker and identifying aluminum tag.

In harvested portions of the group selection and group retention treatments, regeneration sub-plots will be centred around stand development station points-of-commencements (POC's).

Data Collected

Trees less than 30 cm in height will be tallied within each regeneration plot by species and by two size classes: a) "germinants" less than 2 years old, and b) "seedlings" more than 2 years old, but less than 30.0 cm height.

The following information will be recorded for each **tree 30 cm or more in height**

- species
- height
- vigour (good / medium / poor / moribund / dead / missing)

8.2.4 Understory Vegetation Sampling:

Pre-harvest temporary plots are a standard 30 m x 30 m (0.09 ha) square in size and dimensions, while permanent post-harvest plots using stand development plot locations will be 20m X 50m or 0.1 hectare. The plots are divided into 4 sectors of equal size, and each sector is assessed and recorded individually. Moss and lichen layer, herb layer, and shrub layer are recorded. For pre-harvest sampling percent cover is only recorded for species abundance over 5% in increments of 5%. The balance of remaining species are assessed only for presence or absence, and if present, a species < 5% is given a cover of 1% on the field sheet.

In harvested portions of the group selection and group retention treatments, vegetation plots will also be centred around stand development station points-of-commencements (POC's).

8.2.5 Coarse Woody Debris Sampling

Coarse woody debris transects in each treatment unit are established in multiples of three transects. Each set of three is systematically located within the unit based on systematic random grid sampling. Within a set of transects, all three have the same original reference point; however, all three have physically separate points-of-commencement. All 3 transects proceed on randomly generated bearings from their respective points of commencement (POC). To remain consistent, direction of travel e.g. (direction in which plots were established on the strip line, along with direction in which plots are established across the block) is used to establish plot centers for transects 1 and 2. Fifty meters up the strip line, in the direction of travel, the POC for transect 2 is established. The POC for the third transect is located 50 m at a 90° bearing from the large-tree plot center.

Beginning and end points for all CWD transects are marked with 1" width 4' high angle iron markers painted with yellow rust-inhibiting enamel paint. Angle-iron markers are fixed with identifying aluminum transect labels at start and end points. Following harvest of prescribed treatment units, CWD transects in each treatment unit will be re-established as permanent transects in the same locations. In partial-cut units, the transects will be post-stratified following the harvest treatment to identify which portions of the transects are located in: a) harvested areas; b) unharvested areas, and; c) edge conditions (< 5 metres from a harvested area).

Data Collected in CWD transects

Coarse woody debris (CWD) sampling includes all pieces of CWD greater than 7.5 cm in piece diameter at the point where the center line of the CWD piece is crossed by the vertically projected transect line. Characteristics and attributes recorded, are: distance from the point of commencement (POC) of the transect, piece diameter, length and origin of the piece, decay class and CWD type (Keisker, in press), and wildlife use (if evident).

Each piece of coarse woody debris > 7.5 cm in diameter at the point where the sampling line crosses the piece will be tallied and measured according to Resource Inventory Committee (1998) procedures. As well, the following information will be recorded:

a) *Origin* (Stathers *et al.* 1994) Categories are stem break, stock break, root break, tree throw, felled, and unknown

b) *Diameter class at stump height* Categories are <25 cm, 25-50 cm, 50-75 cm, >75 cm

c) *Coarse woody debris type* (Keisker, In Press) The Types are described in Appendix 2.

d) *Wildlife use*: Sign class and type and user codes of Hatler (1991) will be used to record evidence of wildlife use.

Post-harvest data collection for coarse woody debris is the same as preharvest data collection. Pieces that are no longer intercepted by the transect line after a harvest disturbance, or due to natural processes, will be recorded as missing or absent, and new pieces deposited on the transect after a disturbance (harvesting or natural disturbance) will be added to the dataset.

Intensive CWD Tracking (ICH Control Units Only)

To provide additional detail and long-term tracking of the rate of decomposition and fate of CWD pieces of various sizes, species, and initial decay status, CWD pieces in ICH are assessed uncut control units every 10 years in conjunction with other standard CWD assessments. Included in this intensive assessment are all CWD pieces that are classes 1-4 and any that are transitional between 4 and 5. Very soft class 5 pieces, especially of smaller size, are not included, as it will be difficult to maintain stable markings, and these are most prone to accidental damage by foot traffic during assessments.

It is important that field research crews avoid disturbance or damage to the CWD piece on these transects. In working around these pieces, it will be very important to avoid stepping on or brushing against them -- this could easily damage more fragile decay classes, and compromise the integrity of our long-term monitoring.

In the uncut controls only, the intensive assessment is carried out only on included all CWD1 transects for all plots, and all CWD2 transects for odd-numbered plots.

Permanent markings on each individual piece will consist of

- two or three 10" heavy spikes driven vertically into the CWD piece, with usually 1 located at the point of intersection of the transect. These spikes with orange paint for greater visibility.
- two numbered aluminum disks (each with the same number). One is nailed onto the upper surface of the log, usually near the intersection point with the transect, and the other is attached by brass wire looped around the circumference of the log at a suspended portion. Tag numbers must be a unique identifier that will be linked to our permanent records.

8.2.6 Windthrow

In addition to the sample plots used to measure and monitor most stand attributes and processes, an additional sampling strategy is used to collect data on windthrow and input of coarse woody debris. Because windthrow is by nature an episodic, infrequent, and spatially heterogeneous phenomenon, sampling of rates of windthrow will be by means of belt transects 20 m wide (10 m on each side of a center line). In uniform treatment units, these will be located at systematic intervals (e.g. - 100 m) throughout the stand. In heterogeneous treatment units, the belt transects will encircle the uncut perimeter of randomly-selected harvest openings or retention patches.

Post-harvest, transects will be surveyed and established, and all downed live and dead stems with a point of germination inside the transect will be painted with a red line at dbh and/or the point at which the stem crosses the transect centre-line. In each transect sampled after the harvest, all fallen trees 17.5 cm dbh or greater and greater than 3 m in height, living or dead, will be tagged at breast height, tallied, and sampled. The following information will be recorded:

a) treatment unit #
b) distance along transect
c) sample #
d) species
e) living or dead
g) dbh (cm)
h) height
i) type of wind damage (snapped or uprooted)
j) if snapped, height of snap
k) characterization of damage sequence (primary or secondary wind damage)
l) height to base of live crown
m) percent live crown
o) contributing factors to wind damage
p) pathological indicators

Table 6 : Overview of sampling methods by treatment unit

POPULATION OF INTEREST	Temporary Sampling of Pre-harvest Forest Attributes	Long-term Monitoring of Post-harvest Forest Attributes	
	(All treatments)	UNIFORM Treatments (UN, CC, or STS)	PATCHY Treatments (GS, GR, or PC)
Stand Development (trees > 4 cm dbh)	Temporary fixed-area circular plots	Permanent fixed-area rectangular 20 m X 50 m (0.1 ha.) stand development plots (statistically independent locations)	Permanent fixed-area 20m wide stand development plots transects from patch edge-interior-patch edge in the partially-cut stand.
Regeneration (trees > 4 cm dbh)	Temporary 3.99 m radius (0.005 ha.) fixed-area circular regeneration sub-plots (4 per stand development plot)	Permanent fixed-area 3.99 m radius (0.005 ha.) regeneration plots located at the centre of each of 4 sectors within the large-tree stand development plot.	Permanent fixed-area circular (0.005 ha.) regeneration plots located at the centre of each of 4 sectors within the large-tree stand development plot. In group retention / group selection / patch cut treatments, regeneration plots will sample both harvested and uncut areas.
Coarse Woody Debris (CWD)	Permanent 24m linear CWD transects (established pre-harvest)	Reassessment of 24m permanent linear CWD transects	Reassessment of permanent linear CWD transects
Understory Vegetation Abundance	Temporary fixed-area (0.09 ha.) 30X30m square vegetation assessment plots.	Permanent fixed-area 20m X 50m (0.1 ha.) rectangular square vegetation assessment plots (using same plot boundaries as stand development plots)	Paired permanent fixed-area 20m X 50m or 33mX33m (0.1 ha.) rectangular square vegetation assessment plots. In group retention / group selection / patch cut treatments, vegetation plots will assess both harvested and uncut areas.
Windthrow	Not applicable	Permanent 20 metre wide (10 m on either side of centreline) belt transects at approx. 100 m intervals systematic intervals within treatment units.	Permanent 20-metre-wide belt transects around the interior (uncut) edge of group selection or group retention patches.

9. DATA ANALYSIS

9.1 Response variables

For residual growing stock, the response variables are:

Sampling Unit	Response Variable
large-tree plot	change in stand basal area by species
large-tree plot	change in stand volume by species
Large-tree plot, regeneration plot	change in stem density by species and layer
regeneration plot	survival by species and size class during a time period
windthrow transect	volume windthrown during a time period

For structural biodiversity, the response variables are:

Sampling Unit	Response Variable
large-tree plot	frequency of Wildlife Tree (Visual Appearance) Classes 1-8
large-tree plot	frequency of Wildlife Use
large-tree plot	frequency of Wildlife Tree Types
large-tree plot	frequency of Damage Agents
CWD transect	coarse woody debris volume (m^3/ha)
CWD transect	frequency of CWD Decay Classes 1-5
CWD transect	frequency of CWD Types
windthrow transect	input rate of CWD (m^3/ha/yr)

9.2 Analysis of residual growing stock data

Response variables for residual growing stock will be summarized using descriptive statistics and graphic displays. The data will tested for normality and homogeneity of variance, and transformed if necessary. Analysis of variance will be used to examine significant differences for the various response variable. Generalized ANOVA models for variables measured at the large-tree plot level and the regeneration plot level in the ICH zone and the ESSF zone are in Appendix 4. Sources of variation in the ANOVA are block (3 in the ICH; 2 in the ESSF), treatment (4 in the ICH; 3 in the ESSF), large-tree plot (8), and, for some variables, regeneration plot (4). A repeated measures model is used, covering planned reassessments during the period 2000-2020 (Section 11.2).

9.3 Analysis of structural biodiversity data[1]

Most of the response variables for structural biodiversity are categorical variables, expressed as frequencies. An analysis of frequency classes is therefore proposed, using log-linear modelling (Sokal and Rohlf 1995). For inclusion in these analyses, the few variables measured on a continuous scale (e.g. volume of coarse woody debris) will also be put into class-intervals. A usable number of classes will be determined from data available from the cruise information and preliminary data collected in 1997 and 1998. The treatment response in any variable over time will be measured as changes in the frequencies of occurrence in different classes.

Each site will be analyzed separately since there is no replication of treatment within a block (site). If the response among sites is the same, then those sites could be analyzed together. The log-linear method for analyzing frequencies is analogous to the general linear model for continuous variables, as in Analysis of Variance and multiple regression. The model for a two-way contingency table (by analogy to a two-way ANOVA) is:

$$\ln f_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij}$$

where f_{ij} is the expected frequency in row *i*, column *j* of the two-way contingency table, μ is the mean of the logarithms of expected frequencies, α_i and β_j are the effects of categories *i* and *j* of factors A and B, respectively, and the interaction term $\alpha\beta_{ij}$ expresses the dependence of category *i* of factor A on category *j* of factor B (Sokal and Rohlf 1995). For multi-way tables, successive factors are added in a step-wise fashion and tested first for the presence of interactions. Testing for the significance of a factor in the log-linear model requires fitting two models, one with the factor present and one with it omitted. The *G*-statistic for goodness of fit is computed for each of the two models, and the difference between the *G*-values is used to test for the relevance of the factor concerned. A statistically significant reduction inG indicates that the factor is relevant, and can be retained in the model. The next candidate factor is then added, and so forth. An example of an analysis is:

[1] We thank Dr. Art Lance (Industrial Forestry Service Ltd., Prince George, BC) for his assistance with this section.

Trees $\geq$ 17.5 cm dbh classified by 1)wildlife tree class, 2) size class, 3) edge distance, and 4) treatment in a four-way analysis to answer the question: Does treatment affect the relative frequencies of wildlife tree classes, and, if so, is this dependent on the size of the trees and their proximity to the stand edge?

9.4 Other applications of the data

Forest ecosystems are highly complex systems characterized by many nonlinear relationships. The relationships among the various components - living trees, old and young trees, vegetation, dead trees, and the wildlife that inhabit and use these features — are poorly understood. Within these ecosystems, managers are commonly asked to make treatment decisions that will preserve and/or create desirable conditions, such as visual quality, wildlife habitat, and wood production.

Analysis of Variance, log-linear modelling, and other familiar statistical methods have limitations in their ability to provide directly useful information to managers who must deal with uncertainties in our current knowledge about complex systems. Often, managers wish to know the probabilities of certain outcomes of possible management actions. While the results of this study will not furnish this kind of information directly, they may provide input to the development of decision-support tools through methods such as Bayesian inference (Bergerud and Reed 1998) and fuzzy logic models (Cox 1994; Meester *et al.* 1998). Approaches such as these are particularly suitable to adaptive management because they lend themselves to incorporating prior knowledge and to being repeatedly updated.

10. RESEARCH ROLES AND RESPONSIBILITIES

The principal project scientific team will include the following members assigned the following primary roles and responsibilities within the project:

Scientific Team Member	Agency / Organization	Primary Roles and Responsibilities
Michael Jull *MScF, RPF*	Research Associate (Silvicultural Systems) University of Northern BC	Project Leader • Overall project management • Study working plan co-ordination and preparation; • Design and co-ordination of implementation of harvest planning and execution • Stand dynamics and productivity; • Wind damage monitoring; • Data analyses and scientific reporting.
Susan Stevenson, *MSc., RPBio*	Silvifauna Research, Prince George, BC; Adjunct Faculty Member, Biology Program, University of Northern BC	Project co-leader • Wildlife tree attributes pre- and post-harvest inventory and dynamics; • Coarse woody debris pre-and post-harvest inventory and dynamics; • Data analyses and scientific reporting.
Andrea Eastham, *MSc, Pag*	Industrial Forestry Service Ltd, Prince George BC	• Understory tree and regeneration pre- and post-harvest inventory and dynamics; • Data analyses and scientific reporting; • Overall project data management
Dr. Paul Sanborn, *PhD, Pag*	Soil Scientist, BC Ministry of Forests, Prince George Region; Adjunct Professor, Forestry Program, University of Northern BC	• Coarse woody debris pre- and post-harvest inventory and dynamics; • Data analyses, and scientific reporting. • Pre-harvest forest soils descriptions
Dr. Robert Sagar, *PhD*	RM Sagar and Associates	(if approved; 2001+) • Post-harvest installation of baseline climate reference stations at Lunate and Bearpaw; • Maintenance of Fleet Creek reference stations

11. WORK SCHEDULE

TABLE 7: Schedule of Planned Study Site Assessments

Year	Sites Remeasured	Comments
2001	East Twin ICH (2000), Minnow Creek ICH (2001), Lunate Creek ICH (2001)	Year 0 post-harvest assessment (All ICH sites)
2003	Pinkerton ESSF Bearpaw Ridge ESSF	Year 5 post-harvest assessment Year 0 post-harvest assessment
2006, 2011, 2016	East Twin ICH Minnow Creek ICH Lunate Creek ICH	Year 5, 10, and 15 post-harvest assessments (All ICH sites)
2008, 2013, 2018	Pinkerton ESSF Bearpaw Ridge ESSF	Year 10, 15 and 20 post-harvest assessments Year 5, 10, and 15 post-harvest assessments
2021+, every 5 yrs	All ICH sites	Year 20+ ICH study area remeasurements
2021+, every 5 yrs	All sites	Year 20+ ESSF study area remeasurements

12. PROJECT ARCHIVING AND DATA MANAGEMENT

12.1 Project Archiving

The approved working plan will be submitted to the BC Ministry of Forests' Research Branch under the existing EP 1119 series (*Silvicultural Systems Research in the Prince George Forest Region*).

For this working plan, EP number 1119.03 will be requested to provide consistency with existing silvicultural systems trials. The Lucille Mountain ESSF trial is already are under this EP number as EP 1119.01. The Fleet Creek working plan (previously reviewed and peer-reviewed under Ministry of Environment auspices under Silvicultural Systems funding) will be submitted to BC Ministry of Forests Research Branch and archived under EP 1119.02.

For this project, data and reports will be submitted under EP 1119.03 to ensure continuity of record keeping and data management. Backed-up data files will be archived at the University of Northern BC and at the BC Ministry of Forests, in non-magnetic compact disk or similar media, in both database and equivalent flat-file spreadsheet formats.

12.2 Project Data Management

All data will be stored in an object-oriented database, preferably in Microsoft Access 97 or a compatible database program. This storage design does not affect the form that the data is collected in the field and allows for easy extraction of data-sets in flat-files (i.e. - spreadsheets) for analyses in statistical analysis programs such as SAS, SPSS, and SYSTAT. By having all of the data (often collected under the supervision of different scientists) in one database, data analyses for use in adaptive management environments is made possible in future. Also, the documentation required to design, build, and maintain a large biological database ensures that all details are retained for use in the future, allowing smooth transfer of data and documentation to those that inherit this project.

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APPENDIX 1.

Analysis of Variance Tables

ANOVA table for analyzing stand-development (large-tree) variables in the ICH zone using a nested, repeated measures design

source of variation	degrees of freedom	error term
block B	(3-1)	
treatment T	(4-1)	BT
block x treatment BT	(3-1) (4-1)	P(BT)
plot (BT)	3x4 (8-1)	
time	(5-1)	TxP(BT)
time x B	(5-1) (3-1)	
time x T	(5-1) (4-1)	
time x BT	(5-1) (3-1) (4-1)	
time x P(BT)	(5-1)3x4(8-1)	
total	480 - 1	

ANOVA table for analyzing regeneration-plot variables in the ICH zone using a nested, repeated measures design

source of variation	degrees of freedom	error term
block B	(3-1)	
treatment T	(4-1)	BT
block x treatment BT	(3-1) (4-1)	P(BT)
plot (block x treatment) P(BT)	3x4 (8-1)	M(P(BT))
microplots in P(BT)	(4-1) (8(3x4))	
time	(5-1)	T x M(P(BT))
time x B	(5-1) (3-1)	
time x T	(5-1) (4-1)	
time x BT	(5-1) (3-1) (4-1)	
time x P(BT)	(5-1)3x4 (8-1)	
time x M(P(BT))	(5-1) (4-1) (8(3x4))	
total	1920-1	

ANOVA table for analyzing stand-development (large-tree) variables in the ESSF zone using a nested, repeated measures design

source of variation	degrees of freedom	error term
block B	(2-1)	
treatment T	(3-1)	BT
block x treatment BT	(2-1) (3-1)	P(BT)
plot (BT)	2x3 (8-1)	
time	(5-1)	T x P(BT)
time x B	(5-1) (2-1)	
time x T	(5-1) (3-1)	
time x BT	(5-1) (2-1) (3-1)	
time x P(BT)	(5-1) 2x3 (8-1)	
total	240-1	

ANOVA table for analyzing regeneration-plot variables in the ESSF zone using a nested, repeated measures design

source of variation	degrees of freedom	error term
block B	(2-1)	
treatment T	(3-1)	BT
block x treatment BT	(2-1) (3-1)	P(BT)
plot (block x treatment) P(BT)	2x3 (8-1)	M(P(BT))
microplots in P(BT)	(4-1) (8(2x3))	
time	(5-1)	T x M(P(BT))
time x B	(5-1) (2-1)	
time x T	(5-1) (3-1)	
time x P(BT)	(5-1) 2x3 (8-1)	
time x M(P(BT)	(5-1) (4-1) (8(2x3))	
total	960-1	

ANOVA table for analyzing coarse woody debris or windthrow abundance in the ICH zone using a nested, repeated measures design

source of variation	degrees of freedom	error term
block B	(3-1)	
treatment T	(4-1)	BT
block x treatment BT	(3-1) (4-1)	S(BT)
transect strips S(BT)	3x4 (4-1)	
time	(5-1)	T x S(BT)
time x B	(5-1) (3-1)	
time x T	(5-1) (3-1)	
time x BT	(5-1) (3-1) (4-1)	
time x S(BT)	(5-1) 3x4 (4-1)	
total	240-1	

ANOVA table for analyzing coarse wood debris or windthrow abundance in the ESSF zone using a nested, repeated measures design

source of variation	degrees of freedom	error term
block B	(2-1)	
treatment T	(3-1)	BT
block x treatment BT	(2-1) (3-1)	S(BT)
transect strips S(BT)	2x3 (4-1)	
time	(5-1)	T x S(BT)
time x B	(5-1) (2-1)	
time x T	(5-1) (3-1)	
time x BT	(5-1) (2-1) (3-1)	
time x S(BT)	(5-1) 2x3 (4-1)	
total	120-1	